*Trapped in the Middle:*
*On the Detrimental Welfare Effects of Low-Wage Competition on Medium-Wage Countries*

**Dissertation zur Erlangung des Grades eines Doktors der Wirtschaftswissenschaft**

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*"In contrast to verbal theories, mathematical modelling, as a tool for exploring natural- and human-created phenomena, gives a precise and explicit connection between a set of assumptions and conclusions. A good mathematical model starts with the smallest possible number of essential assumptions and follows the implications rigorously to their logical conclusions. Thus, a simple and elegant model often has greater intrinsic value than an accurate one that is overloaded with detail; in this aspect mathematical modelling is akin to Ockham's razor."*

Andrei Korobeinikov, 2009.

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Note: This thesis builds upon Arnold and Heyna (2022). In particular, Sections 3.2 and 4.2 of this work are more elaborate versions of Sections 3 to 6, and Section 7 respectively of Arnold and Heyna (2022).

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# 1. Introduction

*"New industries are constantly emerging in the developed region, then disappearing in the face of low-wage competition from the less developed region. The picture of trade seems in some ways more like that of businessmen or economic historians than that of trade theorists."*

Paul Krugman, 1979.

The introductory statement is from Paul Krugman's seminal paper *A Model of Innovation, Technology Transfer, and the World Distribution of Income*, published in the Journal of Political Economy in 1979 (Krugman, 1979a). At that time, the Heckscher-Ohlin model (Heckscher, 1919 and Ohlin, 1933) was and would continue to be the predominant theoretical approach to international trade (Baldwin, 2008). The Heckscher-Ohlin (H-O) model predicts that international differences in relative factor endowments give rise to trade. The country that is relatively abundant in one factor of production exports the good that uses this factor relative intensively. The model builds on the principle of comparative advantage, which was first formally described by David Ricardo in his *Principles* (Ricardo, 1817). Unlike Heckscher and Ohlin, Ricardo assumes comparative advantage in labor productivity, not in factor endowments. Notwithstanding, the line of argument is the same in both theories: Comparative advantage gives rise to international relative price differences, which in turn, determine the pattern of trade. Beyond that, a corollary of the H-O model is factor prize equalization (FPE). The FPE theorem was formulated by Paul A. Samuelson (1948). It states that in the absence of complete specialization, identical factors are equally paid across countries as a result of international free trade. Thus, the economic theorists, who Krugman refers to, paint a picture of trade centered around comparative advantage and international factor prize equalization.

Krugman's impression, however, is that trade patterns are rather determined by international wage differentials, in this way resembling the picture of trade that business people or economic historians have. How does a business person's picture of trade actually look like? Krugman does not further describe it, but it is easy to grasp what it conceals: Business people, being representatives of firms, seek to minimize cost. Therefore, they locate production where costs, above all labor costs, are lowest. Thus, a business person's picture of trade can be described as trade patterns being determined by *absolute* advantage rather than comparative advantage: Out of all countries that are able to produce a

certain good, the country that pays the lowest wages (in absolute terms) produces and exports this good. Whereas trade theorists predict international wage *equalization* as the *result* of trade, business people consider wage *differentials* as a *reason* for trade.
There is overwhelming evidence that labor cost is indeed the main determinant of business people's offshoring decisions. Offshoring refers to transferring production from the home country to another country, either within the same firm or across firms. In the latter case, the literature speaks of offshore outsourcing (see Gylling et al., 2015).
Kinkel and Maloca (2009) survey a representative sample of 1663 German manufacturing companies. They find that personnel cost reduction is by far the predominant offshoring driver, not only for multinationals but also for small and medium-sized firms. In 2006, 88% of the surveyed metal and electrical companies stated that labor cost is one of the vital factors when it comes to offshoring decisions. Other motives like market opening (27%), capacity bottlenecks (26%), vicinity to customers (20%), taxes and subsidies (11%), and knowledge and clusters (4%) rank far behind. These secondary motives even saw a recent drop in importance whereas labor costs gained relevance during the survey period (see Figure 1.1).

Figure 1.1: Offshoring motives of German metal and electrical industry over time (whole manufacturing sector in brackets)


Source: Kinkel and Maloca (2009), Fig. 3.

Against this backdrop, it is not surprising that only two years after the 2004 EU enlargement, 55% of the surveyed companies had already offshored production to the new Central and Eastern European low-wage EU members, with Czech Republic (26%) and Poland (22%) being the main target countries. Outside the EU, China (19%) was the

primary recipient of production offshoring (see Fig. 4 in Kinkel and Maloca, 2009).
Surveys conducted in other countries confirm the predominant role of labor costs in business people's offshoring decisions. Johansson et al. (2019) interviewed a representative sample of 275 experienced managers from Denmark, Finland, and Sweden who are responsible for offshoring projects of manufacturing plants. The respondents' answers paint a clear picture: Labor cost is the strongest relocation driver. Tate et al. (2014) surveyed 319 U.S. managers from thirteen different industries who are responsible for sales volumes from less than $100 million to more than $40 billion. The managers were asked about the factors that influence their manufacturing location decisions. 58% of the respondents stated that overall labor costs, the most important factor, have recently gained in importance. 66% of the respondents stated that labor costs would play an even more important role in the near future. Canham and Hamilton (2013) report for a sample of 151 representative manufacturers from New Zealand that the main reason for offshoring is lower labor cost. Theyel et al. (2018) interviewed managing directors, production directors, and/or operations staff from 50 high-value manufacturing, i.e., R&D-intensive, firms based in the U.K. Among others, information about the reasons for manufacturing relocation was collected. 40% of the surveyed firms offshored production in part or completely. The first and foremost reason stated was lower labor cost. Ok (2011) provides evidence from the Netherlands. Questionnaires from 156 enterprises from the manufacturing and services sector that engaged in offshoring prior to the survey reveal that reducing labor costs was among thirteen factors by far the most important one. Cross-country evidence can be found in Manning et al. (2008). Among 1,600 large, medium-sized, and small U.S. and European companies, 91% cited labor cost savings as an important or very important offshoring driver. No other factor was cited more often. Di Mauro et al. (2018) review the literature on offshoring motivations. In a sample of 68 papers, they identify 24 different offshoring motivations. The most frequent one found is costs (and productivity) of labor.
The studies presented so far reflect the views of business people from developed (high-wage) countries only. Do business people in developing (medium-and-low-wage) countries share this view? They do. The 2009 International Manufacturing Strategy Survey covers 677 companies from 19 countries worldwide, including China, Taiwan, Mexico, and Brazil. It reveals that for business people also from these countries the strongest offshoring motive is low-cost labor.[1]
The literature strongly suggests that if firms - be they operating in high-wage or low-wage countries - decide to offshore production, then mainly because of labor cost saving prospects. Since each offshoring activity affects trade patterns, this insight supports Krugman's claim that the picture of trade he describes resembles that of business people: Assume high-wage country A hosts a firm that sells her good to domestic consumers and to consumers in low-wage country B. In this case, country A is the exporting and country

1 See `http://www.manufacturingstrategy.net/wp-content/uploads/2012/12/IMSS_V_Global_Report_2009.pdf`

B the importing country of that good. If the said firm offshores production to country B, the two countries switch roles. Country B becomes the exporting and country A the importing country. The trade pattern has changed for this specific good.

The question that follows is whether offshoring is so prevalent that it shapes trade patterns not only on the micro level, i.e., for goods of selected firms but also on the macro level, i.e., for whole sectors and countries. Framed differently: Is the international relocation of production due to low-wage competition such a determining phenomenon that it is justified to say that this is *the* picture of trade? da Silveira (2014) considers offshoring as "one of the defining phenomena of 21st century manufacturing" (da Silveira, 2014, p. 163). I will argue in the same direction further below. Before that, I turn to the economic historians' picture of trade.

Krugman claims that industries that historically emerged in the developed region are *constantly* disappearing in the face of low-wage competition from the less developed region. Here, he refers to the international product cycle, which was first described by Vernon (1966): A new product is invented in a developed country. It is initially produced to meet demand of the country's high-income consumers. As the product matures, mass-production techniques are adopted and foreign demand (also from developing countries) expands. In the next stage, the product becomes standardized and production is offshored to a developing country, where it can be manufactured at lower cost. At the end of this cycle, the product is almost exclusively imported by its country of invention.

One famous example of such a cycle is the T-shirt. It was created in the U.S. at the beginning of the 20th century. Its original purpose was to serve as underwear in the U.S. Navy. Soon, companies like The P.H. Hanes Knitting Company, Fruit of the Loom or the Cooper Underwear Company added the T-shirt to their product range. In 1938, the T-Shirt was advertised as outerwear for the first time by Sears, Roebuck, & Company. Actors like Marlon Brando and James Dean finally made it fashionable among Americans in the 1950s.[2,3] Today, the T-shirt is the most common clothing item around the globe, and the U.S., its country of creation, is the world's biggest importer ($6.78 billion in 2020). The world's largest exporters are low-wage China ($6.33 billion) and Bangladesh ($5.74 billion).[4]

Another example for the international product cycle is the U.S. semiconductor industry. In the 1960s, labor-intensive manufacturing operations, like assembly and testing, were offshored to Asia; followed by increasingly complex operations, including wafer fabrication, some research and development, and design work in the 1970s.[5] This was the picture of (semiconductor) trade Paul Krugman saw when he published *A Model of Innovation,*

2 See `https://www.realthread.com/blog/history-of-the-tshirt`

3 See `https://medium.com/left-out-of-the-will/a-brief-history-of-the-t-shirt-2ae994241e49`.

4 See `https://oec.world/en/profile/hs/knit-t-shirts`.

5 See the 2006 United States Governmental Accountability Office report: `https://www.gao.gov/assets/gao-06-423.pdf`

*Technology Transfer, and the World Distribution of Income* in 1979. Until today, this picture hasn't changed. The international product cycle has been spinning on. In 1990, the U.S. was still among the three dominant semiconductor-manufacturing countries in the world (alongside Europe and Japan), with a global market share of almost 40%. Yet, in the following decade, the U.S. share dropped sharply and is projected to be only 10% by 2030. To date, South Korea, Taiwan, and China have taken the lead in global semiconductor production. Their combined market share amounted to around 60 percent in 2020.[6]

The following anecdote is paramount for the automotive product cycle. On January 4th 2017, 16 days before his inauguration as 58th president of the United States of America, Donald Trump posted on Twitter: "Thank you to Ford for scrapping a new plant in Mexico and creating 700 new jobs in the U.S. This is just the beginning - much more to follow."[7] Ford, the U.S. based automobile manufacturer, had previously announced to have their new Focus model produced in Mexico. As Donald Trump promised to bring U.S. industries back home during his administration, he took action and managed to have Ford scrap their plan, apparently. Six months later, on June 20th 2017, The New York Times headlined: "Ford Chooses China, Not Mexico, to Build Its New Focus"[8] The story had a different ending to what Donald Trump had predicted. Ford didn't bring production back from Mexico to the U.S. The company relocated even farther away instead. The main reason for this move was the higher cost saving prospects in China compared to Mexico.

Whereas the car industry cycle has arrived in China lately, other industries have already left the country heading to countries with even lower wages. Newspaper headlines accompany the relocation of smartphone production from China to Vietnam by Google and Samsung. While recently a looming U.S.-Chinese trade war and the Coronavirus outbreak are cited as causes, the trend has been going on before with 'cheap labour' playing a vital role, as stories in the August 28th 2019 edition of *Nikkei Asia*[9] and in the April 12th 2018 edition of *The Economist*[10] document (manufacturing wages equaled $227 per month in Vietnam compared to $493 per month in China in 2018 according to the Japan External Trade Organization[11]).

In software services offshoring, India has been the number one destination for more than a decade. Now, Bangladesh is expected to grow as the leading software development hub in the world. Bangladesh delivers the same quality at a significantly lower cost of labor. Hourly rates for a junior level software engineer ($18-$20) underbid Indian rates ($30-$40)

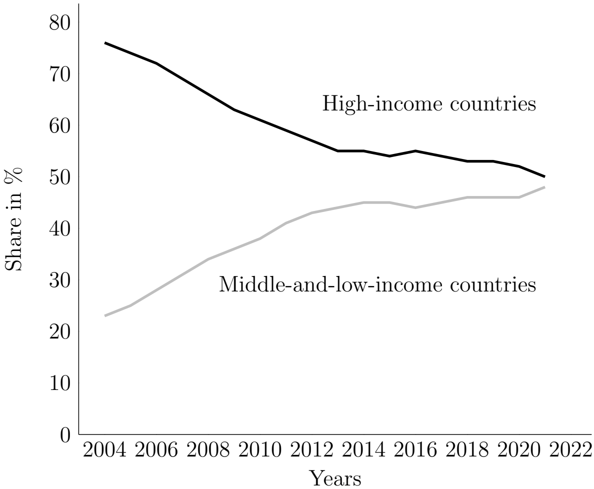
6 See https://www.statista.com/chart/25552/semiconductor-manufacturing-by-location/.
7 See https://www.bbc.com/news/business-38525389.
8 See https://www.nytimes.com/2017/06/20/business/ford-focus-china-production.html.
9 See https://asia.nikkei.com/Spotlight/Tech-scroll-Asia/Google-to-shift-Pixel-smartphone-production-from-China-to-Vietnam.
10 See https://www.economist.com/asia/2018/04/12/why-samsung-of-south-korea-is-the-biggest-firm-in-vietnam.
11 See https://www.jetro.go.jp/en/news/releases/2019/6980a2e6ad84b745.html.

by half.[12]

The fashion industry cycle has already arrived in East Africa. H&M and GAP just recently produce their garment collections in Ethiopia, where a textile worker's average monthly salary ($26) makes up less than 30% of a textile worker's salary in Vietnam ($160) or Bangladesh ($95).[13,14]

These examples provide anecdotal evidence for an ongoing change in global production patterns, viz. the shift of manufacturing from high-wage to low-wage countries. Figure 1.2 highlights this. It shows the share in global manufacturing value added (MFVA) of the group of high-income countries and the group of middle-and-low-income countries between 2004 and 2021.[15,16]

Figure 1.2: Share in global manufacturing value added (MFVA) over time




Source: World Bank.

There has been a massive downstream shift of global manufacturing. Whereas in 2004

12 See `https://bjit.medium.com/offshore-software-development-offshoring-in-bangladesh-vs-india-e75c9dd6e7ab`.

13 See `https://www.cnbc.com/2019/05/07/report-ethiopias-garment-workers-are-worlds-lowest-paid.html`.

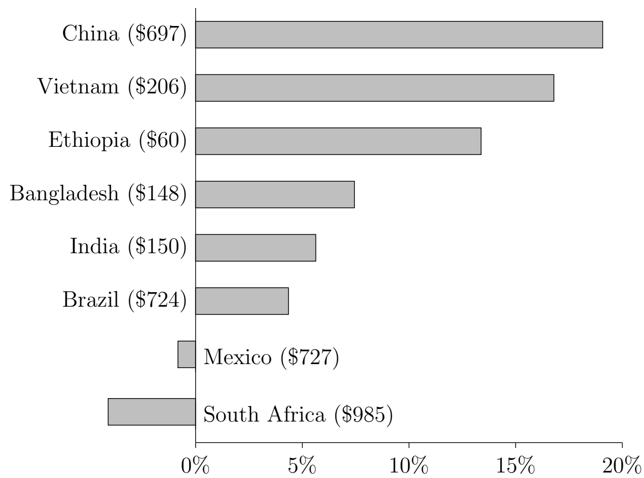
14 Data on wages and salaries that is not found in the cited articles is taken from `https://www.statista.com`.

15 I calculated the numbers using data from the World Bank indicator *Manufacturing, value added (current U.S.$)*: `https://data.worldbank.org/indicator/NV.IND.MANF.CD`.

16 There is no data for the low-income group separately but for the middle-income group. The middle-income group accounts for more than 99% of the middle-and-low-income group's share in global MFVA. This is because China is part of that group, and because low-income countries are considered those whose gross national income (GNI) per capita was $ 1,085 or less in 2021. Hence, even Bangladesh and Vietnam appear as middle-income countries. The low-income group comprises only the world's 24 poorest countries, including Ethiopia (see `https://datahelpdesk.worldbank.org/knowledgebase/articles/906519`).

global MFVA was still very unequally distributed between the two groups (around 76% for high-income countries against 23% for middle-and-low-income countries), their shares have practically equalized recently (50% against 48% in 2021).
Let's have a closer look at the group of middle-and-low-income countries. In the aforementioned examples, China is the new low-wage competitor in car production, Vietnam the new low-wage competitor of China in smartphone production, Bangladesh the new low-wage competitor of India in software development, and Ethiopia the new low-wage competitor of Vietnam and Bangladesh in garment production. Mexico, India, and China, alongside Brazil and South Africa, are often referred to as the Group of Five (G5), a coalition of the world's five most promising emerging countries. Irrespective of the World Bank's classification, within the present sample, these countries can be considered as medium-wage countries. They are low-wage competitors for high-wage countries like the U.S., while simultaneously facing low-wage competition from countries like Vietnam, Bangladesh, and Ethiopia. Figure 1.3 shows the average annual percentage gain in global MFVA share between 2004 and 2014 for these countries. Mean monthly earning in manufacturing is written in brackets.[17]

Figure 1.3: Average annual gain in global MFVA share 2004-2014



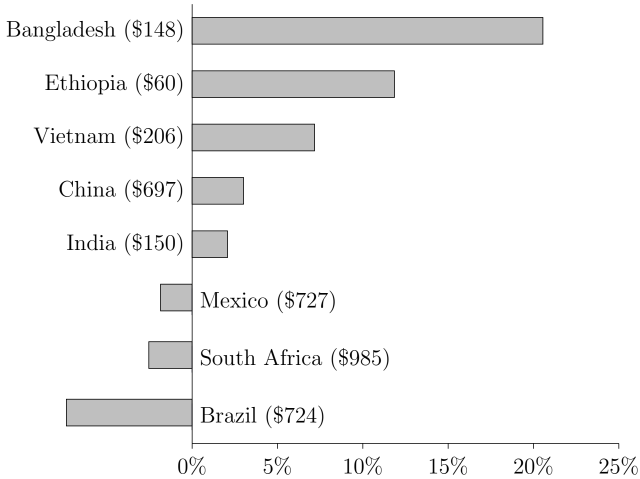

Source: World Bank.

China's average annual growth in global MFVA share was around 19% between 2004 and 2014. No other country gained more. Vietnam ranked second with an annual growth of

17 For Brazil, China, India, Mexico, and Vietnam, the indicated values are from 2014. For Bangladesh, Ethiopia, and South Africa, the indicated values are from 2013. The values are taken from the International Labor Organization's (ILO) Data catalogue: `https://ilostat.ilo.org/topics/wages/`. The indicator is *Average monthly earnings of employees by sex and economic activity.* The ILO dataset does not include Bangladesh and India. The values for these countries are calculated from `https://tradingeconomics.com/`.

17%, followed by Ethiopia (13%), Bangladesh (7%), India (6%), and Brazil (4%). Mexico (-1%) and South Africa (-4%) lost shares. Overall, the ranking of middle-income and low-income countries with respect to their gain in global MFVA share was somewhat mixed for that period. When looking at the more recent period of 2014-2021, however, the picture changes (see Figure 1.4). Low-wage Bangladesh, Ethiopia, and Vietnam are top-ranked, while the G5 countries invariably show a significantly lower annual gain compared to the 2004-2014 period. Most notably, China's growth rate dropped from 19% per year between 2004 and 2014 to only 3% per year between 2014 and 2021. Brazil changed from being a gainer between 2004 and 2014 to being the biggest loser between 2014 and 2021.

Figure 1.4: Average annual gain in global MFVA share 2014-2021.




Source: World Bank.

Figures 1.2, 1.3, and 1.4 have two important implications. First, there has been a substantial shift of manufacturing production from high-income to middle-and-low-income countries. Second, within the group of middle-and-low-income countries, low-income countries like Bangladesh, Ethiopia, and Vietnam have recently gained market shares at the expense of middle-income countries like China, Mexico, and Brazil. This confirms the impression drawn from the aforementioned examples of offshoring activities by selected firms.

Here, the question follows: Does this shift in global manufacturing from high-wage and medium-wage countries to low-wage countries entail a change in global trade patterns? If so, it is fair to say that the picture of trade is painted by international low-wage competition. One could argue to the contrary that a country's gain in global manufacturing share may be due to within-country demand-led growth. The settlement of foreign firms or the foundation of new domestic firms in that country does not necessarily mean that this country is now an exporter. These firms may just as well serve an enlarged domestic market. In this case, the country's share in global manufacturing would increase without affecting global trade patterns. In the following, I argue that this change in the pattern of global manufacturing does in fact entail a long-run change in the pattern of world trade; a change which is characterized by the successive emergence and subsequent rise of low-wage countries as exporters of manufacturing goods to industrial countries. This change in the pattern of trade is well-documented (see Krugman, 2008, 107 ff.). Table 1.1 (an update of Table 2 in Krugman, 2008, p. 109) describes this trend from the viewpoint of the United States. It shows the top ten U.S. trading partners and this group's average hourly compensation in manufacturing over time.

Table 1.1: Average hourly compensation in manufacturing of the top ten U.S. trading partners over time

| Year | Top ten trading partners (largest first) | Average hourly compens. (percent of U.S. average)[a] |
|---|---|---|
| 1975 | Canada, Japan, Germany, United Kingdom, Mexico, France, Italy, Brazil, Netherlands, Belgium | 76 |
| 1990 | Canada, Japan, Mexico, Germany, United Kingdom, Taiwan, South Korea, France, Italy, China | 81 |
| 2005 | Canada, Mexico, China, Japan, Germany, United Kingdom, South Korea, Taiwan, France, Malaysia | 65 |
| 2011 | Canada, China, Mexico, Japan, Germany, United Kingdom, South Korea, Brazil, France, Taiwan | 59 |
| 2016 | China, Canada, Mexico, Japan, Germany, South Korea, United Kingdom, France, India, Taiwan | 46[b] |
| 2021 | Canada, Mexico, China, Japan, Germany, South Korea, United Kingdom, Taiwan, India, Vietnam | n.a.[c] |

Sources: Krugman (2008), U.S. Bureau of Labor Statistics, The Conference Board, United States Census Bureau.

[a] Averages are weighted by the countries' shares in total U.S. trade.

[b] China's and India's hourly compensation are estimated to be 18 and 5 percent of the U.S. level, respectively.

[c] The sources from which the preceding averages were calculated have no data for 2021 available yet.

In 1975, no East Asian country was listed in the top ten. In 1990, Taiwan, South Korea, and China appeared and have remained there until today. India is listed since 2016. China made it even to the top of the list that year. China has lost its top position again recently (2021), most probably due to the U.S.-Chinese trade war during the Trump administration and the Coronavirus outbreak. Brazil dropped out, India held its position, and Vietnam has reached the top ten replacing France. The overall picture is that East Asian low-wage countries replaced European economies and then moved upwards in the list, this leading to a monotonic decrease in average hourly compensation in manufacturing of the top ten U.S. trading partners since 1990.

And this figure captures the impact of 'cheap labor' only partially, since countries that export to the U.S. (like China) import parts and half-finished goods from third countries with still lower wages (like Vietnam). In 2005, China's top ten trading partners were almost exclusively high-wage countries from North America (United States and Canada) and Europe (Netherlands, United Kingdom, Spain, Italy, Belgium, and Turkey), plus Hong Kong and the United Arab Emirates. By 2011, India, Vietnam, Mexico, and Panama have replaced Canada, Spain, Belgium, and Turkey. From 2011 to 2016 to 2021, Vietnam climbed up the list from rank seven to six to five.[18]

These figures show that low-wage competition does indeed define global trade patterns. Firms (business people) around the globe shape these patterns by constantly engaging in offshoring activities, which are mainly incentivized by labor cost savings. Thus, metaphorically speaking, low-wage competition is the brush that paints the picture of trade. This pattern, fueled by 'cheap labor', is the picture that business people and economic historians would sketch. Since the monotonic decrease in average hourly compensation as a percentage of U.S. level can be interpreted as a widening of the wage gap between the U.S. and its trading partners, this picture is in stark contrast to the one painted by traditional trade theorists. They explain trade patterns with comparative advantage and neglect the role of international wage differentials. Paradoxically, they predict international wage equalization fueled by trade.

The successive emergence of new low-wage competitors entails an aspect that often remains unnoticed: Former low-wage countries like Mexico (in the eyes of Ford), China (in the eyes of Google and Samsung), and Bangladesh (in the eyes of H&M and GAP) become - in relative terms - medium-wage countries when countries with even lower wages like Vietnam and Ethiopia emerge. Former destination countries of international manufacturing relocation lose their competitive advantage and become countries of origin of manufacturing relocation. This may have adverse effects on economic outcomes in these new medium-wage countries. The launch of NAFTA in 1994 for example did not stop three decades of real wage stagnation in Mexico starting in the early 1980s. Blecker and Esquivel (2010, pp. 25 and 29) had put forward the following explanation: "although Mexico is the low-wage country in North America, it is a medium-wage country globally. [...] Thus, Mexico does not have a global advantage in labor costs and should not have been expected to reap large gains in wages from opening up to trade [...] increasing regional integration in the late 1990s [...] was partially reversed as the lower trade barriers within North America were overwhelmed by other developments, including [...] the emergence of

18 See the World Integrated Trade Solution: `https://wits.worldbank.org/CountryProfile/en/Country/CHN/Year/2005/TradeFlow/EXPIMP/Partner/by-country` for the rankings in 2005, 2011, and 2016, and `https://www.worldstopexports.com/chinas-top-import-partners/` for the year 2021.

China as an economic powerhouse." Similarly, Castillo and de Vries (2018, p. 201) argue that "Mexico's accession to GATT in 1985, and the emergence of China by 2001, also appear related to a gradual decline in the domestic value added of aggregate maquiladora exports." These two examples provide anecdotal evidence of competitive pressure (with associated adverse effects on economic outcomes) on former low-wage countries as new trading partners with still lower wages appear in the world economy, with China having switched roles in the interim (consistent with ambivalent effects of China's growth on emerging economies; see e.g., Wang and Chen, 2016).

This begs for a theoretical foundation, which is the focus of the present work. I analyze the effects of the entry of a low-wage country into the world economy, with a particular emphasis on the new medium-wage country. To this end, I investigate the comparative statics effects of the entry of a third country, with low wages, in a general equilibrium model of product cycle trade. I employ the static version of Krugman's model of international trade with absolute cost advantages (1979a). The model assumes a high-wage country, which has the technological ability to produce the whole range of a given set of goods, and a low-wage country, which is able to produce only a subset of the product range but at lower cost. Both countries gain when they open up trade. Consumers in the high-wage country benefit from cheaper access to the subset of goods that were produced domestically in autarky and are now imported from the low-cost trading partner. Consumers in the low-wage country gain from importing additional goods; goods they are not capable of producing domestically. Krugman's baseline model is a very convenient framework for addressing my research question. By introducing a third country, the model does not lose its analytical tractability. This third country is assumed to have even lower wages than the former low-wage country. I show that while the high-wage country benefits, the gains from trade in the former low-wage and then medium-wage country may go down. This happens if the benefits in terms of access to cheap varieties produced in the new low-wage country do not outweigh the deterioration in the terms of trade with the high-wage country caused by the relocation of production to the newcomer country. This case tends to occur if the high-wage country has a big technological advantage or the cost differential between the other two countries is small. As all inhabitants of the medium-wage country are alike, such 'pains from trade' (Sapir, 2000, p. 180) are not a distributional issue.[19]

I proceed to take some steps in the direction of the analysis of the endogenous formation of the equilibrium free trade area (FTA) in the presence of wage differentials. Keeping attention to welfare in the middle-income country, I investigate the 'exclusion incentives' (Missios et al., 2016) for the other two countries. Starting with the simplifying assumption

19 Krugman (1979a, Sec. III) also considers a dynamic version of his model. Grossman and Helpman (1991) extend this dynamic model to endogenous growth (see also Arnold, 2002, 2003). These dynamic models focus on growth effects, as it is not possible to obtain analytical welfare results (an important exception is Helpman, 1993). I build on the static Krugman model (1979a) because my focus is on welfare effects.

that there is no external trade between members of an FTA on the one hand and non-member countries on the other hand, I show that in the absence of international transfers, formation of an FTA following the core principle or sequential bargaining may lead to an FTA that does not include the medium-wage country. I also consider the case of (exogenous) non-prohibitive tariffs and construct examples in which the medium-wage country is excluded from the equilibrium FTA. Additionally, I show that with optimal tariff setting, the entry of a dormant (i.e., uninvolved in tariff setting) low-wage country strengthens the incentive of a high-wage country to reap welfare gains in a tariff war at the expense of the medium-wage country. If, by contrast, international transfers are part of the negotiations over the formation of an FTA, then global free trade is the likely outcome. This is because global free trade is the only way to achieve the unique allocation of production across countries that is part of any Pareto optimal allocation. The medium-wage country may or may not be compensated for the reduction in its gains from trade if necessary. In a final variation of the model, I introduce capital as a factor of production, which is assumed to be internationally mobile so that there is scope for international investment. I show that with international investment, the pains from trade for workers are more pronounced than in the model with only labor in production. An interesting corollary is that the entry of a low-wage competitor may cause capital to flow one-way upstream, i.e., from 'poor' to 'rich' countries, or away from the medium-wage country in two directions, to the high-wage country and, simultaneously, to the low-wage country.

The thesis is organized as follows. Chapter 2 discusses related literature. Chapter 3 presents the baseline model. I first introduce the two-country static version of Krugman's original model (1979a) to highlight the mechanisms at work. Then I turn to the three-country model to analyze the conditions under which pains from trade occur. The remainder of that chapter is concerned with the endogenous formation of the equilibrium FTA assuming prohibitive external tariffs, i.e., no trade between the FTA and the outsider country takes place. Chapter 4 considers the case of non-prohibitive tariffs. Again, I take a detour through the two-country setup showing gains from tariff imposition. In a next step, I analyze the formation of customs unions in the three-country setup. Chapter 4 closes with a note on optimal tariffs and tariff wars. Chapter 5 introduces internationally mobile capital as a factor of production. I formalize Krugman's verbal and graphical discussion about the implications of international investment in the two-country model (1979a) and apply this to the three-country case. Chapter 6 summarizes, presents controversies to which my insights may contribute, and proposes future research. Proofs are collected in Appendix A. Details of the algebra and additional information about the determination of equilibria are delegated to Technical Appendix B. Notes on finding numerical examples and supplementary numerical examples can be found in Numerical Appendix C. Appendix D presents a social welfare analysis. Appendix E contains the Mathematica Code for the numerical analyses.

# 2. Related Literature

This work complements the literature that consists of the diverse set of models that leave the canonical two-country setup in order to analyze a middle-income country in general equilibrium with wage differentials. It contributes to two fields of research: One which addresses the economic development of middle-income countries with special attention to the (negative) welfare effects of trade, and another which is concerned with the economics of preferential trade agreements, in particular the endogenous formation of free trade areas and customs unions between heterogenous countries. Literature related to these two strands is presented in this chapter. My work is also linked to the theory of optimum tariffs and tariff wars, and to the theory of international capital flows. Literature on these topics is reviewed in chapters 4 and 5, respectively.

## 2.1 Welfare Effects of Trade on Middle-Income Countries

The result that entry of a new low-wage country possibly harms a former low-wage and then medium-wage country offers a new explanation for the middle-income trap, i.e., the "sharp deceleration in growth, following a period of sustained increases in per capita income" (Agénor 2017, p. 771) observed in many countries.[1] Existing theoretical explanations (diminishing returns to physical capital, exhaustion of imitation gains, lack or misallocation of human or financial capital; see Agénor, 2017, Section 3) rely on two-country models. In my three-country framework, free trade with a high-wage country brings gains from trade, which come under pressure when a new low-wage competitor steps in. This explanation of a middle-income trap squares nicely with the idea of being 'caught in the middle' (the title of Agénor's 2017 survey).

Collins (1985) is an early contribution to the economics of middle-income countries. She presents a three-country Ricardian model with a continuum of goods. There is an industrialized country, a newly developing country, and a least developed rest of the world. Technical progress in one of the two latter regions reduces welfare in the other one. It can be shown that the same holds true when one of the two countries newly enters the world economy (which can be interpreted as an initial step forward technologically). Insofar, the

1 Countries are classified as middle-income if their gross national income per capita is between $1,086 and $13,205 (see https://datahelpdesk.worldbank.org/knowledgebase/articles/906519).

Ricardian continuum of goods model is an alternative framework that could be used to obtain results similar to mine. However, the model is missing one important point: There is no cost differential between the two less developed countries in that the producers in neither of the two regions face low-cost competition. International wage differentials prevail in free trade equilibrium, but production costs equalize across the two less-developed regions. If there was a cost differential, one of the two would not produce at all.

Pains from trade in terms of diminishing gains from trade compared to autarky when a newcomer emerges in the world economy can also be an outcome in the Heckscher-Ohlin model. A simple example is that of an entrant whose factor endowments equalize the global relative supplies to one country's national relative supplies, so that that country ceases to trade with the rest of the world (cf. Dixit and Grossman, 2005). Also this model misses one important point: The Heckscher-Ohlin model implies international factor prize equalization. The case of a medium-wage country that loses market shares due to low-wage competition from a newcomer country does not arise.

Özyildirim (1996) utilizes a dynamic game approach with two less developed countries and an industrial one. The two less developed countries produce a homogenous raw material, which the industrial country uses in the production of a consumption commodity. In equilibrium, the industrial country maximizes its consumption stream by choosing the optimal savings and investment mix given each less developed country's price setting of the raw material. Three cases are distinguished: First, identical productivities and no cooperation in the less developed region. Second, identical productivities and coordinated price setting in the less developed region, and third, different productivities and no cooperation in the developed region. The latter case is related to my work. Production cost differences prevail between the less developed countries and the more productive country prices the less productive one out of the market.

Chu (2009) considers a three-country endogenous growth model with international product cycles in which a middle-income country both innovates and imitates. It is assumed that innovation of a new good is more costly, i.e., requires more units of labor, than imitation of an existing good. However, consumers value original goods more than copied ones. This incentivizes firms in the middle-income country to innovate. The author shows that an increase in the labor force or technical progress in the low-wage country has an ambiguous effect on the middle-income country's relative wages but in any case speeds up growth in the world economy. In the present model, the entry of a low-wage newcomer country (which again can be interpreted as an initial step forward technologically) unambiguously lowers the middle-income country's wage relative to the high-wage country, with an ambiguous effect on the country's welfare.

Lin (2010) analyzes a product variety growth model with a medium-wage country that faces a trade-off between imitation of varieties innovated in a high-wage country and outward foreign direct investment (FDI) in a low-wage country. Labor is the only input to manufacturing and investment activities. Innovation and imitation rates are exogenous.

The author solves the model numerically and shows that it tends to be beneficial for the middle-income country to constrain outward FDI. Similarly, I find that when a low-wage country enters the global economy, the relocation of production from the medium-wage country to the low-wage country (outward FDI by firms in the medium-wage country) may cause a reduction of the middle-income country's welfare.

## 2.2 Endogenous Formation of FTAs between Heterogenous Countries

The analysis of FTAs in the three-country world economy with wage differentials draws upon and contributes to the literature concerned with the endogenous formation of FTAs between heterogenous countries (see Maggi, 2014, Section 4; Limão, 2016, Section 6).
Maggi (2014) identifies three major developments that have impacted the nature of international trade agreements since the mid-1990s: The establishment of the World Trade Organization (WTO), the growing role of newly industrialized and developing countries within the WTO, and the sharp increase in the number of regional trade agreements (RTAs) - between 1993 and 2023, the number of active RTAs increased more than tenfold from 32 to 355.[2,3] He also highlights the failure of the Doha Round, the latest attempt towards global free trade via multilateral trade negotiations, a "non-development" (Maggi, 2014, p. 318) as he puts it. The round failed to agree on further multilateral trade liberalization mainly because of the irreconcilable positions of developing and developed countries in negotiating them. Paul Krugman questions trade negotiations anyway: "What should trade negotiators negotiate about?" (the title of Krugman, 1997) His claim is that from an economist's perspective there is no need for an institution like the WTO given that a country always fares best by pursuing free trade regardless of other countries' actions. Krugman presumes that the mercantilist paradigm of exports being 'good' and imports being 'bad' continues to govern trade policy although it is inconsistent with the

2 See `http://rtais.wto.org/UI/Charts.aspx`

3 The WTO defines an RTA as "any reciprocal trade agreement between two or more partners, not necessarily belonging to the same region" (see `https://www.wto.org/english/tratop_e/region_e/scope_rta_e.htm`). Limão (2016) highlights the proliferation of preferential trade agreements (PTAs) since the 1990s. He defines a PTA as an "international treaty with restrictive membership and including any articles that (i) apply only to its members and (ii) aim to secure or increase their respective market access" (Limão, 2016, p. 284). This is a rather general definition very similar to the definition of an RTA by Maggi (2014), only that reciprocity is not required. Accordingly, the figures he shows for the number of PTAs in place do not deviate strongly from the ones presented by Maggi (2014) for RTAs. Interestingly, the WTO's definition of a PTA is fundamentally different, viz. a lot more specific: "[PTAs] refer to unilateral trade privileges [...] some WTO members implement for products from developing and least-developed countries" (see `https://www.wto.org/english/tratop_e/region_e/scope_rta_e.htm`). Not surprisingly, the WTO counts only 37 PTAs currently in place (see the *List of All PTAs* on `http://ptadb.wto.org/?lang=1`). I use PTA and RTA synonymously. For my purpose, it is sufficient to consider an FTA as a specific form of a trade agreement (call it regional or preferential), viz. free trade between the member countries, and to consider a customs union (CU) as a special case of an FTA, viz. free trade between the members and a common external tariff on imports from non-members.

logic of trade theory. The large body of literature on the economics of trade agreements, including the present one, proves Krugman wrong. Economics alone can very well explain why countries fail to liberalize trade as it happened with the Doha Round. This work presents a case in which precisely a developed and a developing country have opposing positions on whether to include a third, newly developing, country into global free trade or not. The high-income country would gain whereas the middle-income country would lose from the low-income country's entry. The remainder of this section reviews further literature on that.

Early studies of trade liberalization between countries at different stages of economic development found that liberalization in developed countries provides incentives for less developed countries to cut the influence of special interest groups aimed at securing rents. Ethier (1998) for example constructs a model of multiple developed and less developed countries. If a developed country strives after multilateral trade liberalization, autarkic less developed countries may want to liberalize if the expected social welfare benefit is sufficiently large to excel special interests. The less developed countries then compete among themselves in establishing regional arrangements with the developed country to attract direct investment, i.e., the establishment of foreign subsidiaries. This competition for a preferential trade agreement with the developed country is somewhat also present in the model I use. In the middle-income country's desire to keep the low-wage country out and maintain the FTA with the high-wage country, it may end up being excluded from free trade.

Puga and Venables (1998) pose the question of whether developing countries are better advised to seek PTAs with developed countries or amongst themselves. In their model, countries do not differ in technology and relative factor endowments, and firms operate in imperfectly competitive markets. Agglomeration forces determine their location choice. The extent of agglomeration in equilibrium depends on the level of trade barriers. At both extremes, free trade and autarky, there is no agglomeration. An uneven pattern of industrialization associated with cross-country income differences occurs only at levels of trade barriers in-between the two extremes. The authors start their analysis from an initial equilibrium in which two developed countries have industry, whereas two developing countries don't have industry. They deal with different scenarios of FTA formation of which the closest related to the present study is the one that assumes a PTA of the developed region with only one of the two developing countries. This reduces the wage gap between the PTA members by reducing the extent of agglomeration of industry in the developed region. The outsider country, by contrast, does not attract any industry and ends up at the lower end of the income range. Different to the setup that I consider, FTA formation is exogenous and wage differentials are rather the result of industrial relocation than the source of it. Also, the excluded country is never in the middle of the income range but at the lower end. The authors conclude that less developed countries seem to be better advised to seek PTAs with developed countries than arrangements among themselves, which is in line with my findings.

Das and Ghosh (2006) draw upon the observation that PTAs are very common among countries at relatively similar levels of economic development and comparatively rare among dissimilar ones. In a model with two identical high-income and two identical low-income countries, they indeed show that the coalition-proof Nash equilibrium of a trading bloc formation game entails either global free trade or, if market size differences are sufficiently large between the high-income and the low-income region, polarization, i.e., two trading blocs form, each made up of one type of countries. The FTA that excludes the medium-wage country in the present model is an example of the opposite outcome.

Aghion et al. (2007) consider a dynamic bargaining model of three countries with internationally transferable utility. They allow for positive and negative coalition externalities as well as for grand-coalition superadditivity. A leader country can choose between sequential and simultaneous bargaining in order to achieve its welfare maximizing trading system. If coalition externalities are disregarded and grand-coalition superadditivity prevails (two properties shared with the model I utilize), global free trade is the unique outcome. I draw the same conclusion. However, the authors do not account for the fact that international transfers are hardly observed in practice. Once disregarded in my framework, global free trade is no longer the unique outcome.

Saggi and Yildiz (2010) use an approach similar to Aghion et al. (2007) but without international transfers. They derive the stable Nash equilibria of a three-country game with pre-existing non-discriminatory tariffs in which each country simultaneously announces whether or not it wants to form an FTA with each of the other two countries. Matching announcements are implemented. Under asymmetry (two symmetric low-cost countries and one high-cost country), there is a strong presumption that either global free trade or a coalition of the two low-cost countries is a stable outcome. Exclusion of one of the low-cost countries - a salient feature of the present model - does not occur.

Thompson (2015) develops a model in which trade may be limited to two of three countries, depending on the extent of productivity and country size differences. Productivity is measured in terms of the unit input coefficient of a single factor. Country size is measured in terms of the endowment of this factor. In the two-goods variant of the model, a country may be too productive to gain from trade with the other two countries. Likewise, a country may be excluded from trade because it is too small to offer gains from trade to the other two. With three goods, global trade emerges only if each country has the highest production potential in a unique good, which is rarely the case. Trade limited to two countries is hence unexceptional. The more goods are assumed the more cases occur in which each country has the highest rank for at least one good and the more likely is global trade. This extends to the continuum of goods model of Collins (1985).

Missios et al. (2016) utilize a three-country-three-goods trade model, which is Racardian in nature. Each country has a comparative advantage in one good while having a comparative disadvantage in the other two goods. A world economy in which all countries impose their optimal tariff on one another is the initial situation. Then, the countries play a three-stage game of trade liberalization. In the first stage, each country simultaneously declares with which country it wants to form a PTA. The establishment of a PTA requires consent from both sides. Once it is in place, countries choose their optimal tariffs. In the final stage, international trade takes place. The authors consider two different games, a FTA game (free trade between the members and a common prohibitive external tariff on the outsider) and a customs union (CU) game (free trade between the members and a common non-prohibitive external tariff on the outsider). While in the CU game global free trade does not emerge, it is the only coalition-proof Nash equilibrium in the FTA game. Countries have an exclusion incentive but due to the structure of the game they are unable to exercise it. In the present model, exclusion can be the equilibrium outcome under both assumptions, prohibitive and non-prohibitive external tariffs.

Missios and Yildiz (2017) compare welfare across different constellations of bilateral free trade agreements in a model of two high-wage and two low-wage countries. A PTA with a high-wage country may harm a low-wage country, and the dynamic incentives to maintain global free trade are weaker when the fallback option is an FTA that includes a high-wage country compared to no agreement. The pre-existing trade agreement (membership effect) and the extent of the cost asymmetry between high-wage countries and low-wage countries (asymmetry effect) determine the likelihood of achieving multilateral (global) free trade. The more symmetric the two regions are the more willing is the high-wage region to engage in free trade with the low-wage region. This is contrary to my findings. The high-wage country prefers multilateral free trade with the other two countries only if the medium-wage country is sufficiently asymmetric to the high-wage country.

Nken and Yildiz (2021) employ the same baseline model of endogenous PTA formation as Missios et al. (2016), with one difference: Each country has a comparative advantage in two (instead of one) of three goods. They investigate how the continual reduction in tariff bindings affects the formation of PTAs and the attainment of global free trade. Countries face exogenously given bound tariff rates (a feature that the model I use shares) while playing FTA and CU games. In the FTA game, global free trade always emerges. In the CU game, which is more closely related to my analysis, exclusion obtains for sufficiently tight tariff bindings. The conclusion drawn from my analysis is somewhat similar, albeit not that clear-cut. With prohibitive external tariffs (FTA game) and no international transfers, global free trade does not always emerge and for the case of non-prohibitive external tariffs (CU game), I find examples in which exclusion is independent of the tariff binding.

# 3. Free Trade

This chapter formalizes the entry of a low-wage country into a two-country world-economy with pre-existing wage differentials. Throughout this chapter, I assume that for each pair of countries there is either free trade or no trade at all. No trade at all is equivalent with assuming that, if tariffs are imposed, they are prohibitive. The discussion of positive but non-prohibitive tariffs is postponed to Chapter 4.

## 3.1 Two Countries

Before analyzing the middle-income country in the three-country setup, I present the two-country baseline model to familiarize the reader with the mechanisms at work. This helps to understand why pains from trade for the middle-income country due to the entry of a low-wage competitor may arise in the three-country model. This section first outlines the assumptions. Then it derives the two-country free trade equilibrium (FTE) and proves gains from trade. It also includes an extensive discussion about how to interpret the assumed utility function and how to classify the model.

### 3.1.1 Model

*Assumptions*

The model I analyze is the static variant of Krugman's technology transfer model (1979a). The world economy is composed of two countries, South ($S$) and North ($N$). The countries are populated by $L^S$ and $L^N$ (both $> 0$) consumers, respectively. Each consumer supplies one unit of labor, the only factor of production. There are $\bar{A}^N$ consumption goods available indexed $\left[0, \bar{A}^N\right]$. Consumers have identical preferences. The utility of an inhabitant of country $i$ ($\in S, N$) is represented by a function à la Dixit and Stiglitz (1977):[1]

1 Formulation (3.1) is different to the one introduced by Dixit and Stiglitz (1977) in two respects. First, in Dixit and Stiglitz (1977) an additional numeraire good (an aggregate of the rest of the economy) enters utility separately to account for inter-industry interactions in demand. This is omitted here, which makes the model purely intra-industry. Second, Dixit and Stiglitz (1977) take a countable number of goods and assume that this group of goods is sufficiently large to neglect cross-price elasticities, i.e., to ignore the effect of a price change of a single good on the demand of any other good within that group. Here, the more rigorous concept of a continuum of goods is used. This has the same implication of cross-price elasticities being negligible.

$$U^i = \left[ \int_0^{\bar{A}^N} y^i(j)^\alpha dj \right]^{\frac{1}{\alpha}}, \quad 0 < \alpha < 1, \tag{3.1}$$

where $y^i(j)$ is the quantity consumed of good $j$. Individual utility is the measure of welfare throughout this work. A country's social welfare is the sum of individual utilities. As every individual in country $i$ has the same preferences and supplies one unit of labor, country $i$'s social welfare is individual utility times labor supply $L^i$. For this reason, I use the terms utility and welfare synonymously. Utility function (3.1) has an important property: It is increasing in goods variety. For given income and prices, a consumer prefers to consume a larger set of goods at lower quantities per good over a smaller set of goods at higher quantities per good.[2] With $0 < \alpha < 1$, each variety's marginal utility is positive but decreasing and infinite at zero consumption. Hence, reducing the quantity consumed of an already existing variety, to consume the first unit of a new variety is utility enhancing. In other words: As soon as new varieties become available ($\bar{A}^N$ increases) the individual chooses to buy them. This is referred to as love of variety. All goods enter symmetrically into utility. Thus, they have identical demand functions given by

$$y^i(j) = \frac{p(j)^{-\frac{1}{1-\alpha}} w^i}{\int_0^{\bar{A}^N} p(j')^{-\frac{\alpha}{1-\alpha}} dj'}, \tag{3.2}$$

with $w^i$ denoting consumer $i$'s wage income (for derivation of (3.2) and all subsequent equations see Technical Appendix B). If we define a price index[3]

$$\mathcal{P} = \left[ \int_0^{\bar{A}^N} p(j)^{-\frac{\alpha}{1-\alpha}} dj \right]^{-\frac{1-\alpha}{\alpha}},$$

demand function (3.2) can be written as

$$y^i(j) = \left[ \frac{p(j)}{\mathcal{P}} \right]^{-\frac{1}{1-\alpha}} \frac{w^i}{\mathcal{P}}. \tag{3.3}$$

Demand for good $j$ is a function of the price of good $j$ relative to the price index, i.e., relative to the price of all other goods - the first factor in (3.3), and real income - the second factor in (3.3). All goods are equally good substitutes for one another with $1/(1-\alpha)$ being the uniform and constant elasticity of substitution. The larger $\alpha$ the higher the substitutability of two arbitrary goods $j$ and $j'$.

Given utility (3.1) and the entailing demand function (3.3) there are two ways to interpret the set of goods in $\left[0, \bar{A}^N\right]$. One is to assume that this is a set of varieties belonging to one single product class. In manufacturing, examples of product classes include cars, smartphones, and garments, just to name the ones already mentioned in the introductory

2 The terms good and variety are used synonymously throughout the text.

3 A necessary property of a price index is linear homogeneity in the prices. This is fulfilled here. If not obvious, see Technical Appendix B for clarification.

chapter. Along these lines, $\left[0, \bar{A}^N\right]$ is either a range of cars from different makes, or of smartphones from different producers, or of garments from different brands. This interpretation is consistent with uniform elasticity of substitution across all goods in $[0, \bar{A}^N]$. It is reasonable to assume that for a single consumer a Ford Focus and a Volkswagen Golf have identical demand functions, as well as a Google Pixel and a Samsung Xperia, or two T-shirts, one from H&M, the other from GAP. This interpretation, however, also implies that an individual buys the whole range of products within the respective class. It is hardly observed that an individual possesses more than one car or more than one smartphone, though. She certainly possesses several T-shirts but hardly one each from all available brands. There is a way to escape from this interpretational dilemma: We simply assume that utility function (3.1) reflects aggregate utility of all individuals. Avinash Dixt and Joseph Stiglitz themselves put this idea forward by saying that (3.1) "can be regarded as representing Samuelsonian[4] social indifference curves [...] Product diversity can then be interpreted [...] as different consumers using different varieties" (Dixt and Stiglitz, 1977, p. 298). This implies that each individual buys a different make of car, a different type of smartphone or wears a T-shirt from a different brand, and new varieties of cars, smartphones or T-shirts meet the tastes of some individuals better than old ones, so that if new varieties become available, these individuals shift consumption from old to new varieties. In this case, (3.1) does not reflect individual love of variety but that of a whole society.

The alternative interpretation is to assume that $\left[0, \bar{A}^N\right]$ is a range of manufacturing goods *across* product classes. This implies that an individual spreads her income over the whole variety of industrial goods, meaning that she buys one car, one smartphone, several garments etc. This interpretation is more consistent with real consumer choice if (3.1) is supposed to reflect individual utility. However, it is inconsistent with uniform substitutability and identical demand across goods. Paul Krugman chooses this interpretation in his article (1979a) and admits that "[it] is clearly unrealistic. There is no reason why mopeds and toothbrushes should have identical demand functions [...] The only justification for this assumption is its simplifying power which allows us to analyze economies producing many goods" (Krugman, 1979a, p. 256). He could have circumvented this confession by suggesting the interpretation I presented above. Why didn't he do so? My read is that he was fully aware of the possibility to interpret $\left[0, \bar{A}^N\right]$ as a range of goods within one product class. Yet, he didn't come up with this interpretation because it makes little sense when the goods in $\left[0, \bar{A}^N\right]$ shall serve to illustrate the international product cycle.

4 I suppose this attribute refers to Paul Samuelson (1956). In this article, he proves the impossibility of social indifference curves in countries populated by heterogenous consumers. He shows that social indifference curves can only exist "where tastes [preferences] are identical, not only for all men, but also for all men when they are rich and poor" (Samuelson, 1956, p. 5). Both conditions are met here. Consumers are identical with respect to their preferences and homotheticity of (3.1) implies that relative demand of two goods is independent of income.

This brings us to the assumption about North's and South's technological abilities. $[0, \bar{A}^N]$ is the range of goods producible in the North and $[0, \bar{A}^S]$ is a subset of goods also producible in the South. This makes the North a developed country with a better state of technological knowledge than the South, the developing country. If $[0, \bar{A}^N]$ was interpreted as a mass of goods within the same product class, North would then be capable of producing all varieties of cars, smartphones or T-shirts, whereas the South would only be able to produce some of them in each class. However, why should a country capable of producing a Ford Focus, a Samsung Xperia, or a H&M shirt, not also be capable of producing a Volkswagen Golf, a Google Pixel or, not to mention, a GAP shirt (the only difference to the H&M shirt is probably the logo)? So, considering $[0, \bar{A}^N]$ as varieties of a single product class does not fit into the story of technologically developed and underdeveloped countries. This interpretation is simply not practical to illustrate the international product cycle, and that is probably the reason why Paul Krugman didn't even discuss it. Against this, considering $[0, \bar{A}^N]$ as goods across product classes makes total sense. A country's technological ability may be high enough to produce T-shirts but too low to produce smartphones (e.g. Bangladesh or Ethiopia). And a country that is capable of producing smartphones too, may not be capable of producing more sophisticated manufacturing products like cars (e.g. Vietnam). The three-country-model I analyze in the next section is an extension of Krugman's product cycle model. For this reason, I stick with the across-product-class interpretation and acknowledge the restrictiveness of the assumption that cars, smartphones, and T-shirts (as well as mopeds and toothbrushes) have identical demand functions.

Let's continue with the assumptions about the supply side of the model. There are constant returns to scale in production and firms operate under perfect competition. These two assumptions are identifying features of traditional trade theory. They stand in stark contrast to what Paul Krugman is actually renowned for, namely his achievement of explaining intra-industry trade under the assumptions of increasing returns to scale and imperfect, i.e., monopolistic, competition. Intra-industry trade, as opposed to *inter*-industry trade, refers to trade between similar (or even identical) countries in similar (or even identical) goods. One example is Japan and Germany (two almost identical countries in terms of capital abundancy) exchanging cars, let's say Toyota Yaris and Volkswagen Golf (two almost identical products in terms of capital intensity). Traditional trade theory, which - as I already outlined in the Introduction - considers trade as a result of country differences (more precisely, differences in relative factor endowments) is not able to explain this kind of trade pattern. From the viewpoint of traditional trade theory there is no reason why two capital abundant countries should trade two capital intensive goods with each other. Paul Krugman filled this explanatory gap by kicking off New Trade Theory. The theory originates from two seminal papers: Paul R. Krugman (1979b), "Increasing Returns, Monopolistic Competition, and International Trade", *Journal of International Economics* 9, 469–479, and Paul R. Krugman (1980), "Scale Economies, Product Differentiation, and the Pattern of Trade", *American Economic Review* 70, 950–959. As I already mentioned and as the titles indicate, this New Trade Theory makes use of increasing returns to scale in production and monopolistic competition instead of constant returns to scale and perfect competition. Increasing returns takes the form of diminishing average cost due to a fixed cost of production. Labor is the only input and all varieties are produced using the same technology so that trade can neither arise from differences in relative factor endowments nor from technological differences between the countries. Countries are identical. Individual preferences are identical, too. It is assumed that consumers love variety. This prompts product differentiation. Product differentiation means that the goods produced are identical with respect to the general purpose they accomplish but slightly differentiated with respect to their accessories or designs (blue T-shirts from different brands, smartphones within the same price class from different producers, middle-class cars from different makes etc.). Each firm produces a distinctive variety. Therefore, each firm is a monopolist for its own variety and charges a mark-up on unit cost of production. Free market entry by new firms drives this mark-up down to covering just the fixed cost of production so that each monopolist charges a price higher than unit cost but doesn't make positive profits. This is referred to as monopolistic competition. Increasing returns to scale ensures that in free trade equilibrium each variety is produced by a single firm in a single country. It is cost-efficient as the fixed cost of production is borne only once globally. This, together with consumers' love of variety, gives rise to trade between identical countries. It distinguishes New Trade Theory from traditional trade theory according to which identical countries do not trade at all. Even though the two theories explain two different kinds of trade, they have one major aspect in common: international factor price equalization. Krugman (1979a) explicitly pursues the goal of rationalizing the prevalence of international wage differentials in free trade equilibrium. The recently (1977) introduced Dixit-Stiglitz utility provided just the right tool for this. Krugman (1979a) preserved constant returns to scale and perfect competition from traditional trade theory in a one factor model and replaced 'love of quantity' (own neologism for Cobb-Douglas-like) utility with love of variety (Dixit-Stiglitz-like) utility. Countries differ from each other as in traditional trade theory but not with respect to relative factor endowments or technological differences but with respect to their ability of producing parts of the variety range. Each firm is a monopolist for its variety but does not charge a mark-up on unit cost (see equilibrium conditions below). In this way, Krugman's North-South model is a hybrid. It combines features of both traditional trade theory and New Trade Theory. Fittingly, Krugman's hybrid model was published in April 1979, seven month before his first pure New Trade model came forth. So, historically, Krugman's North-South model can be regarded as an intermediate step from traditional trade theory towards New Trade Theory. Viewed from a different angle: If Krugman had his increasing returns to scale model already at hand as a template, and if he wanted to modify it so that wage differentials emerge, he had to make countries somehow different

from each other, e.g. by assuming that the set of varieties the trading countries are able to produce is fixed a priori (how this determines wage differentials is shown further below). With this assumption, increasing returns to scale is redundant. Love of variety is sufficient to give rise to trade. In free trade equilibrium, consumers purchase all varieties that are not produced (or cannot be produced) domestically from abroad. In this case, it is convenient to 'return to' constant returns to scale, which is the easier concept to analyze.
To complete the assumptions of the model, suppose labor requirement for the production of one unit of a good in country $i$ is positive and denoted $a^i$ (input coefficient). Thus, $w^i a^i$ is the unit cost of production in country $i$. Firms locate where production cost is lowest.

### *Equilibrium*

Profit maximization under perfect competition and constant returns to scale implies that price equals unit cost (see Technical Appendix B for derivation). As all varieties in country $i$ are produced using the same technology, there is a uniform country-specific price for all varieties denoted $P^i$ ($i \in \{S, N\}$):

$$P^N = w^N a^N, \quad P^S = w^S a^S. \tag{3.4}$$

(3.3) together with (3.4) implies that the quantity demanded for each variety $j$ produced in country $i$, denoted $Y^i$, is uniform too. The demand for a variety produced in the North relative to a variety produced in the South is then given by

$$\frac{Y^N}{Y^S} = \left(\frac{P^N}{P^S}\right)^{-\frac{1}{1-\alpha}}. \tag{3.5}$$

In equilibrium, labor markets clear. Labor supply equals the amount of labor demanded to produce $Y^i$ units of $A^i$ varieties:

$$L^N = A^N a^N Y^N, \quad L^S = A^S a^S Y^S. \tag{3.6}$$

$A^i$ is the number of varieties *actually produced* in country $i$ ($\in \{S, N\}$). From equilibrium conditions (3.4)-(3.6), the North's terms of trade with South are

$$\frac{P^N}{P^S} = \frac{w^N a^N}{w^S a^S} = \left(\frac{\frac{a^N}{L^N} A^N}{\frac{a^S}{L^S} A^S}\right)^{1-\alpha}. \tag{3.7}$$

(For derivation, see Technical Appendix B). North's terms of trade are high if it is technologically advanced in that the mass of varieties it produces is large relative to its labor supply. In other words: North's terms of trade are high if it is able to spread its labor supply over a wide range of goods compared to the South. The same holds true for the relative wage: The North pays high wages if a Northern worker is capable of producing a wide range of goods compared to a Southern worker, i.e., if the North is relatively high skilled. The relative wage is even higher if a Northern worker is productive in that only a few units of labor are needed to produce one unit of output per variety compared to South, i.e., if $a^N$ is relatively low.[5] This economic intuition gets clear if we isolate $w^N/w^S$ in (3.7):

$$\frac{w^N}{w^S} = \left(\frac{L^S}{L^N}\frac{A^N}{A^S}\right)^{1-\alpha}\left(\frac{a^S}{a^N}\right)^{\alpha}.$$

In autarky, each country produces the set of goods it is able to produce. This satisfies consumers' love of variety. North produces the goods in $[0, \bar{A}^N]$ and South produces the goods in $[0, \bar{A}^S]$, with $\bar{A}^N > \bar{A}^S$. This work is all about international low-wage competition. It only considers cases in which an absolute cost differential between South and North prevails in free trade equilibrium. This is ensured by the following condition:

$$\frac{a^S}{L^S}\bar{A}^S < \frac{a^N}{L^N}(\bar{A}^N - \bar{A}^S). \tag{3.8}$$

Inequality (3.8) implies that $(w^N a^N)/(w^S a^S) > 1$ in free trade equilibrium. Wages, and thus cost of production, are higher in the North than in the South. In the moment that both countries open up trade, consumers in the North face higher prices for domestic goods than for goods produced in the South. Hence, Northern consumers will want to import the subset of goods $[0, \bar{A}^S]$ from South instead of purchasing them domestically. This gives firms in the North an incentive to relocate production of the goods in $[0, \bar{A}^S]$ to the low-cost South. The equilibrium allocation of production is henceforth given by $A^S = \bar{A}^S$ and $A^N = \bar{A}^N - \bar{A}^S$. With international cost differentials in free trade equilibrium the incentive to relocate production from North to South is maintained. However, relocation of varieties over and above $\bar{A}^S$ is not attainable. South's technological ability is already exploited. South produces all goods it is able to produce (the lower set) and the North produces the remaining goods (the upper set).

The gray dot in Figure 3.1 provides a graphical illustration of the free trade equilibrium. The free trade area composed of South and North is denoted $SN$. Under assumption (3.8), $A^N/A^S$, the independent variable, takes the value $(\bar{A}^N - \bar{A}^S)/\bar{A}^S$. This yields terms of trade between North and South larger than one.

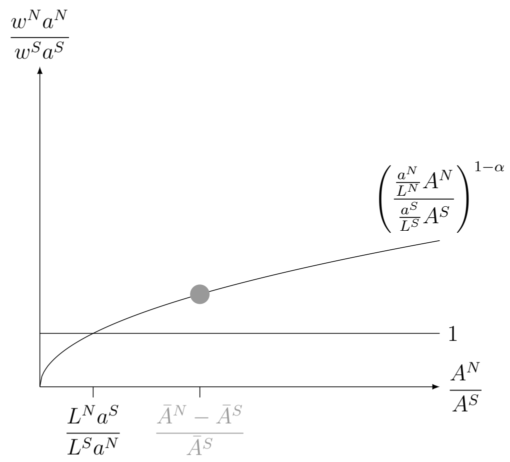
It may also happen that North's technological advantage is not sufficient to pay higher wages than South such that (3.8) is reversed. In this case, when trade opens, goods are relocated from South to North until $A^N/A^S = (a^N/L^N)/(a^S/L^S)$ and prices equalize, i.e., $w^N a^N = w^S a^S$ in equilibrium. Then, the countries produce fractions of the total number of goods equal to

$$A^N = \frac{a^N L^S}{a^N L^S + a^S L^N}\bar{A}^N, \quad A^S = \frac{a^S L^N}{a^N L^S + a^S L^N}\bar{A}^N.$$

5 In all numerical examples I present throughout this work, $a^i$ is normalized to one such that the terms of trade are equivalent to the relative wage.

(The derivation is in Technical Appendix B.) As we are concerned with international low-wage competition, I abstract from this case throughout this work.

Figure 3.1: Free trade equilibrium between South and North ($SN$)




### 3.1.2 Gains from Trade

Are there gains from trade in the two-country free trade equilibrium with wage differentials? Intuitively, there should be, for both countries. The North gains because in free trade equilibrium consumers have access to the same, viz. the whole, set of goods as in autarky but they import some of them more cheaply from the South. The South gains because consumers purchase the domestically produced set of goods at the same price as in autarky but gain access to additional goods from North. Love of variety implies that they choose to buy them although they are more expensive than the domestic ones.[6]

In the following, I prove gains from trade. For both countries, I derive general expressions for indirect utility in autarky on the one hand and in free trade equilibrium on the other hand. Then, I show that with free trade equilibrium in both countries utility is always at least as high as in autarky.

6 Interestingly, David Ricardo already claimed that "foreign trade [is] highly beneficial to a country, as it increases the amount and variety of the objects on which revenue may be expended" (Ricardo, 1817, p. 89). His famous example of Portugal and England exchanging cloth and wine formally shows that trade enables access to a larger *amount* of each good. The second source of gains from trade, however, viz. the access to a larger *variety* of goods, was formalized only 162 years later by Paul Krugman (1979a).

With identical consumers and uniform technology in the production of goods in country $i$, each consumer in country $i$ earns the same wage $w^i$ and faces the same price $P^i = w^i a^i$ for each good. Hence, utility (3.1) of a representative consumer in $i$ takes the form

$$U^i = \left[A^N (Y^N)^\alpha + A^S (Y^S)^\alpha\right]^{\frac{1}{\alpha}}, \tag{3.9}$$

where $Y^N$ and $Y^S$ are the quantities consumed of each good produced in North and South, respectively. These quantities are given by

$$Y^i = \frac{(P^i)^{-\frac{1}{1-\alpha}} w^{i'}}{A^N (P^N)^{-\frac{\alpha}{1-\alpha}} + A^S (P^S)^{-\frac{\alpha}{1-\alpha}}}, \tag{3.10}$$

for $i \in \{S, N\}$ and $i' \in \{S, N\}$. (3.10) is the model specific form of demand function (3.2). For $i = S$ and $i' = S$, (3.10) denotes the quantity of a good produced in the South and consumed by a worker earning her wage in the South. For $i = S$ and $i' = N$, it is the quantity of a good produced in the South and consumed by a worker earning her wage in the North. For $i = N$ and $i' = N$, it denotes the quantity of a good produced in the North and consumed by a worker earning her wage in the North. Lastly, for $i = N$ and $i' = S$, it is the quantity of a good produced in the North and consumed by a worker earning her wage in the South.[7]

Inserting (3.10) into (3.9) yields indirect utility

$$U^i = \frac{1}{a^i} \left[A^i + A^{i'} \left(\frac{w^i a^i}{w^{i'} a^{i'}}\right)^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}. \tag{3.11}$$

A consumer in country $i$ derives utility from the consumption of domestic goods $A^i$ purchased at terms of trade one and of foreign goods $A^{i'}$ purchased at terms of trade $(w^i a^i)/(w^{i'} a^{i'})$. In autarky, the second summand in brackets drops out and $A^i = \bar{A}^i$ so that autarky utility is given by

$$U^i_{aut} = \frac{1}{a^i} \left(\bar{A}^i\right)^{\frac{1-\alpha}{\alpha}}.$$

A Northern consumer's utility in free trade equilibrium $SN$ is greater than or equal to her utility in autarky:

$$\begin{aligned} U^N_{SN} = \frac{1}{a^N} \left[A^N + A^S \left(\frac{w^N a^N}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} &= \frac{1}{a^N} \left\{\bar{A}^N + \bar{A}^S \left[\left(\frac{w^N a^N}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}} - 1\right]\right\}^{\frac{1-\alpha}{\alpha}} \\ &\geq \frac{1}{a^N} \left(\bar{A}^N\right)^{\frac{1-\alpha}{\alpha}} = U^N_{aut}. \end{aligned}$$

7 In the three-country model with non-prohibitive tariffs in Chapter 4, the superscript $i$ indicates the country of consumption. A subscript $i$ is added to indicate the country of production. For now and for the three-country model with prohibitive tariffs, the subscript is not necessary. Hence, it is omitted.

Use is made of $A^N = \bar{A}^N - \bar{A}^S$ and $A^S = \bar{A}^S$. In an equilibrium with international cost differentials $(w^N a^N)/(w^S a^S)$ is greater than one. The inequality is strict and North gains from trade. In an FTE with cost equalization $(w^N a^N)/(w^S a^S)$ is equal to one and North is in $SN$ as well off as in autarky. In any case, North does not lose from trade. q.e.d.
A Southern consumer's utility in free trade equilibrium $SN$ is strictly greater than her utility in autarky:

$$U_{SN}^S = \frac{1}{a^S}\left[A^S + A^N\left(\frac{w^S a^S}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} = \frac{1}{a^S}\left[\bar{A}^S + (\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}$$
$$> \frac{1}{a^S}\left(\bar{A}^S\right)^{\frac{1-\alpha}{\alpha}} = U_{aut}^S.$$

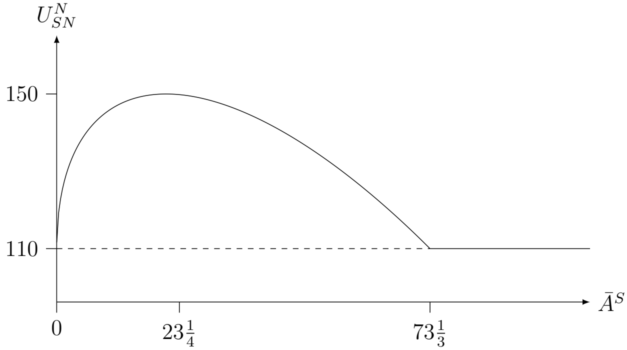
In any case, $(w^S a^S)/(w^N a^N)$ is positive and South is unambiguously better off with free trade. q.e.d.

At this point, it is worth asking how large the gains from trade for North and South are at different stages of South's development, i.e., with different values of $\bar{A}^S$ ceteris paribus. Again, I confine the analysis to values of $\bar{A}^S$ for which condition (3.8) holds, i.e., for which international cost differentials prevail in free trade equilibrium.
South's utility is increasing in $\bar{A}^S$. The economic intuition is straightforward. Increasing $\bar{A}^S$ c.p. has two welfare enhancing effects. First, the mass of goods the South imports from North at a higher price gets smaller, and second, the terms of trade with North improve. The latter effect follows from (3.7).
For North, the welfare effect of increasing $\bar{A}^S$ is ambiguous. On the one hand, the mass of goods the North imports cheaply from South gets larger, which is welfare enhancing. On the other hand, the terms of trade with South deteriorate which is welfare diminishing. Figure 3.2 illustrates these opposing effects. It shows North's welfare for the following parameter values:

| $\alpha$ | $\bar{A}^N$ | $L^S$ | $L^N$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|
| 0.5 | 110 | 200 | 100 | 1 | 1 |

With $\bar{A}^S = 0$, South is at the lowest possible stage of development. South is not able to produce any of the manufacturing goods in $[0, \bar{A}^N]$. In this case, there is no trade. North produces the whole range of goods on its own and derives autarky utility, which is equal to 110 in this numerical example. With $\bar{A}^S \geq 73\frac{1}{3}$, South's stage of development is such that there is international cost equalization. North imports the goods produced in the South at terms of trade equal to one, which entails the same utility as in autarky ($U_{aut}^N = 110$). So, for $\bar{A}^S \geq 73\frac{1}{3}$, $U_{SN}^N$ is a horizontal line. For $0 < \bar{A}^S < 73\frac{1}{3}$, $U_{SN}^N$ is an inverted parable. Its maximum is at $\bar{A}^S \approx 23\frac{1}{4}$ in this example. This implies that if the North had to choose between two trading partners on different development stages

Figure 3.2: North's utility in $SN$ with varying $\bar{A}^S$




beyond $\bar{A}^S \approx 23\frac{1}{4}$, it would choose the less developed one. There is no such decision to make in the two-country model. However, in the three-country model, to which I turn now, this property is crucial when it comes to FTA formation.

## 3.2 Three Countries

In this section, I analyze the effects of the entry of a low-wage country into the world economy, with a particular focus on the new medium-wage country. I first show that, while the high-wage country benefits, the gains from trade in the former low-wage and then medium-wage country may go down. Then, I show that the endogenous formation of an FTA may result in an exclusion of the medium-wage country implying that the medium-wage country's gains form trade even vanish entirely.

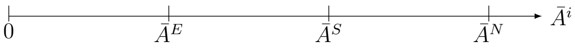
### 3.2.1 Model

*Assumptions*

This model extends the two-country static variant of Krugman's technology transfer model (1979a) presented in the previous section in that the world economy consists of three countries now, East ($E$), South ($S$), and North ($N$). All other assumptions are carried over. I just use a more general notation: Country $i$ ($\in \{E, S, N\}$) is populated by $L^i$ ($> 0$) consumers, each of whom supplies one unit of labor, the only factor of production. There are $\bar{A}^N$ Dixit-Stiglitz goods indexed $[0, \bar{A}^N]$ and utility of an inhabitant of country $i$ is represented by (3.1). Firms in country $i$ are able to produce the varieties indexed $[0, \bar{A}^i]$ and $a^i$ ($> 0$) units of labor yield one unit of a producible variety in country $i$. There is perfect competition and firms locate where production cost is lowest. $[0, \bar{A}^i]$ is the set of goods producible in country $i$, with $\bar{A}^N > \bar{A}^S > \bar{A}^E$ (see Figure 3.3 for illustration).

East is assumed to have less technological knowledge than South so that East, South, and North can be labeled least developed, developing, and developed, respectively.

Figure 3.3: Technological knowledge of East, South, and North



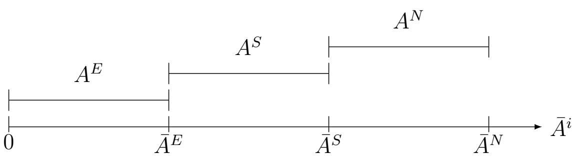

### *Equilibrium*

The equilibrium conditions are according to (3.4)-(3.6) from the two-country model: Due to perfect competition, the price of a variety produced in country $i$ is $P^i = w^i a^i$, where $w^i$ is the wage rate in country $i$. The mass of goods produced in $i$ is $A^i$, and the quantity consumed of a variety produced in $i$ is $Y^i$. Utility maximization implies $P^i/P^{i'} = (Y^{i'}/Y^i)^{1-\alpha}$ for each pair of varieties. Labor market clearing implies $L^i = A^i a^i Y^i$. Hence, the terms of trade between countries $i$ and $i'$ are

$$\frac{P^i}{P^{i'}} = \frac{w^i a^i}{w^{i'} a^{i'}} = \left( \frac{\frac{a^i}{L^i} A^i}{\frac{a^{i'}}{L^{i'}} A^{i'}} \right)^{1-\alpha}, \quad (i, i') \in \{(E, S), (E, N), (S, N)\}. \tag{3.12}$$

Recall that a country's terms of trade are high if it is technologically advanced in that the mass of varieties it produces is large relative to its labor supply.
I consider the world economy with no trade, with FTAs made up of two countries and no trade with the third country, and with the FTA that covers all three countries, i.e., global free trade. The FTA made up of East and South is called $ES$. The FTAs $EN$, $SN$, and $ESN$ are defined analogously. Any such partition of the set of countries is called a trading system. For a given trading system, an equilibrium consists of a free trade equilibrium of the FTA, if there is one, and autarky equilibria of the countries not in the FTA.
Since the topic of this thesis is low-wage competition, I focus on equilibria with absolute cost differentials between the member countries of an FTA. The North has the highest unit cost $w^i a^i$, and unit cost is higher in the South than in the East if both are in an FTA. As a result, firms in $i$ produce the subset of varieties in $[0, \bar{A}^i]$ no foreign firm can produce more cheaply in an FTA. In $ESN$ (global free trade), this implies that $A^E = \bar{A}^E$, $A^S = \bar{A}^S - \bar{A}^E$ and $A^N = \bar{A}^N - \bar{A}^S$. Figure 3.4 serves as an illustration.

Figure 3.4: Equilibrium allocation of production with global free trade ($ESN$)



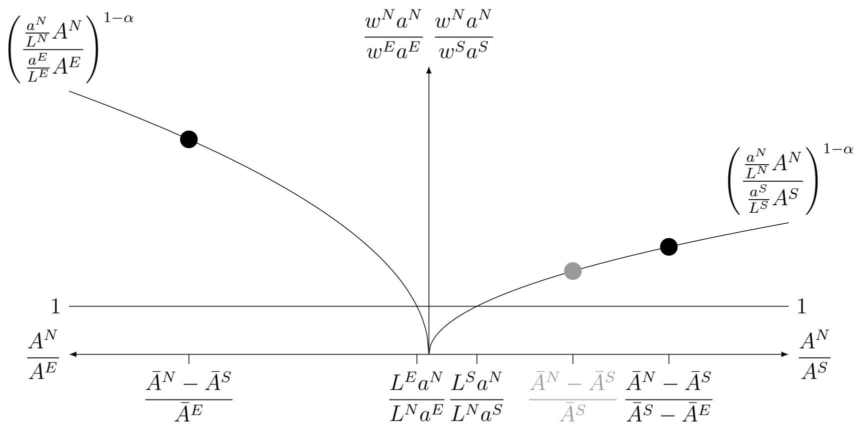
The following assumption ensures the existence of an equilibrium with absolute cost advantages for all trading systems:

$$\frac{a^i}{L^i}\bar{A}^i < \frac{a^{i'}}{L^{i'}}(\bar{A}^{i'} - \bar{A}^i), \quad (i, i') \in \{(E, S), (E, N), (S, N)\}. \tag{3.13}$$

That (3.13) implies the existence of a free trade equilibrium for the two-country FTAs is obvious from (3.12). Validity of (3.13) for $(S, N)$ implies $(a^S/L^S)(\bar{A}^S - \bar{A}^E) < (a^N/L^N)(\bar{A}^N - \bar{A}^S)$ and, therefore, the existence of a free trade equilibrium with absolute cost differentials of $ESN$.

Figure 3.5 depicts the comparative statics effect of the entry of the new low-wage competitor on North's terms of trade. The black dot reproduces the pre-existing FTA $SN$ from Figure 3.1. As soon as low-wage East enters the global economy, South becomes a medium-wage country, and firms in the South relocate production of the goods in $[0, \bar{A}^E]$ to the East. North continues to produce the upper set of goods $(\bar{A}^S, \bar{A}^N]$. With East's entry, $A^N/A^S$, the number of goods produced in the North relative to South, increases. From (3.12), this entails an improvement (deterioration) of North's (South's) terms of trade with South (North). This comparative statics effect is indicated by the black dot that lies to the right and above the gray dot. The black dot on the left connects the number of varieties produced by North relative to East with the entailing terms of trade between North and East. It lies above the black dot on the right implying that condition (3.13) holds, i.e., South's terms of trade with East are larger than one. Both black dots together constitute the free trade equilibrium of $ESN$.

Figure 3.5: Free trade equilibria $SN$ and $ESN$



### 3.2.2 Pains from Trade

The deterioration of South's terms of trade with North as a result of East's entry is a first hint towards pains from trade for the middle-income country. It already provides a theoretical ground for Blecker and Esquivel's assertion (2010) that the emergence of China (East) was - among other developments - responsible for Mexico's (South) real wage stagnation after the launch of NAFTA, the pre-existing FTA with the U.S. and Canada (North).

East's entry reduces South's welfare because the deterioration of the terms of trade with North makes the goods in $(\bar{A}^S, \bar{A}^N]$ more expensive. Simultaneously, East's entry increases South's welfare because the goods in $[0, \bar{A}^E]$, previously purchased domestically, are now imported at a lower price. What is the net effect on South's welfare? What are the welfare effects for East and North? To answer these questions, we employ the general form of indirect utility of a consumer in country $i$ for the three-country model. This, analogous to (3.11), a consumer's indirect utility from the two-country model, is represented by

$$U^i = \frac{1}{a^i}\left[A^i + A^{i'}\left(\frac{w^i a^i}{w^{i'} a^{i'}}\right)^{\frac{\alpha}{1-\alpha}} + A^{i''}\left(\frac{w^i a^i}{w^{i''} a^{i''}}\right)^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} . \tag{3.14}$$

(For derivation see Technical Appendix B). Consumer $i$ earns income $w^i$ and faces prices $w^i a^i$ for domestic varieties and prices $w^{i'} a^{i'}$ and $w^{i''} a^{i''}$ for varieties produced in the two other countries $i'$ and $i''$ that trade with $i$. $A^{i'} = 0$ if $i'$ is not in an FTA with $i$ and $A^{i''} = 0$ if $i''$ is not in an FTA with $i$.

There are two potential sources of gains from trade that we already know from the two-country model. First, due to her love of variety, the worker benefits from additional varieties supplied by her home country $i$'s trading partners $i'$ and $i''$. Second, she benefits from the opportunity of buying goods that could also be produced at home but are imported from a country with lower cost (i.e., if $(w^{i'} a^{i'})/(w^i a^i) < 1$ or $(w^{i''} a^{i''})/(w^i a^i) < 1$). Use subscripts $i\,i'$ and $ESN$ to distinguish values of variables in an equilibrium of FTA $i\,i'$ and of $ESN$, respectively.

**Proposition 1:** *Consumers rank the equilibria of $ESN$ and $SN$ as follows: $U^E_{ESN} > U^E_{SN}$, $U^S_{ESN} > U^S_{SN}$ if, and only if,*

$$(\bar{A}^N - \bar{A}^S)\left[\left(\frac{w^S a^S}{w^N a^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}} - \left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right] < \bar{A}^E\left[\left(\frac{w^S a^S}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} - 1\right], \tag{3.15}$$

*and $U^N_{ESN} > U^N_{SN}$.*

The proof is in Appendix A. East unambiguously gains from entering global free trade. This follows from revealed preference: In $ESN$, an Eastern worker can get her autarky utility by consuming only the domestically produced goods. The fact that she chooses to import varieties from the South and from the North implies that this makes her better off, even though the imported varieties are more expensive than domestically produced ones.

North is also unambiguously better off after East's entrance. It produces the goods in $(\bar{A}^S, \bar{A}^N]$ domestically in $SN$ and in $ESN$. No other country is capable of producing these goods. Access to the goods in $[0, \bar{A}^S]$ is guaranteed in both trading systems, too. The amount of goods accessible to Northern consumers does not change. So, in terms of product variety, North's welfare is unaffected by East's entry. In terms of cost, however, it is affected; in two ways: First, in $ESN$, North imports $[0, \bar{A}^E]$ at lower cost (from East) than in $SN$ (from South), and second, terms of trade with South are more favorable after East's entry, as shown in figure 3.5, so that the goods in $(\bar{A}^E, \bar{A}^S]$ are imported at lower cost, too.

South only gains from East's entry if (3.15) holds. As the production of a subset of the varieties is relocated to the East, the South's terms of trade with the North deteriorate in $ESN$ compared to $SN$. The left-hand side of (3.15) is the associated utility loss: the difference in terms of trade with North between $SN$ and $ESN$ multiplied with the number of goods imported from North. The subset of varieties that is relocated to East is purchased more cheaply in $ESN$ than in $SN$. The right-hand side of (3.15) is the associated utility gain: the difference in price of $\bar{A}^E$ between $ESN$ (terms of trade with East) and $SN$ (1) multiplied with the number of goods imported from East. Hence, the South benefits from East's entry on net only if the welfare enhancing effect of cheap imports from the East more than outweighs the welfare diminishing effect of deteriorated terms of trade with North. If the inequality sign in (3.15) is reversed, the South prefers an two-country FTA with the North over global free trade. A sufficient condition for this case to arise is that $\bar{A}^N$ is sufficiently large. This follows from the fact that, from (3.12), increases in $\bar{A}^N$ raise the left-hand side of (3.15) and leave the right-hand side unaffected. The economic intuition is straightforward: The larger the number of goods that are imported from North, the heavier weighs a deterioration of the terms of trade with North. Another simple sufficient condition is that $[(w^S a^S)/(w^E a^E)]_{ESN}$ is close enough to unity, i.e., that the positive effect of cheap imports from the East is sufficiently small. To illustrate Proposition 1 consider the following example:[8]

**Example 1:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 40 | 70 | 110 | 400 | 200 | 100 | 1 | 1 | 1 |

From (3.12), the relative cost terms in Proposition 1 between South and North, and East and South, are $[(w^S a^S)/(w^N a^N)]_{ESN} = 0.61$, $[(w^S a^S)/(w^N a^N)]_{SN} = 0.94$, and $[(w^E a^E)/$

8 In what follows, whenever inequality constraints are used to distinguish cases, examples of parameters for each possible case are given either in the running text or in Numerical Appendix C.

$(w^S a^S)]_{ESN} = 0.81$. The condition of the proposition ($12.92 < 9$) is violated. The South's utility is $U^S_{SN} = 107.42$ before and $U^S_{ESN} = 103.49$ after the entry of East. South suffers from panis from trade in this example.

As already mentioned in the literature review, analogous results can be derived from the three-country Ricardian model with a continuum of goods (Collins, 1985), from a one-factor neoclassical model with technology differences (Thompson, 2015), and from the Heckscher-Ohlin model (cf. Dixit and Grossman, 2005). The three-country Krugman model (1979a) provides a novel explanation for a reduction in gains from trade for a medium-wage country that loses market shares to a new low-wage competitor.

### 3.2.3 Formation of Free Trade Areas

This section investigates the endogenous formation of an FTA in the three-country model. As markets are perfectly competitive and there is no lobbying, the formation of the equilibrium FTA is determined by terms-of-trade effects alone (cf. Maggi 2014, Section 2). I assume that countries in an FTA do not trade with non-member countries. This allows the derivation of analytical results that highlight the 'exclusion incentives' present in the three-country world economy with wage differentials. The corresponding section in Chapter 4 deals with the case of non-prohibitive external tariffs. This section is divided into two parts. The first part allows for international transfers within the FTA. These are transfers of utility via goods or income. The second part analyzes the formation of the equilibrium FTA in the absence of international transfers.

## Part I: International Transfers

In what follows, I show that in the presence of international transfers there is a strong presumption that global free trade emerges, as this is the only way to achieve a Pareto optimal allocation. Whether or not the South is compensated for a reduction in its gains from trade if necessary depends on the specific rules that govern the formation of the equilibrium FTA. There are cases in which full compensation of the South is even impossible.

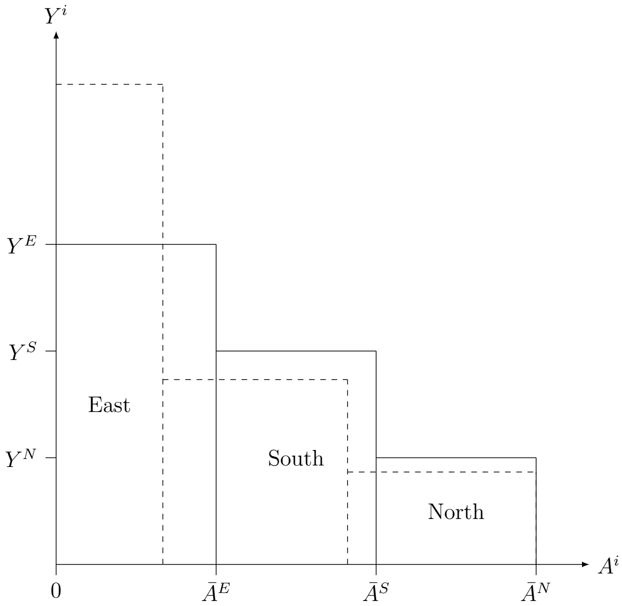
Global free trade is the only way to achieve a Pareto optimal allocation:

**Proposition 2:** *The set of Pareto optimal allocations is characterized as follows: East produces the varieties in $[0, \bar{A}^E]$, South produces the varieties in $(\bar{A}^E, \bar{A}^S]$, and North produces the varieties in $(\bar{A}^S, \bar{A}^N]$. Each country $i$ produces the same quantity $Y^i = L^i/(a^i A^i)$ of each variety it produces. A given consumer $k$ gets the same fraction $\lambda_k$ of the output of each variety. This fraction is equal to her share in world income and the $\lambda_k$'s add up to unity.*[9]

9 Here and in what follows I omit the qualification 'except for a set of varieties of measure zero'.

The proof is quite intricate and delegated to Appendix A. The intuition why the allocation in the proposition is Pareto optimal is straightforward: From (3.13), the output per variety is lower in the North than in the South and lower in the South than in the East. So consumers would benefit from a shift of Southern labor to varieties produced in the North or of Eastern labor to varieties produced in the South. But that is not feasible, since the South is unable to produce the varieties manufactured in the North and the East is unable to produce the varieties manufactured in the South. The proof in Appendix A is constructive. It establishes that no other Pareto optimal allocations exist. Figure 3.6 illustrates Proposition 2.

Figure 3.6: Pareto optimal allocation of production in $ESN$




The allocation of production depicted by the dashed-framed bars is an allocation in which there is full employment in the three countries. The North produces less units per variety than the South and the South produces less units per variety than the East. Hence, shifting Eastern labor to varieties produced in the South and Southern labor to varieties produced in the North is Pareto superior. It is feasible because the mass of varieties produced in East and South lies within their range of producible varieties, $[0, \bar{A}^E]$ and $[0, \bar{A}^S]$ respectively. This shift of production continues until East's and South's technological abilities are exhausted, the situation depicted by the solid-framed bars. With this allocation, $Y^E > Y^S > Y^N$ still holds, meaning that the incentive to shift production is still present. Due to the technological frontiers, however, it is not feasible. Thus, the solid-framed bars constitute the Pareto optimal allocation.

In the equilibrium of $ESN$, firms' production decisions lead to the outputs described in Proposition 2 and each consumer $k$ buys a fraction of the output of each variety that is equal to her share in world income. So the equilibrium allocation with global free trade and no transfers is Pareto optimal. Since Pareto optimal allocations differ only with respect to the proportions of production individual consumers get, any Pareto optimal allocation can be established as an equilibrium allocation using transfers. All other trading systems lead to a different equilibrium pattern of production and, therefore, to Pareto inefficiency.

For the sake of clarity, suppose consumers' individual utilities are cardinal and interpersonally comparable and define the (Utilitarian) social welfare of a set of consumers $k$ as the sum of these consumers' utilities $\sum_k U_k$. An allocation that is not Pareto optimal does not maximize worldwide social welfare. Given that Pareto optimal allocations differ only with respect to the proportions of aggregate output that accrue to the individual consumers, the fact that all consumers have the same linearly homogenous utility function (3.1) implies that worldwide social welfare is uniform across all Pareto optima. So, Pareto optimality is equivalent to maximization of worldwide social welfare. The fact that the only trading system that brings forth Pareto optimality is global free trade implies grand-coalition superadditivity: Social welfare is maximum with global free trade (cf. Aghion et al. 2007, p. 8).

From Proposition 2, any rule that determines the equilibrium trading system leads to global free trade if it obeys the Pareto principle or, equivalently, welfare maximization. Whether or not the South is better off than in $SN$ depends on the specific rules that govern the formation of the FTA. Three standard examples serve to illustrate this: the core principle (cf. Riezman, 1985), cooperative Nash bargaining, and strategic sequential bargaining (cf. Aghion et al., 2007).[10]

Consider first the core. "The core of an economy consists of those states of the economy which no group of agents can 'improve upon'. A group of agents can improve upon a state of the economy if the group, by using the means available to it, can make each member of that group better off, regardless of the actions of the agents outside that group" (Hildebrand, 1982, p. 831). This definition of the core in the context of a multi-country trade model reads as follows: The core of the world economy consists of those trading systems which no group of countries can improve upon. A group of countries can improve upon a trading system if the group, by forming a different trading system, can make each member of that group better off, regardless of the actions of the countries outside that

10 The core principle and bargaining games are the standard approaches to the endogenous formation of regional trade agreements among a small number of countries. The multi-country network approach (cf. Goyal and Joshi, 2006) does not lend itself well to the three-country setup. See Limão (2016, p. 348 ff.).

group. In short: The core is the set of trading systems that are not blocked by any coalition of countries (see also Mas-Colell et al., 1995, p. 653 f., Definitions 18.B.1 and 18.B.2).

**Proposition 3:** *In the presence of international transfers, each trading system in the core entails the FTA $ESN$.*

In a three-country world economy made up of East, South and North, five possible trading systems can be formed: Autarky, $ES$, $EN$, $SN$, and $ESN$. Each trading system except $ESN$ is blocked by the set of all three countries, because switching to global free trade and using international transfers to distribute the ensuing welfare gains appropriately makes consumers in all countries better off. In the following, I prove that the core is non-empty. Non-emptiness of the core reflects that free trade is not a zero-sum game: There exist international transfers in $ESN$ such that no coalition of two countries can improve upon its situation in an FTA that excludes the third country.

Let $\bar{U}^i_{i'i''}$ denote social welfare in country $i$ given that $i'$ and $i''$ form an FTA. $\bar{U}^i_{ESN}$ is defined analogously. Social welfare is individual utility (3.14) multiplied with national labor supply $L^i$. Let $V^i$ denote the social welfare of country $i$ with the FTA $ESN$ and with international transfers. $ESN$ is in the core if there are $V^E$, $V^S$, and $V^N$ such that

$$V^E + V^S + V^N = \bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN} \tag{3.16}$$
$$V^E \geq \bar{U}^E_{SN} \tag{3.17}$$
$$V^S \geq \bar{U}^S_{EN} \tag{3.18}$$
$$V^N \geq \bar{U}^N_{ES} \tag{3.19}$$
$$V^E + V^S \geq \bar{U}^E_{ES} + \bar{U}^S_{ES} \tag{3.20}$$
$$V^E + V^N \geq \bar{U}^E_{EN} + \bar{U}^N_{EN} \tag{3.21}$$
$$V^S + V^N \geq \bar{U}^S_{SN} + \bar{U}^N_{SN}. \tag{3.22}$$

Condition (3.16) states that global welfare in $ESN$ with transfers (left-hand side of the equation) is equal to global welfare in $ESN$ without transfers (right-hand side of the equation). Not more and not less than global welfare can be allocated among the countries using transfer payments.

Conditions (3.17), (3.18), and (3.19) imply that in $ESN$ (left-hand side) a country is at least as well off as in autarky (right-hand side).

Conditions (3.20), (3.21), and (3.22) make sure that no group of two countries has an incentive to block $ESN$, i.e., the joint welfare of two countries in $ESN$ with transfers (left-hand side) is equal to or larger than their joint welfare in the two-country FTA (right-hand side). If not, the two countries are better off by excluding the third country and sharing the welfare surplus.

The following transfer scheme satisfies these inequalities. It entails that consumers in the South receive only their autarky utility level $U^S_{EN}$.

**Transfer Scheme 1:**

$$\begin{aligned} V^E &= \left(\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN}\right) - \left(\bar{U}^S_{SN} + \bar{U}^N_{SN}\right) \\ V^S &= \bar{U}^S_{EN} \\ V^N &= \left(\bar{U}^S_{SN} + \bar{U}^N_{SN}\right) - \bar{U}^S_{EN}. \end{aligned}$$

Conditions (3.16), (3.18), and (3.22) are satisfied by construction. Validity of (3.17) follows from grand-coalition superadditivity: Joint welfare in $ESN$ is greater than joint welfare in $SN$, i.e., $\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN} > \bar{U}^E_{SN} + \bar{U}^S_{SN} + \bar{U}^N_{SN}$. Hence, $V^E = \left(\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN}\right) - \left(\bar{U}^S_{SN} + \bar{U}^N_{SN}\right) > \bar{U}^E_{SN}$. Validity of (3.21) follows from grand-coalition superadditivity, too: $V^E + V^N = \left(\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN}\right) - \bar{U}^S_{EN}$. Using this in (3.21) and rearranging terms yields $\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN} \geq \bar{U}^E_{SN} + \bar{U}^S_{SN} + \bar{U}^N_{SN}$ (grand-coalition superadditivity). The presence of gains from trade, i.e., $\bar{U}^S_{SN} - \bar{U}^S_{EN} > 0$ and $\bar{U}^N_{SN} > \bar{U}^N_{ES}$, implies that (3.19) holds. Showing that condition (3.20) holds requires an application of Scarf's (1967, pp. 51–53) result for superadditive three-player market models with convex preferences. This is delegated to Appendix A.
Again, there is a parallel in the Heckscher-Ohlin model. As pointed out by Dixit and Norman (1980), if countries differ only in terms of factor endowments, global free trade with factor price equalization reproduces the 'integrated' Walrasian equilibrium that would emerge in the absence of national borders. The fact that Walrasian equilibrium satisfies the core property (see Mas-Colell et al., 1995, p. 654, Proposition 18.B.1) implies that no coalition of individuals and, hence, no coalition of countries can block the grand coalition.

Table 3.1: Example 1 social welfare before transfers

| $\bar{U}^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 25,798 | 26,583 | 16,000 | 33,798 |
| South | 15,798 | 14,000 | 21,483 | 20,697 |
| North | 11,000 | 17,583 | 11,483 | 16,899 |
| Within FTA | 41,596 | 44,166 | 32,966 | 71,394 |

Let's apply Transfer Scheme 1 to numerical Example 1. Table 3.1 shows each country's social welfare in all possible trading systems and joint welfare within each free trade area, both before transfer payments. According to Transfer Scheme 1, social welfare levels in $ESN$ amount to

$$
\begin{aligned}
V^E &= \left(\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN}\right) - \left(\bar{U}^S_{SN} + \bar{U}^N_{SN}\right) &&= 38,428\\
V^S &= \bar{U}^S_{EN} &&= 14,000\\
V^N &= \left(\bar{U}^S_{SN} + \bar{U}^N_{SN}\right) - \bar{U}^S_{EN} &&= 18,966
\end{aligned}
$$

Conditions (3.16) - (3.22) are satisfied:

$$
\begin{aligned}
71,394 &= & V^E + V^S + V^N = \bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN} &&= 71,394\\
38,428 &= & V^E > \bar{U}^E_{SN} &&= 16,000\\
14,000 &= & V^S = \bar{U}^S_{EN} &&= 14,000\\
18,966 &= & V^N > \bar{U}^N_{ES} &&= 11,000\\
52,428 &= & V^E + V^S > \bar{U}^E_{ES} + \bar{U}^S_{ES} &&= 41,596\\
57,394 &= & V^E + V^N > \bar{U}^E_{EN} + \bar{U}^N_{EN} &&= 44,166\\
32,966 &= & V^S + V^N = \bar{U}^S_{SN} + \bar{U}^N_{SN} &&= 32,966
\end{aligned}
$$

Figure 3.7: Example 1 social welfare in $ESN$ before transfers

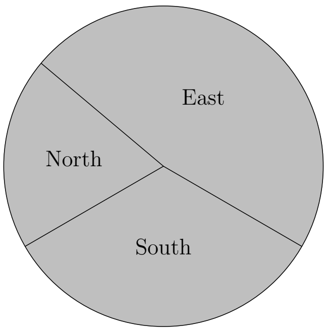
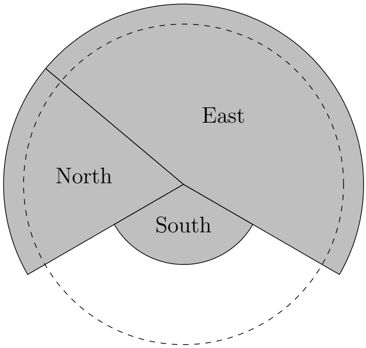



Figure 3.7 is a pie chart illustrating social welfare of the three countries in $ESN$ before transfer payments. The sizes of the pieces of pie are according to the countries' share in global welfare in numerical Example 1. The biggest piece of pie accrues to East, the medium-sized one to South, and the smallest one to North ($\bar{U}^E_{ESN} = 33,798 > \bar{U}^S_{ESN} = 20,697 > \bar{U}^N_{ESN} = 16,899$).

Figure 3.8 shows social welfare in $ESN$ with Transfer Scheme 1. The dashed circle replicates the social welfare pie before transfer payments. Southern consumers have to make do with their autarky welfare level, East and North are better off than before transfer payments.

I showed that Transfer Scheme 1 is in the core. Hence, South can suffer from an outright loss of its gains from trade after East's entry despite the possibility of compensation via

Figure 3.8: Example 1 social welfare in $ESN$ with Transfer Scheme 1




transfer payments. Different transfer payments in $ESN$ lead to different distributions of welfare across countries. Of course, any transfer scheme that makes South better off than in autarky is also in the core as long as East and North are not worse off than in $EN$. The welfare scheme that yields the maximum social welfare for South is the following.

**Transfer Scheme 2:**

$$V^E = \bar{U}^E_{EN} \tag{3.23}$$
$$V^S = \left(\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN}\right) - \left(\bar{U}^E_{EN} + \bar{U}^N_{EN}\right) \tag{3.24}$$
$$V^N = \bar{U}^N_{EN} \tag{3.25}$$

If we apply Transfer Scheme 2 to numerical Example 1, social welfare in ESN amounts to

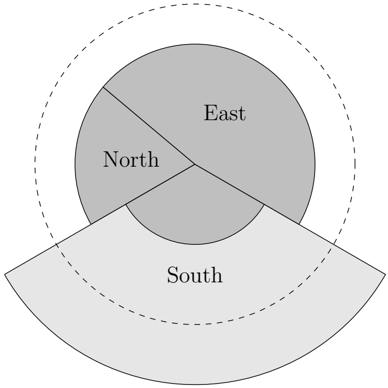
$$V^E = \bar{U}^E_{EN} = 26,583$$
$$V^S = \left(\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN}\right) - \left(\bar{U}^E_{EN} + \bar{U}^N_{EN}\right) = 27,228$$
$$V^N = \bar{U}^N_{EN} = 17,583$$

Conditions (3.16) - (3.22) are satisfied:

$$71,394 = V^E + V^S + V^N = \bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN} = 71,394$$
$$26,583 = V^E > \bar{U}^E_{SN} = 16,000$$
$$27,228 = V^S > \bar{U}^S_{EN} = 14,000$$
$$17,583 = V^N > \bar{U}^N_{ES} = 11,000$$
$$53,811 = V^E + V^S > \bar{U}^E_{ES} + \bar{U}^S_{ES} = 41,596$$
$$44,166 = V^E + V^N = \bar{U}^E_{EN} + \bar{U}^N_{EN} = 44,166$$
$$44,811 = V^S + V^N > \bar{U}^S_{SN} + \bar{U}^N_{SN} = 32,966$$

Transfer Scheme 2 implies $V^S = 27,228 > 21,483 = \bar{U}^S_{SN}$. South is more than compensated for its welfare loss from East's entry. It yields maximum utility for South and minimum utility for East and North in Example 1. This is illustrated by Figure 3.9. The light gray area covers the set of all transfer payments to South that are in the core. Whether South suffers an outright loss of its gains from trade (Transfer Scheme 1) after East's entry, or is more than compensated for possible pains from trade (Transfer Scheme 2), is indeterminate.

Figure 3.9: Example 1 social welfare in $ESN$ with Transfer Scheme 2




Interestingly, numerical analysis shows that it is not always possible to fully compensate the South for potential pains from trade. One example is the following.

**Example 2:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 5 | 11 | 100 | 100 | 100 | 800 | 1 | 1 | 1 |

The ensuing welfare levels before transfers are summarized in Table 3.2.

Table 3.2: Example 2 social welfare before transfers

| $\bar{U}^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 1,048 | 6,664 | 500 | 7,014 |
| South | 1,148 | 1,100 | 9,950 | 7,684 |
| North | 80,000 | 82,165 | 80,050 | 83,702 |
| Within FTA | 2,196 | 88,829 | 90,000 | 98,400 |

South suffers from a reduction in welfare after East's entry: $\bar{U}_{SN}^S = 9{,}950 > 7{,}684 = \bar{U}_{ESN}^S$. Global welfare in $ESN$ is 98,400. This can arbitrarily be distributed among the countries using transfer payments. Condition (3.16) requires $V^E + V^S + V^N = 98{,}400$. Condition (3.21) requires $\bar{U}_{EN}^E + \bar{U}_{EN}^N = 88{,}829 \geq V^E + V^N$, so that East and North are at least indifferent between $ESN$ and $EN$. This leaves scope for transfers to South in the amount of $V^S = 98{,}400 - 88{,}829 = 9{,}571$. This is the maximum utility that can be allocated to South in this example. It is smaller than $9{,}950 = \bar{U}_{SN}^S$, South's social welfare before East's entry. Hence, South cannot be fully compensated without violating condition (3.21), i.e., making East and North worse-off than in $EN$. Put differently: If transfers are such that condition (3.21) holds, (3.18) is violated, i.e., South is worse-off than before East's entry. No transfer scheme that fully compensates South's welfare loss from East's entry is in the core. More generally speaking: Despite grand-coalition superadditivity and the possibility of international transfers, South can be unambiguously worse off in $ESN$ compared to $SN$. Example 1 is not exceptional. Additional examples yielding the same result can easily be found. One of them is in Numerical Appendix C.

Next, consider Nash bargaining. This removes the indeterminacy of the equilibrium transfers between FTA member countries. Suppose countries bargain over the expansion of the pre-existing FTA $SN$, so that the disagreement payoffs are $U_{SN}^i$ for $i \in \{E, S, N\}$. Global free trade emerges, and the South gets utility higher than or equal to $U_{SN}^S$, depending on whether it has positive bargaining power or not. In any case, its utility does not drop to a value $U_{ESN}^S$ lower than $U_{SN}^S$.
Finally, suppose the North as the leader proposes the expansion of the FTA and rejection leads to keeping $SN$. The North offers the South a transfer that keeps its utility at $U_{SN}^S$, the South accepts, global free trade emerges, and the South is as well off as before.

I showed that with the possibility of making international transfer payments, the grand coalition ($ESN$) forms in equilibrium as long as the formation rule follows the Pareto principle. Three standard examples served to illustrate this: the core, Nash bargaining, and sequential bargaining. In the core, it is indeterminate whether South is compensated or not for a possible reduction in its welfare from East's entrance. It can even be the case that full compensation of the South is not in the core. With Nash bargaining, the indeterminacy of the equilibrium transfers in $ESN$ is removed. Whether South gets in $ESN$ a utility higher or equal to its utility in $SN$ depends on its bargaining power. With sequential bargaining and North as the leader, South is as well-off as before East's entry. International transfers are rarely observed in negotiations over the formation of free trade areas. What happens if the assumption of international transfers is abandoned? Which trading system forms in equilibrium then? The following part addresses these questions.

## Part II: No International Transfers

This part analyzes the formation of the equilibrium FTA in the absence of international transfers. While transfers can be used to compensate the South if possible and necessary in the examples in the preceding part, the outlook is bleaker here. If global free trade emerges, then the South gets no compensation for a possible reduction in its gains from trade. If not, the North and the East possibly have incentives to exclude the South from the equilibrium FTA (cf. Missios et al., 2016; Nken and Yildiz, 2021 on exclusion incentives). To illustrate, I consider again the core and strategic bargaining.[11]

Proposition 2 implies that (global) social welfare is maximum in $ESN$. This information was sufficient to determine the equilibrium FTA in the preceding part: By switching to global free trade, international transfers can be used to distribute the ensuing welfare gains such that consumers in all countries are better off. Hence, each trading system except $ESN$ is blocked by all three countries. Each trading system in the core entails the FTA $ESN$ (Proposition 3) and $ESN$ is the outcome of Nash and sequential bargaining. Without international transfers, $ESN$ may not be the only trading system that leads to a Pareto optimal allocation. From Proposition 1, we already know that East and North unambiguously rank $ESN$ higher than $SN$, and South does so too, if and only if condition (3.15) holds. This means that if condition (3.15) is reversed (pains from trade for South), $SN$ is also Pareto optimal because switching to any other trading system makes South worse off. What about the remaining trading systems $EN$ and $ES$? How do the countries rank them? And how do they rank $EN$ and $ES$ with respect to $ESN$ and $SN$? Without also knowing these rankings we cannot determine the equilibrium FTA in the absence of international transfers. To this end, I now complete the countries' comparison of all trading systems.

Let's point out first that there are gains from trade in that every country prefers any other trading system over autarky. The intuition is that every country has either access to additional varieties or gets existing varieties cheaper than in autarky, or both when opening up to trade. The formal proof is in Appendix A. Derivations of the below inequalities and conditions are in Technical Appendix B.

**Comparison of $ESN$ and $ES$:**

**$\mathbf{U^E_{ESN}}$ vs. $\mathbf{U^E_{ES}}$:**
$U^E_{ESN} > U^E_{ES}$ exactly if

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > (\bar{A}^S - \bar{A}^E)\left[\left(\frac{w^E a^E}{w^S a^S}\right)_{ES}^{\frac{\alpha}{1-\alpha}} - \left(\frac{w^E a^E}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right].$$

11 Nash bargaining is not applicable here, as the convexity property underlying its axiomatization is not satisfied with the present discrete choice set.

From (3.12), the right-hand side is zero because East's terms of trade with South do not change if North is included. The left-hand side is positive. This is East's welfare gain from access to varieties produced in the North when switching from $ES$ to $ESN$. Thus, East unambiguously prefers $ESN$ over $ES$.

$\mathbf{U^S_{ESN}}$ **vs.** $\mathbf{U^S_{ES}}$**:**
$U^S_{ESN} > U^S_{ES}$ exactly if

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{ESN} > \bar{A}^E\left[\left(\frac{w^S a^S}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{ES} - \left(\frac{w^S a^S}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}\right].$$

From (3.12), the right-hand side is zero. The same argument as with East holds true with South: South's terms of trade with East do not change if North is included. The left-hand side is positive. This is South's welfare gain from access to varieties produced in the North when switching from $ES$ to $ESN$. Thus, South unambiguously prefers $ESN$ over $ES$.

North prefers $ESN$ over $ES$, too (gains from trade). Thus, all three countries simultaneously rank $ESN$ higher than $ES$.

**Comparison of** $ESN$ **and** $EN$**:**

$\mathbf{U^E_{ESN}}$ **vs.** $\mathbf{U^E_{EN}}$**:**
$U^E_{ESN} > U^E_{EN}$ exactly if

$$(\bar{A}^S - \bar{A}^E)\left[\left(\frac{w^E a^E}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}_{ESN} - \left(\frac{w^E a^E}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}\right] > (\bar{A}^N - \bar{A}^E)\left[\left(\frac{w^E a^E}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{EN} - \left(\frac{w^E a^E}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}\right].$$

The validity of this inequality follows from the fact that from (3.12), the right-hand side is negative and the left-hand side is positive. East is unambiguously better off in $ESN$ compared to $EN$; for two reasons: First, in $ESN$, East has cheaper access to the goods in $(\bar{A}^E, \bar{A}^S]$ than in $EN$ because South has an absolute cost advantage over North. Second, due to the relocation of this same set of goods from North to South when switching from $EN$ to $ESN$, East's terms of trade with North improve. So, East has also cheaper access to the goods in $(\bar{A}^S, \bar{A}^N]$.

$\mathbf{U^N_{ESN}}$ **vs.** $\mathbf{U^N_{EN}}$**:**
$U^N_{ESN} > U^N_{EN}$ exactly if

$$(\bar{A}^S - \bar{A}^E)\left[\left(\frac{w^N a^N}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}_{ESN} - 1\right] > \bar{A}^E\left[\left(\frac{w^N a^N}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN} - \left(\frac{w^N a^N}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}\right]. \quad (3.26)$$

When switching from global free trade to $EN$, the left-hand side of the inequality gives the reduction in Northern consumers' utility due to the loss of cheap access to varieties

in $(\bar{A}^E, \bar{A}^S]$. The right-hand side is the North's utility gain from improved terms of trade with the East, which is due to the fact that in $EN$ it spreads its labor force across a broader range of varieties than in $ESN$. This is evident from (3.12).
The inequality sign is likely to be reversed, i.e., North is likely to be better off in $EN$ than in $ESN$, if East has a relatively high technological ability ($\bar{A}^E$ relatively large) - this puts heavy weight on the difference in terms of trade on the right-hand side and light weight on the difference in terms of trade on the left-hand side - and, simultaneously, if East is large (in terms of $L^E$). This keeps North's terms of trade with East in $EN$ high. Example 1 serves to illustrate this. It is the same example that entails pains from trade for South.

**Example 1 (again):**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 40 | 70 | 110 | 400 | 200 | 100 | 1 | 1 | 1 |

From (3.12), the relative cost terms are $[(w^N a^N)/(w^S a^S)]_{ESN} = 1.63$, $[(w^N a^N)/(w^E a^E)]_{EN}$ $= 2.65$, and $[(w^N a^N)/(w^E a^E)]_{ESN} = 2$. Condition (3.26) is violated: $18.99 > 25.83$. The North's utility is $U^S_{ESN} = 168.99$ with and $U^N_{EN} = 175.83$ without South. North prefers $EN$ over $ESN$. It has an incentive to exclude South from the equilibrium FTA in this example.

**Comparison of $EN$ and $ES$:**

**$\mathbf{U^E_{EN}}$ vs. $\mathbf{U^E_{ES}}$:**
$U^E_{EN} > U^E_{ES}$ exactly if

$$(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{EN} > (\bar{A}^S - \bar{A}^E)\left(\frac{w^E a^E}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}_{ES}.$$

In an FTA with North, East has access to a larger mass of goods than in an FTA with South. Nonetheless, each good in $(\bar{A}^E, \bar{A}^S]$ is more expensive in $EN$ than in $ES$. East is better off in an FTA with North than with South if the positive variety effect more than outweighs the negative price effect. This is likely the more advanced North ($\bar{A}^N$ large) is compared to South ($\bar{A}^S$ small).
Example 1 illustrates this too. From (3.12), the relative cost terms are $[(w^E a^E)/(w^N a^N)]_{EN}$ $= 0.38$ and $[(w^E a^E)/(w^S a^S)]_{ES} = 0.82$. The condition for $U^E_{EN} > U^E_{ES}$ is satisfied: $26.46 > 8.16$. East's utility is $U^E_{EN} = 66.46$ in an FTA with North and $U^E_{ES} = 64.50$ in an FTA with South.
The fact that East prefers to have North over South in a two-country FTA raises the exclusion pressure on South, especially if North is simultaneously better off in $EN$ than in $ESN$, as it is the case in this numerical Example 1.

Gains from trade imply that South unambiguously prefers $ES$ over $EN$ and North unambiguously prefers $EN$ over $ES$.

**Comparison of $SN$ and $ES$:**

$\mathbf{U^S_{SN}}$ **vs.** $\mathbf{U^S_{ES}}$**:**
$U^S_{SN} > U^S_{ES}$ exactly if

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{SN} > \bar{A}^E\left[\left(\frac{w^S a^S}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{ES} - 1\right].$$

In an FTA with North, South gains from access to goods it is not able to produce domestically. This welfare enhancing variety effect is represented by the left-hand side of the inequality. In an FTA with East, South gains from importing each good in $[0, \bar{A}^E]$ at lower cost. This welfare enhancing cost effect is represented by the right-hand side of the inequality. If the variety effect is greater than the cost effect, South prefers to have North over East in a two-country FTA. This is likely to be the case if South's terms of trade with East are sufficiently close to unity.
Again, Example 1 serves as an illustration. From (3.12), East has an absolute cost advantage over South, as well as South over North: $[(w^S a^S)/(w^E a^E)]_{ES} = 1.22$ and $[(w^S a^S)/(w^N a^N)]_{SN} = 0.94$. The condition for $U^S_{SN} > U^S_{ES}$ is satisfied: $37.42 > 8.99$. South's utility is $U^S_{SN} = 107.42$ in an FTA with North and $U^S_{ES} = 78.99$ in an FTA with East.

Gains from trade imply that East unambiguously prefers $ES$ over $SN$ and North unambiguously prefers $SN$ over $ES$.

**Comparison of $EN$ and $SN$:**

$\mathbf{U^N_{EN}}$ **vs.** $\mathbf{U^N_{SN}}$**:**
$U^N_{EN} > U^N_{SN}$ exactly if

$$\bar{A}^E\left[\left(\frac{w^N a^N}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN} - 1\right] > \bar{A}^S\left[\left(\frac{w^N a^N}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}_{SN} - 1\right].$$

In an FTA with East, North has cheap access to fewer goods than in an FTA with South ($\bar{A}^S > \bar{A}^E$ by assumption). However, goods from East are imported at lower cost than goods from South. If Eastern goods are sufficiently cheap, i.e., $[(w^N a^N)/(w^E a^E)]_{EN}$ sufficiently large, and the technological gap between South and East is narrow, North is better off in a two-country FTA with East than in a two-country FTA with South. Another sufficient condition is that North's terms of trade with South $[(w^N a^N)/(w^S a^S)]_{SN}$ are close to unity.

This is also illustrated by Example 1. From (3.12), relative cost terms are $[(w^N a^N)/(w^E a^E)]_{EN} = 2.65$ and $[(w^N a^N)/(w^S a^S)]_{SN} = 1.07$. The condition for $U^N_{EN} > U^N_{SN}$ is satisfied: $65.83 > 4.83$. North's utility is $U^N_{EN} = 175.83$ in an FTA with East and $U^N_{SN} = 114.83$ in an FTA with South.
The fact that North does not only prefer $EN$ over $ESN$ but also prefers to have East over South in a two-country FTA raises the exclusion pressure on South in this example even further.

Gains from trade imply that East unambiguously prefers $EN$ over $SN$ and South unambiguously prefers $SN$ over $EN$.

Now that we have conducted a complete comparison of all trading systems for the three countries, we can turn to the formation of the equilibrium FTA. Consider first the core as the set of trading systems that is not blocked by any coalition of countries.

**Proposition 4:** *In the absence of international transfers, the core of the set of trading systems is* $\{ESN\}$ *or* $\{EN, ESN\}$ *or* $\{SN, ESN\}$.

The proof is in Appendix A. In the absence of international transfers, either global free trade, bilateral free trade between East and North, or bilateral free trade between South and North emerges. South-North trade means that the potential new low-wage competitor is kept out of the FTA made up of South and North. If $ESN$ forms, the South receives no compensation for a possible reduction in its gains from trade. East-North trade is a worst-case scenario for the excluded South. It is an 'anti-polarization' outcome: The countries at both ends of the world income distribution prefer to trade with each other, rather than with the middle-income country. This contrasts with Das and Ghosh's result (2006) that equilibrium FTAs contain countries with similar wages. If $EN$ forms, South suffers not from a reduction in but from an outright loss of its gains from trade. Exclusion of the South can also be the outcome of the maximization of a social welfare functional with sufficiently heavy weight on equality if one modifies (3.13) in such a way that unit cost equalizes in East and South (see Appendix D). Parameters that lead to each of the three cases exist.

Example 1 depicts a situation in which the core is $\{EN, ESN\}$.

**Example 1 (again):**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 40 | 70 | 110 | 400 | 200 | 100 | 1 | 1 | 1 |

Table 3.3: Example 1 individual utility

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 64.49 | 66.46 | 40 | 84.49 |
| South | 78.99 | 70 | 107.42 | 103.49 |
| North | 110 | 175.83 | 114.83 | 168.99 |

North's terms of trade with South in $SN$ are close to unity: From (3.12), $[(w^N a^N)/ (w^S a^S)]_{SN} = 1.07$. So, importing fewer goods but at substantially better terms of trade $[(w^N a^N)/ (w^E a^E)]_{EN} = 2.65$ from East instead of South is welfare enhancing for North: $U^N_{EN} = 175.83 > 114.83 = U^N_{SN}$. East unambiguously prefers $EN$ over $SN$. Thus, $SN$ is blocked by $EN$. North prefers $EN$ over $ESN$, too: $U^N_{EN} = 175.83 > 168.99 = U^N_{ESN}$. With South's inclusion, the gain in Northern consumers' utility due to cheaper access to varieties in $(40, 70]$ does not outweigh North's utility loss due to deteriorated terms of trade with East. So, $EN$ is not blocked by $ESN$. East prefers $EN$ over $ES$ because the access to varieties in $(40, 70]$ at lower cost in $ES$ compared to $EN$ does not compensate for the access to additional, albeit more expensive, varieties in $(70, 110]$ in $EN$ compared to $ES$. Thus, $EN$ is not blocked by $ES$ either. $EN$ is in the core. $ES$ is blocked by $EN$. One of the two countries in $ES$, $EN$ and $SN$ is always better off in $ESN$ than in the two-country FTA. Therefore, $ESN$ is not blocked by any two-country FTA. $ESN$ is also in the core. I conducted extensive numerical analysis to make sure that the parameters underlying this example are not exceptional. Notes on finding examples can be found in Numerical Appendix C. In general, cases in which $EN$ is in the core in the absence of international transfers arise if $[(w^S a^S)/(w^N a^N)]_{SN}$ is sufficiently close to unity, and $\bar{A}^S - \bar{A}^E$ and $L^S$ are small enough. These conditions imply that the North's benefits from comparatively cheap imports of varieties in $(\bar{A}^E, \bar{A}^S]$ are limited, so that it has no incentive to block the FTA $EN$. Numerical Example 1 is not exceptional. Numerical Appendix C contains three additional examples of the exclusion of South.
Pains from trade for the South is not a requisite for $EN$ being in the core. An example is the following:

**Example 3:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 30 | 55 | 100 | 500 | 150 | 100 | 1 | 1 | 1 |

From (3.12), there is a cost differential between North and South, and between South and East: $[(w^N a^N)/ (w^S a^S)]_{SN} = 1.11$ and $[(w^S a^S)/(w^E a^E)]_{ES} = 1.67$. South gains from East's entry ($U^S_{ESN} = 102.39 > 95.62 = U^S_{SN}$), and still, $EN$ is in the core. North gets

Table 3.4: Example 3 individual utility

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 45 | 50.49 | 30 | 61.43 |
| South | 75 | 55 | 95.62 | 102.39 |
| North | 100 | 172.47 | 105.93 | 168.24 |

highest utility in $EN$ ($U^N_{EN} = 172.47$). Hence, $EN$ is not blocked by $SN$ and $ESN$. $EN$ is not blocked by $ES$ either because East's utility drops from $U^E_{EN} = 50.49$ to $U^E_{ES} = 45$. Moreover, in $EN$ every country can afford its autarky consumption bundle.

The following example depicts a situation in which the core is $\{SN, ESN\}$.

**Example 4:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 7 | 15 | 100 | 200 | 200 | 100 | 1 | 1 | 1 |

Table 3.5: Example 4 individual utility

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 14.48 | 25.04 | 7 | 31.73 |
| South | 15.48 | 15 | 40.25 | 33.92 |
| North | 100 | 129.08 | 135.50 | 156.38 |

It is a situation in which the technological gap between North and South is large and the cost differential between South and East is small. From (3.12), the relative cost terms are $[(w^N a^N)/(w^S a^S)]_{ESN} = 4.61$, and $[(w^S a^S)/(w^E a^E)]_{ESN} = 1.07$. The ensuing utility levels are summarized in Table 3.5. North has better terms of trade in $EN$ than in $SN$ but the number of imported goods is sufficiently higher in $SN$ than in $EN$ so that North is better off in a coalition with South than with East: $U^N_{SN} = 135.50 > 129.08 = U^N_{EN}$. South unequivocally prefers $SN$ over $EN$. Accordingly, $EN$ is blocked by $SN$. South is better off in $SN$ than in $ESN$ because the welfare diminishing effect of deteriorated terms of trade with North due to East's entry exceeds the welfare enhancing effect of cheaper access to goods from East. South imports a rather small number of goods, $[0, 7]$, from East at a cost merely below domestic prices. By contrast, South's terms-of-trade deterioration with North weighs heavy due to the relatively large number of imported goods from North, $(15, 100]$. So, $SN$ is not blocked by $ESN$. The same line of argument applies when South switches from $ES$ to $SN$. Access to a large number of new goods in

$SN$ raises utility more than slightly cheaper access to a small number of existing goods in $ES$. $SN$ is not blocked by $ES$ either. $SN$ is in the core. $ES$ is blocked by $EN$. One of the two countries in $ES$, $EN$ and $SN$ is always better off in $ESN$ than in the two-country FTA. Therefore, $ESN$ is not blocked by any two-country FTA. $ESN$ is also in the core.

The following example depicts a situation in which the singleton core is $\{ESN\}$.

**Example 5:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 20 | 50 | 100 | 400 | 200 | 100 | 1 | 1 | 1 |

From (3.12), there is a cost differential between North and South, and between South and East: $[(w^N a^N)/\ (w^S a^S)]_{SN} = 1.41$ and $[(w^S a^S)/(w^E a^E)]_{ES} = 1.73$. The ensuing utility levels are presented in the subsequent table.

Table 3.6: Example 5 individual utility

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 37.32 | 40 | 20 | 53.13 |
| South | 64.64 | 50 | 85.36 | 92.03 |
| North | 100 | 160 | 120.71 | 168.02 |

In this example, North prefers $ESN$ over $EN$ ($U^N_{ESN} = 168.21 > 160 = U^N_{EN}$), and South prefers $ESN$ over $SN$ ($U^S_{ESN} = 92.03 > 85.36 = U^S_{SN}$). East prefers $ESN$ over any two-country FTA. Hence, $EN$ and $SN$ are blocked by $ESN$. $ES$ is blocked by $EN$ which in turn is blocked by $ESN$. $ESN$ is the singleton core.

Next, consider sequential bargaining with the North as the leader. Suppose the North makes a take-it-or-leave-it offer to the East, the South, or both. If the offer is not accepted there is no free trade between any two countries. The North then has the choice between $EN$, $SN$, or $ESN$. Suppose the North prefers $EN$ over $ESN$ as it is the case in Example 1. From Proposition 1, it follows that the North then also prefers $EN$ over $SN$. Hence, it proposes $EN$ and the East accepts. The South is excluded from the equilibrium FTA and falls back to its autarky welfare level.

In this part (no international transfer), I showed that the middle-income country cannot be compensated for pains from trade if necessary in the absence of international transfer payments. Even worse, it may be excluded from the equilibrium free trade area. While expulsion of a member state when a new one enters an FTA is of course not observed in practice, this highlights again the pressure new low-wage competitors exert on medium-wage countries.

# 4. Tariffs

The analysis so far assumes that countries trade with each other either without any impediments or not at all. In this chapter, I allow for non-prohibitive tariffs. I begin with the two-country model to show that a country can reap welfare gains from imposing a unilateral import tariff on goods from another country (Section 4.1). Then I turn to the three-country model. I provide numerical analysis which demonstrates that pains from trade can arise and exclusion of the South from the equilibrium FTA can happen also with non-zero but non-prohibitive tariffs. This analysis assumes exogenous tariff setting under WTO rules (Section 4.2). I relax this assumption and allow for endogenous, i.e., optimal, tariff setting in the final section of this chapter. I show that the entrance of a low-wage competitor puts additional pressure on the medium-wage country by raising the high-wage country's incentive of reaping welfare gains from a tariff war at the expense of the medium-wage country (Section 4.3).

## 4.1 Two Countries

This section considers tariffs in a two-country world economy with pre-existing wage differentials. It highlights how a country can manipulate its terms of trade and reap welfare gains at the expense of the other country by unilaterally applying a tariff on imports. The following subsection presents the model, the subsequent one is concerned with the gains from tariff imposition.

### 4.1.1 Model

Consider Krugman's North-South model from Subsection 3.1.1. All assumptions stated there are adopted here. In addition to that, assume both countries impose an ad valorem import tariff which is exogenous. An ad-*valorem* tariff is a percentage mark-up on the sales price, i.e., on the sales *value*, of a good.[1] The share of ad valorem tariffs in all tariff lines applied to industrial products is greater than 90 percent for almost all countries.[2] Denote $t_S^N$ the ad valorem tariff levied in the North on imports from South. Accordingly, $t_N^S$ is the

1 For other forms of import tariffs see `https://wits.worldbank.org/wits/wits/witshelp/content/data_retrieval/p/intro/C2.Forms_of_Import_Tariffs.htm`.

2 See the World Tariff Profiles report 2022, p. 8 ff: `https://www.wto.org/english/res_e/booksp_e/world_tariff_profiles22_e.pdf`. Exceptions are Norway, Switzerland, Thailand, and Uganda.

ad valorem tariff levied in the South on imports from North. Hence, consumer price in the South of varieties produced in and imported from the North is $(1+t^S_N)P^N$, and consumer price in the North of varieties produced in and imported from the South is $(1+t^N_S)P^S$. North's (South's) tariff revenues are $t^N_S A^S P^S Y^N_S L^N$ $(t^S_N A^N P^N Y^S_N L^S)$. These are assumed to be rebated lump-sum and equally across consumers. With each consumer supplying one unit of labor, per capita income in the North is then given by $e^N = w^N + t^N_S A^S P^S Y^N_S$. Analogously, per capita income in the South is $e^S = w^S + t^S_N A^N P^N Y^S_N$.
While in free trade equilibrium Northern and Southern consumers face the same price for every good, with tariffs, consumers in the North face different prices for every good than consumers in the South. From (3.3), demand of a consumer in the North for a good imported from the South is

$$Y^N_S = \left[\frac{(1+t^N_S)P^S}{\mathcal{P}^N}\right]^{-\frac{1}{1-\alpha}} \frac{e^N}{\mathcal{P}^N}, \tag{4.1}$$

while demand of a consumer in the South for the same good is

$$Y^S_S = \left[\frac{P^S}{\mathcal{P}^S}\right]^{-\frac{1}{1-\alpha}} \frac{e^S}{\mathcal{P}^S}.$$

Analogously, demand of a consumer in the South for a good imported from the North is

$$Y^S_N = \left[\frac{(1+t^S_N)P^N}{\mathcal{P}^S}\right]^{-\frac{1}{1-\alpha}} \frac{e^S}{\mathcal{P}^S}, \tag{4.2}$$

and demand of a consumer in the North for the same good is

$$Y^N_N = \left[\frac{P^N}{\mathcal{P}^N}\right]^{-\frac{1}{1-\alpha}} \frac{e^N}{\mathcal{P}^N}.$$

With tariffs, as opposed to free trade, relative demand is not uniform across countries:

$$\frac{Y^N_N}{Y^N_S} = \left[\frac{P^N}{(1+t^N_S)P^S}\right]^{-\frac{1}{1-\alpha}} \tag{4.3}$$

and

$$\frac{Y^S_N}{Y^S_S} = \left[\frac{(1+t^S_N)P^N}{P^S}\right]^{-\frac{1}{1-\alpha}}. \tag{4.4}$$

The price index defined in Subsection 3.1.1 faced by a consumer in the South is hence

$$\mathcal{P}^S = \left\{A^N\left[\left(1+t^S_N\right)w^N a^N\right]^{-\frac{\alpha}{1-\alpha}} + A^S\left(w^S a^S\right)^{-\frac{\alpha}{1-\alpha}}\right\}^{-\frac{1-\alpha}{\alpha}},$$

and the price index faced by a consumer in the North is

$$\mathcal{P}^N = \left\{A^N\left(w^N a^N\right)^{-\frac{\alpha}{1-\alpha}} + A^S\left[\left(1+t^N_S\right)w^S a^S\right]^{-\frac{\alpha}{1-\alpha}}\right\}^{-\frac{1-\alpha}{\alpha}}.$$

Use is made of the zero profits conditions $P^N = w^N a^N$ and $P^S = w^S a^S$. $A^N$ ($A^S$) is the mass of varieties produced in North (South) the consumer buys. It follows that demand of a consumer in the North for a good produced in the South as a function of the terms of trade $(w^N a^N)/(w^S a^S)$ is given by

$$Y_S^N = \left[\frac{w^N a^N}{(1+t_S^N) w^S a^S}\right]^{\frac{1}{1-\alpha}} \left\{ \left(\frac{w^N a^N}{\mathcal{P}^N}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^N} t_S^N A^S w^S a^S \left[\frac{w^N a^N}{(1+t_S^N) w^S a^S}\right]^{\frac{1}{1-\alpha}} \right\}^{-1} \frac{w^N}{\mathcal{P}^N}. \tag{4.5}$$

(For derivation see Technical Appendix B). Setting $t_S^N = 0$ one obtains (3.3) for $i = N$ and $j = S$ from the two-country free trade model. Accordingly,

$$Y_N^S = \left[\frac{w^S a^S}{(1+t_N^S) w^N a^N}\right]^{\frac{1}{1-\alpha}} \left\{ \left(\frac{w^S a^S}{\mathcal{P}^S}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^S} t_N^S A^N w^N a^N \left[\frac{w^S a^S}{(1+t_N^S) w^N a^N}\right]^{\frac{1}{1-\alpha}} \right\}^{-1} \frac{w^S}{\mathcal{P}^S} \tag{4.6}$$

is demand of a consumer in the South for a good produced in the North as a function of the terms of trade $(w^N a^N)/(w^S a^S)$.

Demand of a consumer in the North for a domestically produced good as a function of the terms of trade $(w^N a^N)/(w^S a^S)$ follows immediately by using (4.5) in (4.3):

$$Y_N^N = \left\{ \left(\frac{w^N a^N}{\mathcal{P}^N}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^N} t_S^N A^S w^S a^S \left[\frac{w^N a^N}{(1+t_S^N) w^S a^S}\right]^{\frac{1}{1-\alpha}} \right\}^{-1} \frac{w^N}{\mathcal{P}^N}. \tag{4.7}$$

Analogously, using (4.6) in (4.4) immediately gives demand of a consumer in the South for a domestically produced good as a function of $(w^N a^N)/(w^S a^S)$:

$$Y_S^S = \left\{ \left(\frac{w^S a^S}{\mathcal{P}^S}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^S} t_N^S A^N w^N a^N \left[\frac{w^S a^S}{(1+t_N^S) w^N a^N}\right]^{\frac{1}{1-\alpha}} \right\}^{-1} \frac{w^S}{\mathcal{P}^S}. \tag{4.8}$$

Goods market clearing on the world market implies $Y^N = L^N Y_N^N + L^S Y_N^S$ and $Y^S = L^S Y_S^S + L^N Y_S^N$, i.e., total supply of each good produced in the North (South), $Y^N$ ($Y^S$), is in demand domestically and abroad. Labor market clearing requires that labor supply of each country is fully employed in production, i.e., $L^N = A^N a^N Y^N$ and $L^S = A^S a^S Y^S$. Substituting goods market clearing into the corresponding labor market clearing condition (or vice versa) yields

$$\frac{L^N}{A^N a^N} = L^N Y_N^N + L^S Y_N^S \tag{4.9}$$

and

$$\frac{L^S}{A^S a^S} = L^S Y_S^S + L^N Y_S^N. \tag{4.10}$$

Substituting (4.6) and (4.7) into (4.9) or (4.5), and (4.8) into (4.10) yields one equation that determines the terms of trade $(w^N a^N)/(w^S a^S)$. The terms of trade determine the four consumption quantities via (4.5) - (4.8). The consumption quantities are used in (3.1) to obtain a representative consumer's utility in the North,

$$U^N = \left[A^N (Y_N^N)^\alpha + A^S (Y_S^N)^\alpha\right]^{\frac{1}{\alpha}},$$

and in the South,

$$U^S = \left[A^N (Y_N^S)^\alpha + A^S (Y_S^S)^\alpha\right]^{\frac{1}{\alpha}}.$$

An alternative way of determining the two-country trade equilibrium with tariffs can be found in Technical Appendix B. The system of equations from Technical Appendix B is used for numerical analysis (see Mathematica Code in Appendix E). At the end of Subsection 4.2.1, I explain how I ensure that both ways of determining the equilibrium yield the same result.

### 4.1.2 Gains from Tariff Imposition

From the two-country model in the previous chapter, I concluded that North and South unequivocally gain in a free trade equilibrium with wage differentials. Why should a country impose an import tariff then? Because it is beneficial compared to free trade if the tariff is small enough and the country is large in that the country's aggregate demand affects the price of that good on the world market. The proposition of welfare gains from a small import tariff for the imposing large country was first advanced by Bickerdike (1906). The intuition is that "a country that faces a downward sloping demand for its exports has market power and therefore, as a monopolist, can benefit from restricting its export supply. When a country's exporters are perfectly competitive, the government can coordinate this restriction via an export tax, which increases the world price for its exports and so improves its terms of trade. Analogously, a country facing an upward-sloping export supply has market power in imports and can benefit from restricting them via a tariff" (Limão, 2008, p. 1). In the present model, firms are perfectly competitive and import demand curves (4.1) and (4.2) are downward sloping. Export supply curves $Y^N - Y_N^N = Y_N^S$ (of North) and $Y^S - Y_S^S = Y_S^N$ (of South) are hence upward sloping. So both countries can turn their terms of trade in their favor by levying an import tariff. At more favorable terms of trade, consumers can purchase more units of the foreign good in exchange for one unit of the domestic good compared to free trade. This raises utility. The import tariff, however, simultaneously reduces absolute demand for foreign goods via the increased consumer price. This reduction in the quantity consumed of each foreign good compared to free trade lowers utility. For sufficiently small tariff rates, the negative quantity effect is more than offset by the positive terms-of-trade effect so that a consumer in the tariff-levying country overall gains from the import tariff.

Let's illustrate this with Example 1, for now, ignoring East:

| $\alpha$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^S$ | $L^N$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|
| 0.5 | 70 | 110 | 200 | 100 | 1 | 1 |

Assume North imposes a uniform tariff $t_S^N$ on the goods in $[0, \bar{A}^S]$ imported from South. Table 4.1 shows individual utilities of a representative Northern consumer and a representative Southern consumer in trade equilibrium with varying tariff rates $t_S^N$. For now, it is assumed that South does not impose an import tariff on goods produced in the North ($t_N^S = 0$). The bottom row shows consumer price of a Northern good relative to a Southern good at the corresponding tariff rate.

Table 4.1: Example 1 individual utility with North imposing an import tariff on South

| $t_S^N$ | 0 | 2.5% | 5% | 7.5% | 10% | 12.5% |
|---|---|---|---|---|---|---|
| $U_{SN}^N$ | 114.83 | 115.47 | 116.08 | 116.66 | 117.22 | 110 |
| $U_{SN}^S$ | 107.42 | 107.09 | 106.77 | 106.46 | 106.15 | 70 |
| $\frac{1}{1+t_S^N} \frac{w^N a^N}{w^S a^S}$ | 1.07 | 1.05 | 1.04 | 1.02 | 1.01 | 0.99 |

A Northern consumer's utility increases with increasing tariff rate $t_S^N$. A Southern consumer's utility is strictly decreasing in $t_S^N$. By imposing a unilateral import tariff, North raises its welfare at the expense of South. A tariff rate of 12.5% is prohibitive. At this tariff rate consumer price of a Northern good relative to a Southern good is smaller than one. It is cheaper for a Northern consumer to purchase the goods in $[0, \bar{A}^S]$ domestically. These goods are still produced at lower cost in the South, but the import tariff of 12.5% more than offsets the cost advantage. The countries cease to trade and derive autarky utility.

Following the same logic, South has an incentive to retaliate, i.e., to impose a counter import tariff, and turn the terms of trade in its favor to regain some part of the utility loss. If the South does so, North will adjust its tariff rate in response to that. South will in turn adjust its tariff rate too, and so on. A tariff war breaks out. A tariff equilibrium prevails as soon as both, North's and South's, tariffs are the best responses to each other. Analysis of the endogenous imposition of tariffs and the determination of a Nash equilibrium in tariffs, i.e., mutually optimal tariff rates, is the purpose of this chapter's final Section 4.3. Before that, I turn to the three-country model with exogenous tariffs. This is the subject of the following section.

## 4.2 Three Countries

This section considers tariffs in the three-country world economy with pre-existing wage-differentials. The first subsection presents the model. The second subsection shows that the first main result, viz. pains from trade, holds also with non-zero but non-prohibitive tariffs. In the final subsection, I provide numerical analysis which confirms the second main result, viz. exclusion of the South from the equilibrium FTA.

### 4.2.1 Model

Consider the three-country world economy with import tariffs $t^i_{i'}$ levied in country $i$ on imports from country $i' \neq i$ (and $t^i_i = 0$). Tariffs $t^i_{i'} = 0$ for $i$ and $i'$ when the two countries form the FTA $ii'$. Global free trade implies $t^i_{i'} = 0$ for all pairs of $i$ and $i'$. The consumer price in $i$ of varieties produced in $i'$ is $(1 + t^i_{i'})w^{i'}a^{i'}$, and the price index faced by a consumer in $i$ is

$$\mathcal{P}^i = \left\{ \sum_{i' \in \{E,S,N\}} A^{i'} \left[ \left(1 + t^i_{i'}\right) w^{i'} a^{i'} \right]^{-\frac{\alpha}{1-\alpha}} \right\}^{-\frac{1-\alpha}{\alpha}}, \tag{4.11}$$

where $A^{i'}$ is the mass of goods produced in $i'$ she consumes. Analogous to the notation in the two-country model, $Y^i_{i'}$ $(= y^i(j))$ denotes the uniform quantity consumed of each good $j$ produced in $i'$ by a consumer located in $i$. The proceeds of the import tariff are redistributed uniformly across consumers so that per capita income in $i$ is wage income plus her share in tariff revenues:

$$e^i = w^i + \sum_{i'} t^i_{i'} A^{i'} w^{i'} a^{i'} Y^i_{i'}. \tag{4.12}$$

Demand of a consumer located in $i$ for a good produced in $i'$ is

$$Y^i_{i'} = \left[ \frac{(1 + t^i_{i'})w^{i'}a^{i'}}{\mathcal{P}^i} \right]^{-\frac{1}{1-\alpha}} \frac{e^i}{\mathcal{P}^i}. \tag{4.13}$$

From (4.12) and (4.13), it follows that

$$\begin{aligned} Y^i_{i'} \;=\; & \left[ \frac{w^i a^i}{(1 + t^i_{i'})w^{i'}a^{i'}} \right]^{\frac{1}{1-\alpha}} \left( \left( \frac{w^i a^i}{\mathcal{P}^i} \right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^i} \left\{ t^i_{i'} A^{i'} w^{i'} a^{i'} \left[ \frac{w^i a^i}{(1 + t^i_{i'})w^{i'}a^{i'}} \right]^{\frac{1}{1-\alpha}} \right. \right. \\ & \left. \left. + \; t^i_{i''} A^{i''} w^{i''} a^{i''} \left[ \frac{w^i a^i}{(1 + t^i_{i''})w^{i''}a^{i''}} \right]^{\frac{1}{1-\alpha}} \right\} \right)^{-1} \frac{w^i}{\mathcal{P}^i}. \end{aligned} \tag{4.14}$$

(For derivation see Technical Appendix B). Given that two relative producer prices (terms of trade) determine the third one, (4.14) gives the $Y^i_{i'}$'s as functions of two of the three relative producer prices $(w^i a^i)/(w^{i'}a^{i'})$. Substitution into two of the three labor market clearing conditions $\sum_{i'} L^{i'} y^{i'}_i = L^i/(a^i A^i)$ yields a system of two equations that determines the two relative producer prices. Analogously, (4.14) with $A^{i''} = 0$ and one labor market clearing condition determine $(w^i a^i)/(w^{i'}a^{i'})$ in the two-country case. In the special case with no tariffs, one obtains (3.12). The relative producer prices determine $Y_{i'}^i$ via (4.14). Substitution into (3.1) yields utility of an inhabitant of country $i$:

$$U^i = \left[ \sum_{i' \in \{E,S,N\}} A^{i'} \left( Y_{i'}^i \right)^\alpha \right]^{\frac{1}{\alpha}} .$$

An alternative way of determining the three-country trade equilibrium with tariffs can be found in Technical Appendix B. I use that way for numerical analysis. To check whether the way presented here yields the same numerical results as the alternative one, I substitute (4.11) into (4.14) to get rid of the price index in (4.14) (see Technical Appendix B for the resulting expression) and solve for the relative producer prices (terms of trade) as outlined above. I do this exemplarily for the FTA $EN$ (see Mathematica code in Appendix E). The numerical results of both ways are identical. I use the alternative way for numerical analysis because it is more convenient to handle in Mathematica.

### 4.2.2 Pains from Trade

The first result in Chapter 3 is that with global free trade, entry of a new low-wage country can reduce the gains from trade for the new middle-income country (Proposition 1). This also holds true for positive but sufficiently small tariffs. This follows from continuity of import demand (4.14) and utility (3.1). In the subsequent numerical analyses, I assume exogenous tariff setting according to WTO rules. The WTO's first and foremost principle is the most-favored-nation (MFN) principle. It says that all member countries of the WTO must be treated equally. If a country lowers the import tariff on goods from one of its trading partners, it must do the same for all other WTO members. Special treatment of one trading partner is not allowed. One exception from this rule is the formation of a free trade area. Countries within the FTA are allowed to discriminate against countries outside the FTA.[3] I assume that if two countries, $i$ and $i'$, form a free trade area, they set an exogenous common external tariff on country $i''$. Formally speaking: $t_{i'}^i = t_i^{i'} = 0$, and $t_{i''}^i = t_{i''}^{i'} > 0$. That is, countries $i$ and $i'$ form a customs union. Let their common import tariff imposed on the outsider country $i''$ be denoted $t_{i''}^{ii'}$. Jacob Viner (1950) pioneered the analysis of customs unions. He defines a customs union as a trading system that fulfills three criteria: (i) free trade between the member countries, (ii) a uniform tariff on imports from countries outside the union, and (iii) the distribution of the tariff revenues among the member countries according to an agreed rule. The latter criterion implies that tariffs that are collected by a member country are first transferred to the union before being redistributed to the member countries again. For example, Germany's tariff revenues are

3 See `https://www.wto.org/english/thewto_e/whatis_e/tif_e/fact2_e.htm`). For more details about how free trade areas and customs unions are governed by the WTO see GATT Article XXIV: `https://www.wto.org/english/tratop_e/region_e/regatt_e.htm`.

due to the EU. These revenues enter into the EU's budget which is then redistributed in the form of funds, grants, and subsidies to national and regional authorities, businesses, farmers, non-profit organizations, individuals, and other beneficiaries.[4] The OECD's definition of a customs union disregards criterion (iii).[5] The WTO even confines the definition of a customs union on criterion (ii) only: "Members apply a common external tariff (e.g. the European Union)".[6] This definition does not require free trade among the member countries. The definition of a customs union in my analysis follows the OECD's definition. There is free trade among member countries and member countries set a common external tariff. If one would like to make use of Viner's definition and add criterion (iii), the apportionment rule of the union's tariff revenues in my analysis is such that each country retains the revenue it collects.

I let outsider country $i''$ retaliate against the union with the same non-discriminatory import tariff rate, i.e., $t_i^{i''} = t_{i'}^{i''} = t_{i''}^{i} = t_{i''}^{i'}$ (in short: $t_{ii'}^{i''} = t_{i''}^{ii'}$). This assumption is in line with WTO rules. Lifting trade barriers, as countries $i$ and $i'$ do in my analysis, is a violation of the WTO's target principle of freer trade.[7] In such a case, the WTO's provision is that at first instance the parties agree on a compensation for the discriminated country (here, country $i''$). If negotiations about a compensation fail, the discriminated country may in a second instance ask the WTO's Dispute Settlement Body (DSB) for permission to impose a counter sanction (against $i$ and $i'$ here). This sanction must be appropriate in that it compensates for the loss incurred.[8] A case in point is the China-U.S. trade dispute. Only recently, the WTO allowed China to impose retaliatory tariffs on U.S. imports worth $645 million per year, as a compensation for tariffs imposed by the U.S. on Chinese goods, like solar panels and steel products, between 2008 and 2012.[9] In my analysis, the retaliatory tariff rate is appropriate in that it is equivalent to the tariff rate imposed by the FTA members $i$ and $i'$, and it does not overcompensate country $i''$ for its utility loss compared to free trade. As an illustration, and to show that pains from trade for the medium-wage country arise also with non-prohibitive tariffs, add 10 percent tariffs to Example 1. Most-favored-nation tariffs for industrial goods are around 10 percent.[10]

**Example 1 (again):**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 40 | 70 | 110 | 400 | 200 | 100 | 1 | 1 | 1 |

4 On EU budget financing and spending see https://commission.europa.eu/system/files/2019-06/budget-brochure-a5-17-05_interactive.pdf.
5 See https://stats.oecd.org/glossary/detail.asp?ID=3130.
6 See https://www.wto.org/english/thewto_e/glossary_e/customs_union_e.htm.
7 See https://www.wto.org/english/thewto_e/whatis_e/tif_e/fact2_e.htm.
8 See https://www.wto.org/english/tratop_e/dispu_e/disp_settlement_cbt_e/c6s10p1_e.htm.
9 See https://www.reuters.com/business/wto-gives-china-right-impose-tariffs-645-mln-us-goods-2022-01-26/.
10 See https://wits.worldbank.org/CountryProfile/en/Country/WLD/StartYear/2019/EndYear/2019/TradeFlow/Import/Indicator/MFN-WGHTD-AVRG/Partner/WLD/Product/all-groups.

Starting from free trade between South and North, let $t_N^S = t_S^N = 0$ and $t_E^S = t_E^N = t_E^{SN} = 10\%$ in the three-country world economy. That is, South and North form a customs union with a 10 percent import tariff. Let East retaliate with the same import tariff, i.e., $t_S^E = t_N^E = t_{SN}^E = 10\%$. Then $U_{SN}^S = 103.49 < 107.42 = U_{SN}^S$. The 10 percent tariffs do not affect the reduction in the South's gains from trade compared to the free trade case, in which $U_{ESN}^S = 103.49$. The welfare gain from improved terms of trade with the East compared to free trade is offset by the welfare loss from the reduction in trade volume. The pattern emerging in this numerical example is a hump-shaped relation between the tariff rate and utility in the South under the FTA $SN$. South's utility increases and then decreases again with rising tariffs (see Table 4.2).

Table 4.2: Example 1 South's utility in $SN$ with common external tariff on East

| $t_E^i = t_i^E$ | 0 | 5% | 10% | 15% | 20% | 25% | 100% | 105% |
|---|---|---|---|---|---|---|---|---|
| $U_{SN}^S$ | 103.49 | 103.55 | 103.49 | 103.33 | 103.08 | 71.14 | 72.22 | 107.42 |

$U_{SN}^S$ with a tariff rate of $t_E^i = t_i^E = 0$ $(i \in \{S, N\})$ is equivalent to $U_{ESN}^S$. 25% is the prohibitive tariff for South-East trade. From the production cost perspective, Southern firms do still have an incentive to relocate the goods in $[0, \bar{A}^E]$ to East: Relative producer price $[(w^E a^E)/(w^S a^S)]_{SN} = 0.81$. Yet, relative consumer price $[(1 + t_E^S)(w^E a^E)/(w^S a^S)]_{SN} = 1.01$. A good produced in low-wage East and taxed at a rate of 25% when exported to South cannot compete with the same good produced in the South. The goods in $[0, \bar{A}^E]$ are produced in the South at higher cost than in the East but sold at a lower price. This makes $t_E^{SN} = t_{SN}^E = 25\%$ prohibitive for South-East trade. However, 25% is still non-prohibitive for North-East trade. In this case, a hub-and-spoke trading system emerges. This is a situation in which one country, the hub, trades with two other countries, the spokes, that do not trade among each other. Here, North is the hub. East and South are the spokes. North imports the goods in $[0, \bar{A}^E]$ from East and the goods in $(\bar{A}^E, \bar{A}^S]$ from South. East imports the goods in $(\bar{A}^E, \bar{A}^N]$ from North and South imports the goods in $(\bar{A}^S, \bar{A}^N]$ from North while producing the goods in $[0, \bar{A}^S]$ domestically. The suspension of South-East trade causes a trade diversion from North-South to North-East trade. This is due to the fact that in the South labor is withdrawn from the production of the goods in $(\bar{A}^E, \bar{A}^S]$ to provide itself with the goods in $[0, \bar{A}^E]$, formerly imported from East. Hence, less units of the goods in $(\bar{A}^E, \bar{A}^S]$ are disposable for exportation to North. As a result, North exports less units of the goods in $(\bar{A}^S, \bar{A}^N]$ to South. Instead, North expands trade with the East. This explains the sharp drop of utility in the South from 103.08 (global trade) to 71.14 (hub-and-spoke trade). How production and consumption quantities and the ensuing utility levels in a hub-and-spoke trade equilibrium are derived is shown in

Technical Appendix B. With a continuing rise of the tariff rate, this trade-diversion effect is mitigated. Tariff rates of 105% or above are also prohibitive for North-East trade. This replicates the equilibrium of $SN$ with no external trade.

If the pains from trade result holds in the absence of tariffs, then it continues to hold for a wide range of tariff rates. Given $t_E^i = t_i^E$ ($i \in \{S, N\}$), $U_{SN}^S$ is not always hump-shaped in the tariff rate. Another usual pattern emerging in numerical examples is a strictly positive relationship between the non-prohibitive tariff rate and utility in the South under the FTA $SN$. If the reduction in the South's gains from trade due to entry of the East is sufficiently pronounced under free trade, then utility in the South falls short of the level that prevailed before entry of the East for all tariff rates up to the prohibitive level. An illustration of this pattern is Example 2.

**Example 2 (again):**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 5 | 11 | 100 | 100 | 100 | 800 | 1 | 1 | 1 |

Table 4.3 depicts individual utility in the South with increasing tariff rates.

Table 4.3: Example 2 South's utility in $SN$ with common external tariff on East

| $t_E^i = t_i^E$ | 0 | 10% | 20% | 30% | 40% | 50% | 60% | 190% | 200% |
|---|---|---|---|---|---|---|---|---|---|
| $U_{SN}^S$ | 76.84 | 77.25 | 77.57 | 77.81 | 77.99 | 78.11 | 56.09 | 56.71 | 99.50 |

A tariff rate of 200% is prohibitive for South-East and North-East trade in this example. At this tariff rate, the FTA $SN$ does not trade at all with outsider East and $U_{SN}^S = 99.50$. If South and North trade freely with East, $U_{ESN}^S = 76.84$ which is equivalent to $U_{SN}^S$ with $t_E^i = t_i^E = 0$ ($i \in \{S, N\}$). South suffers a reduction in its gains from trade from East's entry into global free trade. South's utility in $SN$ is increasing in positive but non-prohibitive tariffs, but remains below the level that prevailed before East's entry for all tariff rates up to the prohibitive one. Tariff rates of 60% and above are prohibitive for South-East trade: $[(1 + t_E^S)(w^E a^E)/(w^S a^S)]_{SN} = 1.01$. A hub-and-spoke trading regime emerges, with North being the hub, and East and South being the spokes. This remains in force until the tariff rate exceeds 190%, which is just non-prohibitive for North-East trade.

### 4.2.3 Formation of Free Trade Areas

The second main result in Chapter 3 is that in the absence of international transfers, the East and the North may have an incentive to exclude the South from free trade

(Proposition 4). The derivation of this result in Chapter 3 makes use of the assumption that the FTA $EN$ does not trade at all with the South. Exclusion of the South is implied by $EN$ being in the core. To show that this result is not dependent on prohibitive tariffs, I present a numerical example and determine the core at a tariff rate that is prohibitive for external trade in all two-country FTAs in a first step. In a second step, I determine the core at the highest tariff rate that is non-prohibitive for external trade in all two-country FTAs. I continue by gradually reducing this tariff rate to zero, always determining the core. Consider the following example.

**Example 6:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 36 | 60 | 110 | 450 | 150 | 100 | 1 | 1 | 1 |

Suppose again that if two countries, $i$ and $i'$, form an FTA $ii'$, they set a uniform import tariff $t^{ii'}_{i''}$ on the third country $i''$. Country $i''$ retaliates with the same tariff, denoted $t^{i''}_{ii'}$, so that $t^{ii'}_{i''} = t^{i''}_{ii'}$. Table 4.4 shows individual utility in each country for all possible FTAs at tariff rates from zero (equivalent to global free trade $ESN$) to prohibitive (equivalent to the case of no external trade of both countries that form a two-country FTA).

Table 4.4: Example 6 individual utility with tariffs

| $t^{ii'}_{i''} = t^{i''}_{ii'}$ | 0 | 5% | 10% | 15% | 20% | 25% | 155% |
|---|---|---|---|---|---|---|---|
| $U^N_{SN}$ | 182.43 | 182.38 | 182.12 | 181.70 | 181.13 | 180.44 | 117.08 |
| $U^S_{SN}$ | 103.20 | 103.17 | 103.02 | 102.79 | 102.46 | 102.07 | 104.72 |
| $U^E_{SN}$ | 72.97 | 72.90 | 72.76 | 72.55 | 72.29 | 71.98 | 36 |
| $U^N_{EN}$ | 182.43 | 183.45 | 184.27 | 184.92 | 185.41 | 185.76 | 183.49 |
| $U^S_{EN}$ | 103.20 | 101.15 | 99.22 | 97.40 | 95.68 | 94.03 | 60 |
| $U^E_{EN}$ | 72.97 | 73.38 | 73.71 | 73.97 | 74.16 | 74.30 | 60.33 |
| $U^N_{ES}$ | 182.43 | 179.51 | 176.72 | 174.04 | 171.47 | 168.97 | 110 |
| $U^S_{ES}$ | 103.20 | 103.77 | 104.21 | 104.54 | 104.77 | 104.92 | 74.91 |
| $U^E_{ES}$ | 72.97 | 73.37 | 73.69 | 73.92 | 74.08 | 74.19 | 52.97 |

The first row shows the tariff rates I consider. I want to show that exclusion of the South occurs also with overall non-prohibitive tariffs. To this end, I skip tariff rates that lead to a hub-and-spoke trading regime. Recall that these are tariff rates that are non-prohibitive for one pair of insider-outsider trade but prohibitive for the other pair of insider-outsider trade (an extended version of Table 4.4 including individual utility at tariff rates that lead to hub-and-spoke trading regimes can be found in Numerical Appendix C). 25% is approximately the highest tariff rate that is non-prohibitive for trade of all pairs of countries in all FTAs: $[(1+t_E^S)(w^E a^E)/(w^S a^S)]_{SN} = 0.88$, $[(1+t_E^N)(w^E a^E)/(w^N a^N)]_{SN} = 0.50$, $[(1+t_E^S)(w^E a^E)/(w^S a^S)]_{EN} = 0.99$, $[(1+t_S^N)(w^S a^S)/(w^N a^N)]_{EN} = 0.63$, $[(1+t_N^S)(w^N a^N)/(w^S a^S)]_{ES} = 1.29$, and $[(1+t_N^E)(w^N a^N)/(w^E a^E)]_{ES} = 1.83$. Rows two to four, five to seven, and eight to ten, depict individual utility levels in $SN$, $EN$, and $ES$ respectively.

A tariff rate of 155% is prohibitive for external trade of both FTA members in all FTAs. This replicates the model from Chapter 3 where no external trade between FTA members on the one hand and the outsider country on the other hand is simply assumed. The ensuing utility levels are shown in the final column of Table 4.4. The second column depicts the case of $t_{i''}^{ii'} = t_{ii'}^{i''} = 0$. This implies that $U_{SN}^i = U_{EN}^i = U_{ES}^i = U_{ESN}^i$ ($i \in \{E, S, N\}$). A two-country FTA that imposes a tariff of size zero on the outsider country is equivalent to global free trade (no exclusion). Starting from $t_{i''}^{ii'} = t_{ii'}^{i''} = 0$, North's and South's utilities in $SN$ decrease with increasing tariff rates. This is because East is relatively large in terms of $L^E$, so that the demand effect of deteriorated terms of trade is relatively large. North and South gain from improved terms of trade with East but lose from the decline in trade volume. As East is relatively large, the latter effect exceeds the former. East's utility in $SN$ also decreases with the tariff rate because its terms of trade with South and North are deteriorating. In $EN$, North's and East's utilities increase with the tariff rate. The welfare gain from improved terms of trade with South more than compensates for the welfare loss from the reduction in trade volume with the South. South's utility decreases with increasing tariff rates from deteriorated terms of trade and reduced trade. The same holds true in $ES$. East and South, the insider countries, gain with increasing tariffs. North, the outsider country, loses. In sum, it is beneficial for a country to form an FTA with relatively large East in this example, to avoid welfare diminishing effects from tariff imposition on and retaliation by East.

With prohibitive tariffs (final column), the free trade area $EN$ is in the core. $EN$ is not blocked by $ESN$, because $U_{EN}^N = 183.49 > 182.43 = U_{ESN}^N$. $EN$ is not blocked by $SN$, because North's utility drops to $U_{SN}^N = 117.08$. East is better off in $EN$ than in $ES$ ($U_{EN}^E = 60.33 > 52.79 = U_{ES}^E$). So, $ES$ does not block $EN$ either.

At a tariff rate of 25%, $EN$ is also in the core. The countries obtain utilities $U_{EN}^E = 74.30$, $U_{EN}^S = 94.03$, and $U_{EN}^N = 185.76$. Each country is better off than in autarky, because it can afford its autarky consumption bundle. South and North do not block $EN$, as North's utility drops to $U_{SN}^N = 180.442$ in $SN$. East and South do not block $EN$, as East's utility drops to $U_{ES}^E = 74.19$ in $ES$. The grand coalition does not block $EN$, as $U_{ESN}^N = 182.43$. The South suffers pains from trade. It is worse off compared to the two-country world economy without tariffs where its utility is $U_{SN}^S = 104.72$. The East and the North are better off compared to free trade (as $U_{ESN}^E = 72.97$ and $U_{ESN}^N = 182.43$). This pattern holds for all positive tariff rates below 25% shown in Table 4.4.

We can conclude that exclusion of South from free trade is not due to the assumption of prohibitive tariffs. The previous analysis shows that this may also happen if positive but non-prohibitive tariffs are considered. In this example, exclusion of the South happens for all tariff rates up to 25%. Given that tariffs are widely observed and the average most-favored-nation tariff on industrial products is around 10%, the entry of a low-wage competitor poses a real threat to the new medium-wage country's welfare.
Again, this example is not exceptional. Example 3 is an additional one that shows that exclusion of the South from free trade is not dependent on prohibitive tariffs.

**Example 3 (again):**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 30 | 55 | 100 | 500 | 150 | 100 | 1 | 1 | 1 |

Recall from Chapter 3 that this is an example in which South gains from East's entry into global free trade but may still be excluded from the equilibrium FTA under the assumption of prohibitive external tariffs.

Table 4.5: Example 3 individual utility with tariffs

| $t^{ii'}_{i''} = t^{i''}_{ii'}$ | 0 | 10% | 20% | 30% | 40% | 180% |
|---|---|---|---|---|---|---|
| $U^N_{SN}$ | 168.24 | 168.03 | 167.18 | 165.87 | 164.24 | 105.93 |
| $U^S_{SN}$ | 102.39 | 102.26 | 101.74 | 100.94 | 99.96 | 95.62 |
| $U^E_{SN}$ | 61.43 | 61.23 | 60.81 | 60.24 | 59.56 | 30 |
| $U^N_{EN}$ | 168.24 | 169.93 | 170.95 | 171.45 | 171.55 | 172.47 |
| $U^S_{EN}$ | 102.39 | 98.66 | 95.30 | 92.24 | 89.40 | 55 |
| $U^E_{EN}$ | 61.43 | 62.05 | 62.42 | 62.60 | 62.64 | 50.49 |
| $U^N_{ES}$ | 168.24 | 162.79 | 157.80 | 153.16 | 148.82 | 100 |
| $U^S_{ES}$ | 102.39 | 103.40 | 103.97 | 104.22 | 104.21 | 75 |
| $U^E_{ES}$ | 61.43 | 62.04 | 62.38 | 62.53 | 62.52 | 45 |

Table 4.5 shows individual utility levels in all FTAs across different tariff rates $t^{ii'}_{i''} = t^{i''}_{ii'}$. Analogous to Table 4.4, the second column shows utilities with global free trade. 40% is approximately the highest tariff rate that is non-prohibitive for trade between all pairs of countries in all FTAs: $[(1+t^S_E)(w^E a^E)/(w^S a^S)]_{SN} = 0.83$, $[(1+t^N_E)(w^E a^E)/(w^N a^N)]_{SN} = 0.51$, $[(1+t^S_E)(w^E a^E)/(w^S a^S)]_{EN} = 0.97$, $[(1+t^N_S)(w^S a^S)/(w^N a^N)]_{EN} = 0.73$, $[(1+t^S_N)(w^N a^N)/(w^S a^S)]_{ES} = 1.03$, and $[(1+t^E_N)(w^N a^N)/ (w^E a^E)]_{ES} = 1.71$. The ensuing

utility levels are shown in the penultimate column. Utilities with no external trade of the member countries, which occurs in all FTAs at a tariff rate of 180%, is depicted in the final column of Table 4.5.

We already saw in Chapter 3 that with no external $EN$ is in the core in this example. At the overall non-prohibitive tariff rate of 40%, $EN$ is also in the core. The countries obtain utilities $U^E_{EN} = 62.64$, $U^S_{EN} = 89.40$, and $U^N_{EN} = 171.55$. Each country is better off than in autarky, because it can afford its autarky consumption bundle. South and North do not block $EN$, as North's utility drops to $U^N_{SN} = 164.24$ in $SN$. East and South do not block $EN$ as East's utility drops to $U^E_{ES} = 62.52$ in $ES$. The grand coalition does not block $EN$, as $U^N_{ESN} = 168.24$. The South suffers pains from trade. It is worse off compared to the two-country world economy without tariffs, where its utility is $U^S_{SN} = 95.62$. The East and the North are better off compared to free trade (as $U^E_{ESN} = 61.43$ and $U^N_{ESN} = 168.24$). This pattern holds for all positive tariff rates below 40%.

Interestingly, with no international transfers and non-prohibitive tariffs, $ES$ can be in the core. For North to be excluded from free trade, the following conditions need to hold simultaneously:

(i) $U^i_{aut} < U^i_{ES}$ for all $i \in \{E, S\}$
(ii) $U^i_{SN} < U^i_{ES}$ for one $i \in \{S, N\}$
(iii) $U^i_{EN} < U^i_{ES}$ for one $i \in \{E, N\}$
(iv) $U^i_{ESN} < U^i_{ES}$ for one $i \in \{E, S, N\}$

Condition (i) is always fulfilled, for $i = E$ and $i = S$, due to gains from trade. For the same reason, conditions (ii) and (iii) are never fulfilled for $i = N$. Thus, it is sufficient to show that $U^E_{ESN} < U^E_{ES}$, $U^E_{EN} < U^E_{ES}$, and $U^S_{SN} < U^S_{ES}$. For this case to arise, parameter values need be set such that North is sufficiently small in terms of the mass of varieties it produces in equilibrium, and in terms of labor supply. Then, trade diversion from a relatively small North, which produces low quantities of a small mass of varieties at relatively high cost, to a relatively large South is beneficial for East ($U^E_{ESN} < U^E_{ES}$ and $U^E_{EN} < U^E_{ES}$), and trade diversion from a relatively small North to a relatively large East is beneficial for South ($U^S_{SN} < U^S_{ES}$). One example is the following.

**Example 7:**

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 30 | 75 | 100 | 500 | 400 | 100 | 1 | 1 | 1 |

Table 4.6 shows individual utilities in all FTAs with increasing tariff rates for this example. Tariff rates of 130% and above are prohibitive in that in all two-country FTAs the FTA members cease to trade with the outsider. This is equivalent to the assumption of no external trade made in Chapter 3. In this case, $ESN$ is the singleton core. Individuals

Table 4.6: Example 7 individual utility with tariffs

| $t^{ii'}_{i''} = t^{i''}_{ii'}$ | 0 | 5% | 10% | 15% | 20% | 25% | 130% |
|---|---|---|---|---|---|---|---|
| $U^N_{SN}$ | 153.32 | 153.82 | 154.12 | 154.24 | 154.21 | 154.05 | 111.60 |
| $U^S_{SN}$ | 102.85 | 103.19 | 103.39 | 103.47 | 103.45 | 103.34 | 96.65 |
| $U^E_{SN}$ | 75.11 | 74.64 | 74.13 | 73.59 | 73.27 | 72.44 | 30 |
| $U^N_{EN}$ | 153.32 | 153.63 | 153.75 | 153.69 | 153.50 | 153.18 | 172.47 |
| $U^S_{EN}$ | 102.85 | 102.45 | 101.97 | 101.42 | 100.83 | 100.18 | 75 |
| $U^E_{EN}$ | 75.11 | 75.26 | 75.32 | 75.29 | 75.20 | 75.04 | 50.49 |
| $U^N_{ES}$ | 153.32 | 149.17 | 145.35 | 141.80 | 138.49 | 135.39 | 100 |
| $U^S_{ES}$ | 102.85 | 103.37 | 103.81 | 104.17 | 104.46 | 104.70 | 86.08 |
| $U^E_{ES}$ | 75.11 | 75.49 | 75.81 | 76.07 | 76.29 | 76.46 | 62.86 |

obtain utilities $U^E_{ESN} = 75.11$, $U^S_{ESN} = 102.85$, and $U^N_{ESN} = 153.32$. East is worse off in $EN$ ($U^E_{EN} = 50.49$), South is worse off in $ES$ ($U^S_{ES} = 86.08$), and North is worse off in $SN$ ($U^N_{SN} = 111.60$). Thus, no two-country FTA blocks $ESN$, and neither does autarky. $SN$ is blocked by $EN$, which is blocked by $ES$, which is blocked by $SN$. A tariff rate of 30% is prohibitive for North-South trade in $ES$: $[(1 + t^N_S)(w^S a^S)/(w^N a^N)]_{ES} = 1.03$. So, I consider tariff rates of 25% and below. 25% is overall non-prohibitive. In $ES$, the ensuing utility levels at this tariff rate are $U^E_{ES} = 76.46$, $U^S_{ES} = 104.70$, and $U^N_{ES} = 135.39$. $ES$ is not blocked by $ESN$ and $EN$, because East's utility declines to $U^E_{ESN} = 75.11$ and $U^E_{EN} = 75.04$, respectively. It is not blocked by $SN$, because $U^S_{SN} = 103.34$. Autarky does not block $ES$ either. Hence, $ES$ is in the core, and East and South are better off compared to global free trade. The same line of argument applies to all tariff rates below 25% for which East and South still obtain their highest utility in $ES$. This outcome contrasts with Proposition 4, which says that with no trade with countries outside of an FTA, $ES$ is the only FTA that cannot be an element of the core.

## 4.3 A Note on Optimal Tariffs and Tariff Wars

The assertion that only for sufficiently small tariff rates the quantity-reduction effect is more than offset by the improved-terms-of-trade effect implies that there is an optimal tariff rate which maximizes a country's welfare. Deriving the optimal tariff in the North-South model and exploring its implications for medium-wage South in the North-South-East model is the subject of this section.

### 4.3.1 Tariff Nash Equilibrium

Derivation of the optimal tariff in the North-South model follows Gros (1987a), who calculates the optimal tariff in a generalized version of Krugman's model with increasing returns to scale in production (1980). The analysis begins with the balanced trade condition:

$$L^N P^S Y_S^N A^S = L^S P^N Y_N^S A^N. \tag{4.15}$$

It postulates that the total value of North's imports from South (left-hand side) equals the total value of South's imports from North (right-hand side). Using relative demand functions (4.3) and (4.4) separately in the balanced trade condition (4.15) yields import demand of a consumer in the North (South) $Y_S^N$ ($Y_N^S$) as a function of domestic demand for domestic goods $Y_N^N$ ($Y_S^S$) and foreign demand for domestic goods $Y_N^S$ ($Y_S^N$):

$$Y_S^N = (Y_N^N)^{-\frac{1-\alpha}{\alpha}} \left[ \frac{L^S}{L^N} \frac{A^N}{A^S} Y_N^S (1 + t_S^N) \right]^{\frac{1}{\alpha}}, \tag{4.16}$$

$$Y_N^S = (Y_S^S)^{-\frac{1-\alpha}{\alpha}} \left[ \frac{L^N}{L^S} \frac{A^S}{A^N} Y_S^N (1 + t_N^S) \right]^{\frac{1}{\alpha}}. \tag{4.17}$$

By solving the labor market clearing conditions (4.9) and (4.10) for $Y_N^S$ and $Y_S^S$, and substituting into (4.16) and (4.17), the latter can be written as

$$\frac{(Y_S^N)^\alpha}{(Y_N^N)^{\alpha-1}} - \frac{L^S}{L^N} \frac{A^N}{A^S} \left( \frac{Y^N}{L^S} - \frac{L^N}{L^S} Y_N^N \right) (1 + t_S^N) = 0 \tag{4.18}$$

and

$$(1 + t_N^S) Y_S^N \frac{\left( \frac{Y^S}{L^S} - \frac{L^N}{L^S} Y_S^N \right)^{\alpha-1}}{\left( \frac{Y^N}{L^S} - \frac{L^N}{L^S} Y_N^N \right)^{\alpha}} - \frac{L^S}{L^N} \frac{A^N}{A^S} = 0, \tag{4.19}$$

respectively.

The total differentials of (4.18) and (4.19) yield

$$(1-\alpha) \left( \frac{Y_S^N}{Y_N^N} \right)^\alpha dY_N^N + \frac{A^N}{A^S} (1 + t_S^N) dY_N^N + \alpha \left( \frac{Y_N^N}{Y_S^N} \right)^{1-\alpha} dY_S^N - \frac{L^S}{L^N} \frac{A^N}{A^S} Y_N^S dt_S^N = 0 \tag{4.20}$$

and

$$\alpha(1+t_N^S)Y_S^N \frac{(Y_S^S)^{\alpha-1}}{(Y_N^S)^{\alpha}} \frac{L^N}{L^S} dY_N^N$$
$$+\left[(1+t_N^S)\left(\frac{Y_S^S}{Y_N^S}\right)^{\alpha-1} - (1+t_N^S)(\alpha-1)Y_S^N\left(\frac{Y_S^S}{Y_N^S}\right)^{\alpha-1}(Y_S^S)^{-1}\frac{L^N}{L^S}\right] dY_S^N$$
$$+ Y_S^N\left(\frac{Y_S^S}{Y_N^S}\right)^{\alpha-1} dt_N^S = 0, \quad (4.21)$$

respectively. After differentiation, use is made of goods market clearing $Y^N/L^S - (L^N/L^S)Y_N^N = Y_N^S$ and $Y^S/L^S - (L^N/L^S)Y_S^N = Y_S^S$ in (4.20) and (4.21), and (4.21) is multiplied with $Y_N^S$.

By using (4.3) and (4.4), equations (4.20) and (4.21) can be written in matrix form $\mathbf{Ay} = \mathbf{x}$:

$$\underbrace{\begin{bmatrix} \frac{A^N}{A^S}(1+t_S^N) + (1-\alpha)\left[\frac{P^S}{P^N}(1+t_S^N)\right]^{\frac{\alpha}{\alpha-1}} & \alpha\frac{P^S}{P^N}(1+t_S^N) \\ \alpha\frac{A^N}{A^S} & \frac{P^S}{P^N}\left[1-(\alpha-1)\frac{Y_S^N}{Y_S^S}\right] \end{bmatrix}}_{\mathbf{A}} \underbrace{\begin{bmatrix} dY_N^N \\ dY_S^N \end{bmatrix}}_{\mathbf{y}}$$

$$= \underbrace{\begin{bmatrix} \frac{P^S}{P^N}Y_S^N dt_S^N \\ -\frac{P^S}{P^N}Y_S^N\frac{1}{1+t_N^S}dt_N^S \end{bmatrix}}_{\mathbf{x}}$$

Assuming that the South does not retaliate ($t_N^S = dt_N^S = 0$), this system of equations can be solved for $dY_N^N/dt_S^N$ and $dY_S^N/dt_S^N$:

$$\frac{dY_N^N}{dt_S^N} = (det\mathbf{A})^{-1}\left\{\frac{P^S}{P^N}\left[1-(\alpha-1)\frac{Y_S^N}{Y_S^S}\right]\frac{P^S}{P^N}Y_S^N\right\}, \quad (4.22)$$

$$\frac{dY_S^N}{dt_S^N} = (det\mathbf{A})^{-1}\left(-\alpha\frac{A^N}{A^S}\frac{P^S}{P^N}Y_S^N\right). \quad (4.23)$$

The first-order condition for the utility maximizing tariff in the North is

$$\frac{d[(U^N)^\alpha]}{dt_S^N} = \frac{A^N}{A^S}\frac{dY_N^N}{dt_S^N} + \left(\frac{Y_S^N}{Y_N^N}\right)^{\alpha-1}\frac{dY_S^N}{dt_S^N} = 0. \quad (4.24)$$

Using (4.22), (4.23), and relative demand (4.3) in (4.24), simplifying, and solving finally yields North's welfare maximizing import tariff:

$$(t_S^N)^* = \frac{1-\alpha}{\alpha}\left(1+\frac{Y_S^N}{Y_S^S}\right). \tag{4.25}$$

(See Technical Appendix B for intermediate steps).
By extending (4.15) with $Y_S^S/Y_S^S$ and solving for $Y_S^N/Y_S^S$, (4.25) can be written as

$$(t_S^N)^* = \frac{1-\alpha}{\alpha}\left[\frac{A^N}{A^S}\frac{L^S}{L^N}\left(\frac{P^N}{P^S}\right)^{\frac{\alpha}{\alpha-1}}(1+t_N^S)^{\frac{1}{\alpha-1}}\right].$$

The North sets its optimal import tariff conditionally on South's import tariff.
Analogously, South's welfare maximizing import tariff is

$$(t_N^S)^* = \frac{1-\alpha}{\alpha}\left(1+\frac{Y_N^S}{Y_N^N}\right). \tag{4.26}$$

(See Technical Appendix B for derivation). By extending (4.15) with $Y_N^N/Y_N^N$ and solving for $Y_N^S/Y_N^N$, (4.26) can be written as

$$(t_N^S)^* = \frac{1-\alpha}{\alpha}\left[\frac{A^S}{A^N}\frac{L^N}{L^S}\left(\frac{P^N}{P^S}\right)^{\frac{\alpha}{1-\alpha}}(1+t_S^N)^{\frac{1}{\alpha-1}}\right].$$

The South does also set its optimal import tariff conditionally on North's import tariff. If both countries endogenously set their import tariffs, an equilibrium prevails as soon as North's and South's import tariffs are mutually best responses. The mutual adjustment process of optimal import tariffs is called a tariff war and the outcome of a tariff war is called a tariff Nash equilibrium.

**Proposition 5:** *In a tariff Nash equilibrium, the high-wage country imposes a higher import tariff than the low-wage country.*

In a North-South trade equilibrium with wage differentials, a Northern consumer buys a larger amount of each good than a Southern consumer. So, $Y_S^N/Y_S^S > Y_N^S/Y_N^N$. From (4.25) and (4.26), $(t_S^N)^* > (t_N^S)^*$. A more formal proof is in Appendix A.
The two labor market clearing conditions (4.9) and (4.10), import demands (4.16) and (4.17), and (4.25) and (4.26) form a system of six equations that determines the four equilibrium consumption quantities $Y_N^N, Y_S^N, Y_N^S, Y_S^S$, and the two optimal tariff rates $(t_N^S)^*$ and $(t_S^N)^*$. Once determined, the equilibrium terms of trade $(P^N/P^S)^*$ can be calculated from (4.3) or (4.4). Since North imposes a higher import tariff than South, North's terms of trade with South are higher in tariff Nash equilibrium than in free trade equilibrium. As a result, North's relative wage in tariff Nash equilibrium,

$$\left(\frac{w^N}{w^S}\right)^* = \left(\frac{P^N}{P^S}\right)^* \frac{a^S}{a^N},$$

is also higher than in free trade equilibrium.
The representative consumers' utilities are again calculated via

$$U^N = \left[A^N (Y_N^N)^\alpha + A^S (Y_S^N)^\alpha\right]^{\frac{1}{\alpha}}$$

and

$$U^S = \left[A^N (Y_N^S)^\alpha + A^S (Y_S^S)^\alpha\right]^{\frac{1}{\alpha}}.$$

### 4.3.2 Gains and Pains from a Tariff War

Gros (1987a) concludes for Krugman's increasing returns to scale model (1980) that the bigger the Northern country in terms of the relative number of produced varieties (in the notation of the present model: $A^N/A^S$), the more likely it gains from a tariff war compared to free trade. He solves the model numerically and finds a critical value of $A^N/A^S$ of around three. Is there a corresponding critical value in the present model? Note that in the increasing returns to scale model, the number of varieties, $A^i$, produced in country $i$ is endogenous and not limited by a pre-defined technological ability. $A^i$ is a function of parameter $\alpha$, labor supply $L^i$, and the fixed cost of production in that model. Hence, a change in relative labor supply alters the relative number of goods produced in the two countries. This is different in the Krugman constant returns to scale model with international cost differentials (1979a): $A^N/A^S = (\bar{A}^N - \bar{A}^S)/\bar{A}^S$ does not change if $L^N/L^S$ changes, as long as the consumer price of a good is lower in the South than in the North. This is implied by

$$\frac{(1+t_S^N) w^S a^S}{w^N a^N} < 1. \tag{4.27}$$

The relative size of North and South is measured in two ways here, in terms of $L^N/L^S$ (relative labor supply) and $A^N/A^S$ (relative number of goods produced). Provided that (4.27) holds, these two measures are independent from each other, and both determine welfare via the terms of trade (3.7). This is why we have to look at $L^N/L^S$ and $A^N/A^S$ separately when determining critical values for a gain from a tariff war for the North. Strictly speaking, relative input coefficient $a^N/a^S$ is also a determinant of the terms of trade. So, relative country size could also be measured in terms of relative *effective* labor supply $(L^N/a^N)/(L^S/a^S)$. It is differences in technological ability, however, rather than differences in individual productivity that I am interested in. For this reason, I assume that input coefficients are uniform throughout all numerical examples, implying that labor supply and effective labor supply are the same. The results of my numerical analysis are summarized in Table 4.7. As usual, it is assumed that $\alpha = 0.5$ and $a^N = a^S = 1$.
With $L^N/L^S = 0.5$, the critical, i.e., minimal, value of $A^N/A^S$ for the North to gain from a tariff war compared to free trade is approximately 21. With both countries being of equal size in terms of labor ($L^N/L^S = 1$), the critical value is approximately 11, and with North having twice as many inhabitants, it is 7. If the North's relative size exceeds

2.2, any value of $A^N/A^S$ that satisfies (4.27) entails that starting a tariff war is beneficial for the North. The bigger North's relative labor supply the smaller is the technological distance to South sufficient to gain from a tariff war.

Table 4.7: Critical values for gains from a tariff war for North

| $L^N/L^S$ | 0.5 | 1 | 2 | 2.2 |
|---|---|---|---|---|
| $A^N/A^S$ | 21 | 11 | 7 | 6.5 |

What is the implication of this for low-wage South? The South unambiguously loses from a tariff war compared to free trade. We know from Proposition 5 that the North unequivocally imposes a higher import tariff than the South in tariff Nash equilibrium. This implies that South's terms of trade deteriorate compared to free trade. As a gain from tariff imposition depends on an improvement of the terms of trade sufficient to offset the quantity reduction, the South is unambiguously worse off if the North decides to start a tariff war. This is likely the smaller in terms of labor supply, and the more under-developed in terms of its technological ability, the South is relative to North.

How do these findings relate to other contributions in the field? An early study on tariff wars is Johnson (1953). In a model of two goods and two endowment economies, he determines the condition under which a country gains from a tariff war. Each country maximizes its social welfare function by exporting one good in exchange for imports of the other good. The author does not make any assumptions about country size differences (in terms of endowments of the goods). Instead, he focuses on cross-country differences in constant elasticities of demand for imports. Johnson (1953) concludes that the country with the higher elasticity gains in a tariff war if the other country's elasticity is sufficiently lower. If the two countries have similar elasticities, both are worse off in a tariff war compared to free trade. Gorman (1957) builds up on this. He shows that Johnson's condition (1953) under which a country gains from starting a tariff war applies to a broader set of models with constant elasticities of import demand. Hamilton and Whalley (1982) relax the assumption of constant elasticities of import demand and they incorporate production in a sequence of two-goods, two-countries trade models. They confirm that the price elasticity of import demand is most crucial for whether a country gains from a tariff war or not.

Kennan and Riezman's approach (1988) is more closely related to mine. They derive conditions for a gain from staring a tariff war in terms of endowments. They assume a two-country world economy in which each country is endowed with a fraction of the global endowment of two goods. The two goods enter symmetrically into Cobb-Douglas utility. If the two goods were assumed to be composite commodities and one country was initially endowed with the total (global) amount of one good and none of the other good (and vice versa for the other country), it would replicate the Krugman model with international wage differentials (1979a), in which each country produces a fixed number of goods. Thus, Kennan and Riezman's results (1988) confirm my finding: A larger country sets a higher optimal tariff and if it is sufficiently large compared to the other country it gains from starting a tariff war. In a less specific framework, Syropoulos (2002) proves that in trade models with identical and homothetic preferences there is always a threshold of relative country size above which a country is better off in tariff Nash equilibrium compared to free trade equilibrium.

Bloch and Zissimos (2009) consider a Heckscher-Ohlin model with multiple identical Northern countries, which are relatively abundant in capital, and multiple identical Southern countries, which are relatively abundant in labor. Size matters in that the larger the number of countries is in one region, the higher is welfare in the other region in a tariff war. This is due to stronger competition within the larger region. The more countries compete to sell their products on the world market, the lower is the (uniform) import tariff each country sets; and consequently, the higher are the terms of trade, and thus welfare in the other region.

Opp (2010) analyzes tariff wars in the Ricardian model with a continuum of goods. He finds that a larger country applies higher tariff rates and prefers the outcome of a tariff war over free trade if it is sufficiently large. Relative size is defined as the sum of absolute productivity advantage and relative labor supply.

Felbermayr et al. (2013) extend Gros (1987b) to the case of heterogenous firms. Gros (1987b) is a broader discussion about protectionism in a framework of intra-industry trade and monopolistic competition than Gros (1987a). The authors confirm Gros' finding (1987a, 1987b) that in Nash equilibrium, the larger country applies the higher tariff, but Nash tariffs are smaller than with firm homogeneity.

Naito (2019) shows that the proposed positive relationship between country size and tariff rates is inconsistent with observed tariff rates. He finds a significant negative relationship between a country's GDP and mean tariffs, and develops a new optimal tariff theory to solve this puzzle. He introduces endogenous growth into Opp's Ricardian optimal tariff model (2010). A rise in import tariff lowers the growth rate and a larger absolute advantage, i.e., higher productivity, aggravates this effect. Thus, the larger country, which in terms of the model is the technologically more advanced one, sets a lower optimal tariff.

Takatsuka and Zeng (2022) consider production capital in an intra-industry trade model with increasing returns to scale. They show that with international capital mobility, smaller countries (in terms of labor supply) set higher tariffs, and that they may even win tariff wars. This is due to an output-expansion effect which is muted without capital mobility: Tariffs increase domestic demand and decrease foreign demand. If non-tariff trade barriers are disregarded, the former effect exceeds the latter in the smaller country. Hence, in a tariff war the smaller country sets a higher tariff, so that foreign capital flows into the smaller country and output is expanded. If, in addition, the other country is sufficiently larger, the small country wins the tariff war, i.e., is better off compared to free trade.

The literature I have just reviewed suggests that in static models without international capital mobility, larger countries set higher import tariffs, and there is a strong presumption that it can be beneficial for the larger country to start a tariff war. My findings from the Krugman North-South model (1979a) confirm this. In this respect, my analysis about optimal tariffs and tariff wars does not provide any new insights. The focus of my work, however, is not on the analysis of optimal tariffs and tariff wars between a low-wage and a high-wage country alone but its implications for the new medium-wage country in the three-country model. So, what are the implications of optimal tariffs for medium-wage South after East's entry? If North can benefit from a tariff war with South, it can also benefit from a tariff war with East. And South itself may benefit from a tariff with East. This would lead into a global tariff war in which each of the three countries sets two import tariffs, one each as the best response on each of the other two countries' import tariffs. How the tariff Nash equilibrium in a three-country world economy can in principle be determined is explained in Technical Appendix B. Unfortunately, numerically solving for the equilibrium is not possible within an appropriate time span. Mathematica does not produce any results, even after more than 24 hours of evaluation. This inhibits to further characterize the tariff Nash equilibrium in the three-country static version of the Krugman model (1979a), and to investigate the welfare effects of a global tariff war on the medium-wage country. I leave this for future research. Authors of related studies faced similar difficulties. Kuga (1973) is the first to leave the canonical two-country setup to study tariff wars in a multi-country framework. He proves the existence of a Nash equilibrium with retaliatory tariffs in an extension of Johnson's and Gorman's models of constant elasticities of import demand (1953, 1957), and undertakes a first attempt to characterize the equilibrium across different pre-defined tariff structures. Hamilton and Whalley (1983) recognize the computational difficulties of determining a tariff equilibrium in a multi-country framework with non-constant elasticities of import demand. Abrego et al. (2005) apply computational techniques to test the validity of various propositions in the field of customs unions. They acknowledge the difficulty in computing three-country Nash equilibria with tariffs. Ossa (2014) combines traditional (inter-industry) trade, new (intra-industry with monopolistic competition) trade and political economy (special interest groups) in a single multi-country framework. Each of these three elements contains an incentive to impose import tariffs, for the sake of terms-of-trade manipulation, profit shifting, and industry protection, respectively. In a global tariff war simulation (for computational reasons restricted to a set of seven countries), the trade volume is predicted to fall so sharply that every country involved loses. Optimal tariffs and welfare effects without retaliation are positively related to country size (in terms of nominal income) in his model. In a tariff war (with retaliation), however, this correlation disappears. Lashkaripour (2021) measures the cost of a global tariff war based on a sufficient statistics approach that does not require iterated optimization. His methodology allows to estimate Nash tariffs and their welfare effects for a larger number of countries and industries than in Ossa (2014). While the simulation doesn't suggest a correlation between the optimal tariff level and country-size, the author points out that smaller economies are hurt the most by a global tariff war. Chattopadhyay and Mitka (2019) are the first to present analytical results on the existence and properties of a non-cooperative Nash equilibrium in optimal tariff imposition, derived from a tractable multi-country two-goods framework with Cobb-Douglas preferences.

Despite the computational limitations, we can draw some analytical conclusion from the three-country Krugman model (1979a) as well. Think of a situation in which South and North are in a free trade equilibrium and high-wage North is small ($A^N/A^S$ low c.p.) such that it is not beneficial for North to start a tariff war with the South. Then low-wage East enters and captures market shares from the now medium-wage South. $A^N/A^S$ increases. If $A^N/A^S$ now exceeds one of the critical values from Table 4.7, North has an incentive to start a tariff war with the South and reap welfare gains at South's expense. If parameter values are such that the South already suffers from a reduction in its gains from trade in free trade equilibrium, a tariff war with the North reduces these gains even further. If parameter values are such that South's welfare is higher after East's entry in FTE, a tariff war triggered by North could push South's welfare below the pre-entry level again. So, the increased likelihood of being involved in a welfare diminishing tariff war with the high-wage country is an additional form of pressure that exerts the low-wage entrant on the medium-wage country.

This conclusion, of course, rests on the assumption that the newcomer country remains dormant, in the sense that it does not interfere in the tariff war but pursues free trade with the other two countries. This assumption is reasonable. From Proposition 5, low-wage East will always set a lower optimal tariff than South and North in Nash equilibrium, and will hence unequivocally lose a tariff war against the two bigger trading partners. If East is sufficiently large, South and North themselves are unlikely to benefit from starting a tariff war with East. Moreover, tariff wars are a bilateral phenomenon. For example, Kreinin et al. (1996) argue that "[i]n reality, when two countries engage in a trade war the rest of the world (ROW) remains passive. Many trade conflicts between the United States and Japan, including the disputes over cellular telephones and automobile parts, were bilateral in nature. Certainly citations under the Super 301 provision of the U.S. trade legislation were strictly bilateral. And many conflicts between the European Community (EC) (or a member thereof prior to 1992) and Japan did not involve other countries" (Kreinin et al., 1996, p. 4). Likewise, Syropoulos et al. (1995) point out that historically, the ROW did not react to trade wars between the U.S. and the European Union, and remained dormant in trade disputes between the United States and Canada as well. A more recent example is the ongoing U.S.-China trade war, which started in 2018. This is also fought bilaterally.

# 5. International Investment

My analysis so far rests on the assumption that labor is the only factor of production. In a free trade equilibrium with international wage differentials, workers in the low-wage region have an incentive to migrate to the high-wage region where they could earn a higher income. Yet, it is assumed that labor cannot move across country borders. In addition, firms in the high-wage region have an incentive to further relocate production to the low-wage region in FTE to reduce cost. Yet, the countries' technological abilities are such that further relocation (of more sophisticated products) is not feasible. Both assumptions are reasonable, and they inhibit international wage equalization. A legitimate objection, however, is that, in addition to labor, manufacturing goods usually require the use of capital in production, and capital goods are internationally mobile. If this is accounted for, neoclassical trade models predict international wage equalization. The argument is that low wages imply low marginal productivity of labor and high marginal productivity of capital. This makes capital flow from the high-wage region to the low-wage region where it is more productive and earns a higher rent. This capital flow continues until the capital-to-labor ratios, and hence wages, in the two regions are equalized (cf. Lucas, 1990). Since a reduction in the medium-wage country's gains from trade from the low-wage competitor's emergence is due to a deterioration of the medium-wage country's terms of trade with the high-wage country (see Figure 3.5 in Subsection 3.2.1), international capital flows, if accounted for, could in principle reverse this effect and the pains-from-trade result may not hold anymore. To check whether the pains-from-trade result is robust against the incorporation of international investment in production capital into the model is the purpose of this chapter. To this end, I formally underpin Krugman's verbal and graphical reasoning about the implications of internationally mobile production capital in the two-country model (1979a, Section IV) in a first step (Section 5.1). In a second step, I augment the model with international investment to the three-country case (Section 5.2).

## 5.1 Two Countries

### 5.1.1 Model

*Assumptions*

Consider the demand side from the preceding chapters with identical preferences represented by Dixit-Stiglitz utility (3.1), and the ensuing demand function (3.3). On the supply side, assume that there are two factors of production: labor and capital. Labor is immobile across countries whereas capital is internationally mobile. There is an exogenous global capital stock $\bar{K}$ which is allocated endogenously among the countries in free trade equilibrium. Every good $j \in [0, \bar{A}^N]$ is produced with the same constant returns to scale technology à la Cobb-Douglas:

$$y(j) = \gamma^i l^\beta k^{1-\beta}, \quad 0 < \beta < 1, \tag{5.1}$$

where $l$ is the amount of labor, $k$ the amount of capital used in production, and $\gamma^i$ is the country-specific total factor productivity. All remaining assumptions from Subsection 3.1.1 are preserved: South and North are populated by a fixed number of consumers, $L^S$ and $L^N$, respectively. Each of them supplies one unit of labor. $[0, \bar{A}^N]$ is the set of goods producible in the North, and $[0, \bar{A}^S]$ is a subset of goods also producible in the South. Firms operate under perfect competition and locate where unit cost of production is lowest. It is assumed that unit cost is higher in the North than in the South in FTE, so that the goods in $[0, \bar{A}^S]$ are produced in the South and the goods in $(\bar{A}^S, \bar{A}^N]$ are produced in the North.

### *Equilibrium*

A firm in country $i$ $(\in \{S, N\})$ maximizes its profits

$$\pi^i(j) = P^i \gamma^i (l^i)^\beta (k^i)^{1-\beta} - w^i l^i - r^i k^i,$$

where $w^i$ is the wage rate, $r^i$ the return rate on capital, and $l^i$ and $k^i$ are the firm-level input quantities of labor and capital in country $i$. The first-order conditions are

$$w^i = P^i \gamma^i \beta \left(\frac{k^i}{l^i}\right)^\beta,$$

and

$$r^i = P^i \gamma^i (1-\beta) \left(\frac{l^i}{k^i}\right)^\beta.$$

Given that capital is internationally mobile, return rates of capital will be equalized in South and North in free trade equilibrium. Thus, dividing the first-order condition for the capital return rate in a Southern firm by the first-order condition for the capital return rate in a Northern firm yields

$$\frac{P^N}{P^S} = \frac{\gamma^S}{\gamma^N} \left(\frac{l^S}{l^N} \frac{k^N}{k^S}\right)^\beta.$$

As all firms in country $i$ use the same technology, represented by (5.1), and demand of a representative consumer is uniform across all goods produced in $i$,

$$\frac{P^N}{P^S} = \frac{\gamma^S}{\gamma^N}\left(\frac{L^S}{L^N}\frac{K^N}{K^S}\right)^{\beta}. \tag{5.2}$$

This is the price ratio as a function of *national* relative labor supply and *national* relative capital stock.
The relative capital stock in equilibrium is determined by means of the first-order condition for utility maximization, i.e., relative demand (3.5). Solving (3.5) for $P^N/P^S$ yields

$$\frac{P^N}{P^S} = \left(\frac{Y^S}{Y^N}\right)^{1-\alpha}. \tag{5.3}$$

$Y^S$ and $Y^N$ are production quantities per varieties $A^S$ and $A^N$, respectively. As all varieties are produced using the same technology, national production quantity per variety according to (5.1) can be written as

$$Y^S = \frac{\gamma^S}{A^S}(L^S)^{\beta}(K^S)^{1-\beta},$$

and

$$Y^N = \frac{\gamma^N}{A^N}(L^N)^{\beta}(K^N)^{1-\beta}.$$

Substitution into (5.3) and equating (5.3) with (5.2) gives us the amount of capital used in the North relative to the South in free trade equilibrium:

$$\frac{K^N}{K^S} = \left(\frac{\gamma^N}{\gamma^S}\right)^{\frac{\alpha}{1-\alpha+\alpha\beta}}\left(\frac{L^N}{L^S}\right)^{\frac{\alpha\beta}{1-\alpha+\alpha\beta}}\left(\frac{A^N}{A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}. \tag{5.4}$$

(For derivation, see Technical Appendix B). By inserting (5.4) into (5.2) we obtain the equilibrium terms of trade:

$$\frac{P^N}{P^S} = \left(\frac{\gamma^S}{\gamma^N}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}\left(\frac{L^S}{L^N}\frac{A^N}{A^S}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}. \tag{5.5}$$

(For derivation, see Technical Appendix B). From the first-order conditions for profit maximization, relative factor prices in South and North are

$$\frac{w^S}{r^S} = \frac{\beta}{1-\beta}\frac{K^S}{L^S},$$

and

$$\frac{w^N}{r^N} = \frac{\beta}{1-\beta}\frac{K^N}{L^N},$$

respectively. Dividing the two equations by each other yields the international relative wage as a function of the relative capital stock and relative labor supply:

$$\frac{w^N}{w^S} = \frac{K^N}{K^S}\frac{L^S}{L^N}.$$

By using (5.4) we obtain the equilibrium relative wage as a function of the relative number of goods produced:

$$\frac{w^N}{w^S} = \left(\frac{\gamma^N}{\gamma^S}\right)^{\frac{\alpha}{1-\alpha+\alpha\beta}} \left(\frac{L^S}{L^N}\frac{A^N}{A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}. \tag{5.6}$$

(For derivation, see Technical Appendix B).

Let $\gamma^i = (1/a^i)^\beta$ $(i \in \{S, N\})$, so that $\gamma^i$ is labor productivity instead of total factor productivity. Then, (5.4) can be written as

$$\frac{K^N}{K^S} = \left(\frac{\frac{a^N}{L^N}}{\frac{a^S}{L^S}}\right)^{\frac{\alpha\beta}{1-\alpha+\alpha\beta}} \left(\frac{A^N}{A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}, \tag{5.7}$$

and (5.5) can be written as

$$\frac{P^N}{P^S} = \left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}. \tag{5.8}$$

Using $\gamma^i = (1/a^i)^\beta$ $(i \in \{S, N\})$ and rearranging terms in (5.6) yields

$$\left(\frac{w^N a^N}{w^S a^S}\right)_\beta = \left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}. \tag{5.9}$$

If we set $\beta$ equal to one (zero capital in production), we get

$$\left(\frac{w^N a^N}{w^S a^S}\right)_0 = \left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{1-\alpha}. \tag{5.10}$$

This is precisely the relative wage from the model with labor as the only input. So, (5.9) is the general form of the relative wage in a trade model of product variety with constant returns to scale in production and international labor immobility.

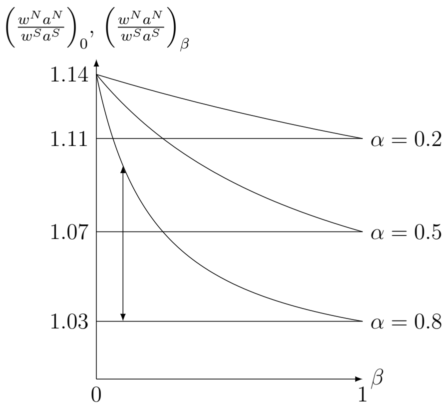
### 5.1.2 Pain from Capital Drain

How does the relative wage (5.9) in the present model variant with international investment compare to the relative wage (5.10) with no capital in production? (5.9) is (5.10) raised to $1/(1-\alpha+\alpha\beta)$:

$$\left(\frac{w^N a^N}{w^S a^S}\right)_\beta = \left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}} = \left[\left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{1-\alpha}\right]^{\frac{1}{1-\alpha+\alpha\beta}} = \left[\left(\frac{w^N a^N}{w^S a^S}\right)_0\right]^{\frac{1}{1-\alpha+\alpha\beta}}.$$

The relative wage with international investment (5.9) is greater than the relative wage (5.10) with no capital in production because the exponent $1/(1-\alpha+\alpha\beta)$ is greater than one: Simplifying $1/(1-\alpha+\alpha\beta) > 1$ yields $1 > \beta$, and this holds by definition. $1/(1-\alpha+\alpha\beta)$ is negatively correlated with $\beta$ and positively correlated with $\alpha$. $1/(1-\alpha)$ is the elasticity of substitution in consumption, which is increasing in $\alpha$. The larger $\alpha$, the stronger is the percentage change of relative demand as a reaction to a one percentage change of relative price. $1-\beta$ is a measure of capital intensity. The larger $\beta$, the lower is the equilibrium capital-labor ratio in production. Hence, the difference in the relative wage between the model with internationally mobile capital and the model without capital is larger, the higher the elasticity of substitution in consumption, and the larger the capital share in production. Figure 5.1 illustrates this. It shows a comparison of the relative wages $[(w^N a^N)/(w^S a^S)]_0$ and $[(w^N a^N)/(w^S a^S)]_\beta$ for different levels of $\alpha$ with varying $\beta$, assuming that $L^N = 100$, $L^S = 200$, $\bar{A}^N = 110$, $\bar{A}^S = 70$, and $a^N = a^S = 1$ (Example 1). The horizontal lines show the values of the relative wage in the baseline model with only labor in production. These values are constant because they are independent of $\beta$. The downward-sloped curves show the values of the relative wage in the model with capital in production and international investment. These curves coincide with their horizontal counterparts at $\beta = 1$ for which the two models predict the same values. We see that the difference between $[(w^N a^N)/(w^S a^S)]_0$ and $[(w^N a^N)/(w^S a^S)]_\beta$ is particularly large for high $\alpha$ and low $\beta$ levels (indicated by the vertical arrow in the figure).

Figure 5.1: Comparison of the international relative wage with and without capital




We can conclude that the model with international investment predicts a larger wage differential between North and South in equilibrium than the model without it. As Krugman puts it: "Migration of mobile factors [capital] [...] will equalize incomes of these factors while increasing the inequality of incomes of immobile factors [labor] in North and South" (Krugman, 1979a, p. 265). This is contrary to the intuition outlined above that interna-

tional capital flows tend to equalize wages across countries. What is the mechanism that produces this counterintuitive result?
Let's assume there is no international capital mobility initially and North and South are endowed with capital stocks such that a relative wage prevails that is equal to (5.10), as if there was no capital in production. Recall that throughout this work I do only consider trade equilibria in which this relative wage is greater than one. A relative wage greater than one implies that goods prices are higher in the North than in the South. This means that the marginal *value* product of capital is higher in the North than in the South. If we now allow capital to be internationally mobile, there is a capital flow from South to North until the marginal *value* products of capital equalize between the two countries. As labor continues to be internationally immobile, the capital-labor ratio increases in the North and decreases in the South. Thus, the difference in marginal products of labor between North and South gets larger and so does the wage differential. The purchasing power of workers in the South for goods imported from the North is weakened. In this way, workers in the South suffer a pain from a drain of capital from South to North.

## 5.2 Three Countries

### 5.2.1 Model

Now consider the three-country model with international investment. $SN$ is the initial FTA characterized in the previous section. South's capital stock in $SN$ is denoted $K^S_{SN}$ and North's capital stock in $SN$ is denoted $K^N_{SN}$. The joint capital stock in $SN$ is denoted $\bar{K}_{SN}$. Then East enters. The FTA $ESN$ emerges. East contributes a positive capital stock of size $K^E_{SN}$, so that $\bar{K}_{ESN} > \bar{K}_{SN}$. Again, East is assumed to produce the goods in $[0, \bar{A}^E]$ (with $\bar{A}^E < \bar{A}^S$) at lower unit cost than South. The three-country FTE is characterized analogously to the two-country case:
The amount of capital used in country $i$ relative to country $i'$ in FTE is

$$\frac{K^i}{K^{i'}} = \left(\frac{\frac{a^i}{L^i}}{\frac{a^{i'}}{L^{i'}}}\right)^{\frac{\alpha\beta}{1-\alpha+\alpha\beta}} \left(\frac{A^i}{A^{i'}}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}, \tag{5.11}$$

terms of trade of country $i$ with country $i'$ are

$$\frac{P^i}{P^{i'}} = \left(\frac{\frac{a^i}{L^i}A^i}{\frac{a^{i'}}{L^{i'}}A^{i'}}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}, \tag{5.12}$$

and the relative wage of country $i$ with respect to country $i'$ is given by

$$\frac{w^i a^i}{w^{i'} a^{i'}} = \left(\frac{\frac{a^i}{L^i}A^i}{\frac{a^{i'}}{L^{i'}}A^{i'}}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}, \tag{5.13}$$

with $(i, i') \in \{(E, S), (E, N), (S, N)\}$.

### 5.2.2 Pain from (Two-Way) Capital Drain

As soon as East enters global free trade, firms relocate production of the goods in $[0, \bar{A}^E]$ from South to low-cost East. North continues to produce $(\bar{A}^S, \bar{A}^N]$. So, $A^N/A^S$, i.e., the relative number of goods produced in North and South, increases. From (5.13), this directly raises the relative wage of North with respect to South, just as in the baseline model with labor as the only input ($\beta = 1$). In the model with capital in production ($\beta < 1$) and international investment opportunities, there is a second effect on the relative wage working through an international shift of capital. From (5.11), an increase of $A^N/A^S$ raises $K^N/K^S$. This, in turn, lifts the relative price $P^N/P^S$ via (5.2). From (5.12), a one percentage change in the relative number of goods produced in the North translates into an increase of the relative price of these goods of $(1-\alpha)\beta/(1-\alpha+\alpha\beta)$ percent.
*Proof*: The elasticity of $P^N/P^S$ with respect to $A^N/A^S$ is the ratio of the percentage change in $P^N/P^S$ and the percentage change in $A^N/A^S$:

$$\frac{\partial\left(\frac{P^N}{P^S}\right)/\left(\frac{P^N}{P^S}\right)}{\partial\left(\frac{A^N}{A^S}\right)/\left(\frac{A^N}{A^S}\right)} = \frac{\partial\left(\frac{P^N}{P^S}\right)}{\partial\left(\frac{A^N}{A^S}\right)}\frac{\frac{A^N}{A^S}}{\frac{P^N}{P^S}}$$

$$= \frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}\underbrace{\left(\frac{\frac{a^N}{L^N}}{\frac{a^S}{L^S}}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}\left(\frac{A^N}{A^S}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}}_{=\frac{P^N}{P^S}}\left(\frac{A^N}{A^S}\right)^{-1}\frac{A^N}{A^S}\left(\frac{P^N}{P^S}\right)^{-1}$$

$$= \frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta} > 0.$$

q.e.d. A price increase of Northern goods raises the marginal value product of capital in the North. This causes a net capital movement from South to North, which raises (lowers) the capital-labor ratio and the marginal product of labor in the North (South). As a result, the marginal product of labor increases (decreases) in the North (South) and the North-South wage gap widens even further. This second effect is captured by the parameter $\beta$ in the exponent of (5.13). It is stronger the lower $\beta$, i.e., the higher the capital intensity in production.
In short, the model with international investment comprises two effects on the wage differential between South and North from East's entry. One direct effect through the change of $A^N/A^S$, and a second one, going in the same direction, through the international movement of capital that stems from a relative price increase due to the change of $A^N/A^S$. The former effect is also present in the baseline model. The latter effect is only present if (the international mobility of) production capital is accounted for. This second effect makes the present model predict a larger widening of the wage gap between North and South due to East's entry than the baseline model. The pains from trade for workers that can arise from East's entry are hence also predicted to be more pronounced in the international-investment variant compared to the baseline model.

Krugman does also derive pains from trade for workers from the two-country dynamic version of his model (1979a, Section IV). He assumes an exogenous innovation rate of new goods in the North, and an exogenous imitation rate of existing goods in the South. In that variant of the model, it is the introduction of new goods in the North that raises $A^N/A^S$, and hence attracts capital from the South via the price increase of Northern goods. There are two inconsistencies. First, the causal chain is from technological progress to capital movement, which is somewhat counterintuitive; causation usually runs the other way around, i.e., from capital investment to technological progress. Second, the innovation process is not modelled. Innovation takes place out of nowhere, without capital accumulation or investment in R&D. My theoretical approach yields the same result, i.e., South-North capital flows associated with an increase in North-South wage inequality, but gets along without technological progress. It only relies on the comparative static effect of a new low-wage competitor's entry into global free trade.

The preceding analysis shows that South suffers from a capital drain in relative terms ($K^N/K^S$ increases) if low-cost East enters the world economy. South may even suffer a capital drain in absolute terms. To demonstrate, let's extend numerical Example 1:

**Example 1 (extd.):**

| $\alpha$ | $\beta$ | $\bar{K}_{SN}$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 0.5 | 100 | 40 | 70 | 110 | 400 | 200 | 100 | 1 | 1 | 1 |

South's and North's joint capital stock is assumed to be $\bar{K}_{SN} = 100$. East's entry increases the global capital stock by $K^E_{SN}$. To be exact: East's entry makes additional $K^E_{SN}$ units of the global capital stock internationally mobile. From (5.12), terms of trade between South and North are $(P^N/P^S)_{SN} = 1.05$ in $SN$. South is a low-cost country compared to North. In $ESN$, $(P^N/P^S)_{ESN} = 1.39$. South's terms of trade with North deteriorate as a result of East's emergence. South's terms of trade with East are $(P^S/P^E)_{ESN} = 1.14$. Since $P^i/P^{i'} = (w^i a^i / w^{i'} a^{i'})^\beta$, and $0 < \beta < 1$, the corresponding relative wages are higher. So it is ensured that in $ESN$, East is the low-wage country and South the new medium-wage country.

Table 5.1 contrasts the equilibrium allocation of capital in $SN$ with the equilibrium allocation of capital in $ESN$ for different values of $K^E_{SN}$. East's entry causes a re-allocation of the global capital stock, and hence a change in countries' relative and absolute capital stocks. Note that terms of trade and wage-ratios are independent of the relative capital stocks. The impact of capital movement on these variables is captured by the parameter $\beta$ already. Values of $K^i_{ESN}$ $(i \in E, S, N)$ are colored in gray if they are lower than $K^i_{SN}(i \in E, S, N)$, i.e., if country $i$ suffers from an absolute capital drain due to East's entry. Bold values indicate an absolute capital gain.

Table 5.1: Example 1 (extd.) allocation of capital before and after East's entry

| $\bar{K}_{ESN}$ | $K^E_{SN}$ | $K^E_{ESN}$ | $K^S_{SN}$ | $K^S_{ESN}$ | $K^N_{SN}$ | $K^N_{ESN}$ |
|---|---|---|---|---|---|---|
| 125 | 25 | **54.70** | | 35.84 | | 34.46 |
| 130 | 30 | **56.89** | | 37.27 | | **35.84** |
| 180 | 80 | 78.77 | 64.66 | 51.61 | 35.34 | **49.62** |
| 225 | 125 | 98.46 | | 64.51 | | **62.03** |
| 230 | 130 | 100.65 | | **65.94** | | **63.41** |

Upon entry, East absorbs capital from South and North up to a threshold where it raises the initial capital stock by 25%, i.e., from $\bar{K}_{SN} = 100$ to $\bar{K}_{ESN} = 125$. This strong attractive force is due to the fact that East has a relatively large labor force, and thus, a relatively low capital-to-labor ratio initially compared to South and North in this example. So the marginal value product of capital per variety is very high in East compared to South and North. In addition, East is able to produce a relatively large set of varieties. Both circumstances make East attract additional capital from South and North, although it already has a considerable amount of capital initially.

If East's initial capital stock is 30 or larger, North experiences an absolute inflow of capital. East does not gain capital in absolute terms if it raises the initial capital stock by 80% or more ($\bar{K}_{ESN} \geq 180$). Beyond this threshold, East's capital-to-labor ratio is not low enough to attract capital from (one of) the two other countries. South is a net importer of capital only if the global capital stock is 230 or larger after East's entry.

The pattern of international capital flows induced by East's entry changes with $K^E_{SN}$ that East contributes to the global capital stock. With $K^E_{SN} < 30$, capital flows downstream from high-wage North and medium-wage South to low-wage East. With $30 \leq K^E_{SN} < 80$, South suffers from a two-way drain. It loses capital to East and North simultaneously. With $80 \leq K^E_{SN} \leq 125$, capital flows upstream from low-wage East and medium-wage South to high-wage North. With $K^E_{SN} \geq 130$, South and North gain capital at the expense of East. These different patterns of international capital flows illustrated by Example 1 can always arise in the static three-country variant of Krugman (1979a). Which pattern eventually arises only depends on the capital stock that East contributes upon entry. Numerical Appendix C contains an example in which North is relatively large in terms of labor supply ($L^N$), and the mass of goods it produces ($A^N$) in free trade equilibrium. In numerical Example 1, South experiences an inflow of capital only if East's initial capital stock is at least 1.3 times as large as South's and North's joint initial capital stock. The case of a low-wage newcomer country contributing a capital stock which is bigger than the capital stock of the rest of the world is odd. Hence, according to the model, the drain of capital is another form of real pressure that exerts the entry of a low-wage competitor on the new medium-wage country. Interestingly, the medium-wage country's capital does not necessarily flow only to the low-wage country. It may also flow to the high-wage country. And even the low-wage country's capital may move North. In this way, the capital flow distortions generated by the successive entry of low-wage competitors into global free trade is closely related to the famous question raised by Robert E. Lucas: "Why doesn't capital flow from rich to poor countries?" (the title of Lucas, 1990) The conventional argument is that poor countries are poor (pay low wages) because labor productivity is relatively low compared to labor productivity in rich countries. This, in turn, implies that the marginal product of capital, i.e., the return on capital, is higher in poor than in rich countries. So in theory, if capital is internationally mobile, it should move from rich to poor countries until capital rents and labor-productivities equalize. Lucas (1990) gives an example. He states that, given the observed income per worker at that time, a model assuming a constant returns to scale production technology (Cobb-Douglas type, just as in the present model variant), which is uniform across countries, would predict a marginal product of capital for India that is 58 times that of the United States. Insofar, a rapid flow of large amounts of capital from the United States to India should take place. This, however, is not observed. It is as if capital rents, and wages, in the two countries were equalized already. Yet, until today, more than 30 years after Lucas (1990), wages in India and the United States are far from being equal.[1] This is known as the Lucas paradox. Lucas proposes two directions to solve this puzzle: One is to account for differences in human capital, i.e., to measure the labor force in terms of *effective* workers instead of the absolute number of workers, and to incorporate a positive externality of human capital (knowledge spillovers between workers within a country but not across countries) into the model. A second is to consider capital market imperfections, in particular, a political will in the rich country to constrain capital flows to the poor country with the aim of keeping wages low and securing monopoly rents. He argues that the rich country's monopoly power over trade in capital goods with the poor country stems from the colonial past. With both approaches, the estimated difference in capital return between the U.S. and India disappears, thus providing an explanation why capital does not flow from rich to poor countries. A large body of literature builds up on Lucas (1990). Reinhart and Rogoff (2004) argue empirically in favor of the credit market imperfections hypothesis. They claim that the high default rates on private lending in poor countries are the main reason for restrained capital flows to these countries. Human capital externalities would only become relevant if better institutions reduced credit risk over time. Alfaro et al. (2008) provide an extensive overview of the theoretical works that are concerned with explaining the Lucas paradox. They group these explanations into two categories: First, differences in fundamentals, such as technology, factors of production, government

1 There is relatively little data available on India's wages. The Conference Board is the most comprehensive source: Hourly compensation costs in manufacturing increased from 2.8% of the U.S. level in 1999 to only 4.8% in 2014. See: `https://www.conference-board.org/ilcprogram/index.cfm?id=38271`.

policies, and institutions, and second, international capital market imperfections, such as asymmetric information and sovereign risk. The authors measure the effect of each of these variables on capital flows in 81 countries between 1970 and 2000. It turns out that institutional quality is the strongest predictor. Benhima (2013) uses a portfolio approach to solve the puzzle. She first argues that in a neoclassical growth model without risk, countries with higher productivity growth, viz. developing countries, experience a capital inflow. She then presents data which show that in practice, productivity growth and capital inflows are negatively correlated. By introducing a risk of capital investment into the model, she can predict the actual cross-country allocation of capital quite accurately. Ju and Wei (2014) point out that a two-goods, two-factors trade model turns the Lucas paradox around. In such a Heckscher-Ohlin-Samuelson framework, there is factor prize equalization across countries even without international factor mobility. Once there is free trade in goods and capital rents have equalized, there is no incentive for capital to flow between countries. So, any observed international capital flow is paradoxical through the lenses of that model. The authors account for firm heterogeneity, financial institutions, and property rights protection. They show that the capital attractive force of a low capital-to-labor ratio in the poor country may be offset by depressed FDI profitability due to a high expropriation risk in that country.

In sum, there seems to be a consensus that credit risk, associated with institutional deficiencies, in poor countries is the main force that restrains capital flows from rich to poor countries. An alternative theoretical explanation is presented by Darreau and Pigalle (2012). They argue that differences in human capital alone cannot solve the Lucas paradox, and human capital externalities can only solve it if they are assumed to be excessive. Instead, a better way is to assume an externality of physical capital. Existing differences in physical capital stocks between rich and poor countries are so large that a physical capital externality of reasonable size is sufficient to remove differences in capital productivity, and thus, the incentive for capital to move from rich to poor countries.

The present model gives a novel explanation; one that does not need to draw on human or physical capital externalities, investment risk, or institutional factors. It is simply the emergence of a new low-wage competitor that may prevent capital to move from rich to poor countries. The entrant country takes over market shares from the new middle-income country. This raises relative demand for goods produced in the high-income country. The relative price, and hence the relative marginal value product of these goods, increases. So, in relative terms, after the low-income country's entry, a larger part of the world capital stock is allocated to the high-income country than to the middle-income country.

Lucas (1990) and the above cited studies are concerned with the paradox of too little capital flows from rich to poor countries. An even more paradoxical pattern has been observed more recently: Gros (2013) shows that between 2002 and 2013 advanced economies run current account deficits and emerging economies run current account surpluses, meaning that the former were capital importers and the latter capital exporters during that period. Given this fact, the question is not, why does too little capital flow from rich to poor countries, but as a modern version of the Lucas paradox, why does capital flow in the opposite direction, i.e., from poor to rich countries? Gros (2013) proposes to apply, instead of the capital-to-labor ratio, a new measure of marginal productivity of capital: the capital-to-output ratio. It is defined as the rate of investment (% of GDP) divided by the GDP growth rate. China has a relatively high capital-to-output ratio compared to the U.S. Hence, according to this measure, return on capital is higher in the U.S. than in China, and capital should flow from China ('poor') to the U.S. ('rich'). This theoretical implication fits well with observed capital flows. Joffe (2017) shows that from the late 1990s onwards, there has been a large outflow of capital from low-and-middle-income East Asian countries to high-income countries, above all from China to the U.S. The explanation he presents is different to that of Gros (2013). He claims that, other than common belief, savings do not foster growth but are the consequence of it. There is excess corporate and household saving in fast growing low-and-middle-income East Asian countries which cannot be invested domestically and is hence exported.

From the viewpoint of the present model, the successive emergence of new low-wage countries can also explain capital flows from poor to rich countries. As can be seen from Table 5.1, it depends on the low-income country's initial capital stock whether the countries experience an inflow or outflow of capital in absolute terms. Four different patterns can arise: (i) The low-income country is a net gainer of capital at the expense of the other two countries, (ii) the medium-income country suffers from a two-way capital drain towards the other two countries, (iii) the high-income country is a net gainer at the expense of the other two countries, and (iv) the low-income country suffers from a two-way capital drain towards the other two countries. Patterns (iii) and (iv) are precisely the ones that entail upstream capital flows from poor to rich countries, thereby explaining the modern version of the Lucas paradox.

# 6. Conclusion

This work departed from Paul Krugman's observation that international trade is shaped by low-wage competition. I set forth that business people around the world share this view in that they consider labor cost as the main driver of offshoring decisions. Firms like Samsung, Google, H&M, and GAP provide anecdotal evidence for a global phenomenon: the persistent relocation of manufacturing from high-wage to low-wage countries, also known as the international product cycle. I showed that low-wage countries have gained substantial shares in global manufacturing value added (MFVA) recently, and demonstrated that this shift of MFVA translates into changing trade patterns: Low-wage countries are increasingly important exporters of industrial goods to developed countries. For example, the average hourly compensation in manufacturing of the top ten U.S. trading partners has been decreasing since 1990 (see Table 1.1 in the Introduction). This is not due to decreasing wages in already existing trading partner countries but due to the successive emergence of new trading partners with lower wages. The same trend can be observed from the perspective of China. Former low-wage and now medium-wage countries have evidently been losing market shares in global manufacturing to new low-wage competitors. To investigate from a theoretical perspective the welfare effects of international low-wage competition on medium-wage countries was my research goal. I pursued this by introducing a third country into the static variant of Krugman's two-country technology transfer model (1979a). I showed that, while in the two-country model both regions gain from trade, an emerging economy with low wages increases the efficiency of the world economy, but potentially poses a threat to the gains from trade of the former low-wage country. Successive emergence of newly industrializing countries to the world economy, as observed over the past decades, thus provides an explanation for the middle-income trap, i.e., a situation in which the gains from trade of former entrants come under pressure from new low-wage competition. Given the aggregate increase in efficiency, appropriate transfers in the enlarged FTA can in principle be used to compensate countries if necessary. However, as direct transfers are not commonly part of trade agreements, compensation is unlikely to happen in practice. The high-wage country may even have an incentive to completely exclude the medium-wage country from free trade after the low-wage country's entry. In this case, the medium-wage country suffers an outright loss if its gains from trade. While exclusion happens in theory, it is not observed in practice. Nonetheless, it highlights the pressure the entry of the low-wage country exerts on the medium-wage country.

The conclusions drawn from the baseline three-country model rest on the assumption of trade without any impediments or no trade at all (prohibitive tariffs). I show that the pains from trade and exclusion results continue to hold when positive and non-prohibitive tariffs are considered. In addition, optimum tariff analysis indicates that the entry of a low-wage country increases the high-wage country's likelihood of starting a tariff war with the medium-wage country. While this is beneficial for the high-wage country, it unequivocally reduces the medium-wage country's welfare even further compared to free trade. Incorporating capital in production and costless international investment opportunities does not alter my findings either. In the model variant with international capital flows, the wage differential between the high-wage and the medium-wage country is larger compared to the baseline model. So with international investment, the pains from the newcomer country's entry for workers in the medium-wage country are predicted to be even more pronounced. An interesting corollary is that the medium-wage country may suffer from a two-way capital drain in absolute terms and, depending on the entrant's initial capital stock, capital may even flow one-way upstream, from the two poor countries to the rich one. This resembles the recent observations of actual international capital flows and provides an explanation for the traditional Lucas paradox (too little capital flows from rich to poor countries) and its modern version (capital flows from poor to rich countries). The static three-country Krugman technology transfer model (1979a) provides a convenient framework for the analysis of the international product cycle driven by low-wage competition and its welfare implications for middle-income countries. It is simple and elegant in that it gets along with a very small number of essential assumptions, and the results carry over to more realistic assumptions like non-prohibitive tariffs and international investment.

Besides the middle-income trap and capital flows from poor to rich countries, my theoretical findings may also explain the rising popularity of contingent protection among developing countries since the mid-1990s (see Bown, 2008). Contingent protection means temporary measures against adverse trade shocks. These shocks harming domestic industries may constitute in a sudden increase of fairly traded imports due to trade liberalization, or in unfairly traded, i.e., subsidized, foreign goods flooding the home market. The most commonly applied measure (contingent on the latter shock) is the anti-dumping duty (see Aggarwal, 2007). Contingent protection is not governed by WTO's most-favored nation clause. Unlike import tariffs, it does not need to be applied uniformly to imports from all WTO members. It can selectively target imports from specific countries, sectors, or firms. Since the mid-1990s there has been a shift of primary use of these measures from industrialized countries like Australia, Canada, the EU, and the U.S. to newly industrializing countries like Mexico, China, Brazil, Indonesia, and Turkey (see Bown, 2008; Myagiwa et al., 2016; Kang and Ramizo, 2020). Vandenbussche et al. (2010) identify the latter as the new 'tough' users of anti-dumping laws. It seems that the need to protect oneself from low-cost competition has passed from high-income to middle-income countries in the

1990s. It is maybe no coincidence that at the very time more and more low-wage countries began to appear on the stage of the world economy and to gain market shares. Low-wage countries appearing among the top ten U.S. trading partners and replacing countries with higher wages (see Table 1.1) is a prime example for this trend. Seen through the lenses of the model I utilize, albeit anti-dumping is not explicitly modelled, a shift of contingent protection's popularity from developed to developing countries is unsurprising as the entry of new low-wage competitors into global free trade make high-wage (developed) countries better off and pose a threat to the medium-wage (developing) countries' gains from trade.
My work also adds a new aspect to the current discussion about the origins of the backlash against globalization, viz. a recently observed opposition against pro-globalization measures, among others trade liberalization (see Colantone et al., 2022; Walter, 2021). This phenomenon manifests itself in a significant drop in the support of globalization and the rise of nationalist and protectionist attitudes in various dimensions: political, socio-cultural, and economic. In the political dimension the elections of Donald Trump and Jair Bolsonaro as well as the success of the Brexit are prominent examples. These parties have in common to oppose the constraints that international organizations like the UN or the EU place on national sovereignty. The social and cultural dimension of the backlash is expressed by the concern of losing a nation's cultural heritage due to increased foreign inflow of products and migrants in a globalized world. As a result, right-wing parties, like PIS in Poland or the Fidesz in Hungary, have gained popularity with anti-immigration and nationalist programs. The economic dimension includes the shutdown of local industries, job displacements, and the loss of income due to intensified international competition. The Fridays for Future movement condemns the environmental costs associated with increased global trade. They are in this way also an example of the backlash's economic dimension. Not to mention the recent failure of concluding international trade agreements like TTIP and CETA. Opposition against globalization in one dimension does not necessarily entail opposition in another dimension. Trumpism can be considered as a backlash in all dimensions, the Brexiteers do not condemn trade liberalization but political integration. They just aim at negotiating free trade agreements independently from the EU. Fridays for Future by contrast, favor political globalization, so that the world's leaders find a common ground to fight the ecological crisis, while highlighting the environmental costs of intensified international trade. The following thoughts shall be limited to the economic dimension of the backlash and the economic factors that may foster the backlash in other dimensions.
An economic explanation can be found in factor proportions models. These are models which comprise within-country income distributional effects of trade liberalization. In the two-goods, two-sectors, two-factors Ricardo-Viner model for example, there is one mobile factor (e.g., labor) and one factor in each sector that is - at least in the short run - specific to that sector, i.e., immobile across sectors. Two standard examples of these factors are land (specific to agriculture) and capital (specific to manufacturing). With

trade liberalization, the factor specific to the exporting sector is better off, and the factor specific to the importing sector is worse off. The effect on the mobile factor's real earnings is ambiguous. In the Heckscher-Ohlin framework, all factors are mobile between sectors. It is considered a long-run version of the Ricardo-Viner model assuming that former agricultural land can be transformed into an industrial site and capital can be modified to serve all kinds of production processes. In that model, the relatively abundant factor (the one used intensively in the expanding export sector) unambiguously gains from trade liberalization, the other factor (the one used intensively in the shrinking import sector) unambiguously loses. If the backlash against globalization reflects a reversal of attitudes towards trade liberalization, the theoretical implications of the factor proportion models provide a rationale: Owners of factors that are not specific in the short run may enjoy gains in the short run, but experience losses in the long run if they are used intensively in the shrinking import competing sectors. As time passes these people change their mind about globalization, from supportive to rejecting. If these economic outcomes determine people's votes, it would at least explain the rising popularity of protectionist or isolationist parties. If the losers are in a majority, these models could also explain electoral victories of protectionist parties. But this contradicts the fact that in factor proportions models it is precisely the (relatively) scarce factor that loses and the (relatively) abundant factor that wins in the long run. Moreover, appropriate redistribution of the gains from trade can compensate the losers and make every individual better off, so that no one would have an economic reason to oppose trade liberalization. Colantone et al. (2022) put forward that models assuming workers with heterogenous skills and firms with heterogenous occupations and technologies as well as geographical frictions of between-sector immobility would yield the same result: A strengthening of within-country inequality due to trade liberalization. With agglomeration externalities due to increasing returns to scale in the expanding sector, this inequality would even be more pronounced. In addition to this, the authors observe an increasing popularity of political action to support somehow strategically important industries. They cope with this theoretically and propose to explain the backlash against globalization with trade-driven economic distress. The idea is that trade liberalization causes a relocation of workers away from a strategic sector. This strategic sector involves a positive externality on welfare. So if trade liberalization destroys 'good' jobs in that sector, there is a permanent cost associated with long-lasting economic distress. This is an explanation based on within-country developments due to trade liberalization of a single country. Hence, factor proportions models predicting a rise of within-country inequality from trade liberalization, i.e., from more trade or stronger exposition to trade, and the one-factor, two-sector model by Colantone et al. (2022) comprising externality driven overall pains from trade can serve as explanatory tools for the economic dimension of the globalization backlash.

My approach adds up on this. In the continuum of goods model (one factor, one sector) with low-wage competition, the successive emergence of low-wage countries inhibits the catch-up of middle-income countries to high-income countries. Cross-country relocation of production lowers the middle-income country's terms of trade with the high-income country and poses a threat to the gains from trade of all consumers in that country. To see that the own purchasing power stagnates while consumers in other countries, especially in the high-income region, unambiguously gain, may lead to the sensation of being left behind by the prospects of trade liberalization. A worker in the middle-income country may have gained at the time when trade with a high-income country was liberalized, but sees her gains melting away from further trade liberalization with low-income countries. This, in turn, may contribute to an attitude of opposing globalization in general. Hence, between-country distributional effects due to trade liberalization may also serve as an explanation of the backlash against globalization. It is in this way a less sophisticated explanatory approach because no modelling of between-factor inequalities or sector-specific externalities is needed to give rise to trade-driven pains.

Yet, there is a caveat. Colantone et al. (2022) and Walter (2021) are concerned with a globalization backlash in mostly industrialized Western economies. The present model predicts unambiguous gains for these countries from trade liberalization, i.e., from the low-wage country's entry into global free trade. So, from the viewpoint of the present model, there shouldn't be an economic globalization backlash in industrialized economies. There should be one in developing (middle-income) countries instead. There is only little work to date that is concerned with a globalization backlash in industrializing middle-income countries. The popularity of right-wing parties in Brazil, Poland, and Hungary[1] can be seen as a manifestation of such a backlash that may work through the economic channel, viz. a stronger exposition to international low-wage competition and the loss of market shares. At the turn of the millennium, Graham (2001) did not observe a general globalization backlash in middle-income countries but already saw some indication, e.g., the rising popularity of Peruvian presidential candidate Alan García in the 2001 campaign. As a declared opponent of market reforms and integration into the world economy, he was unsuccessful in the 2001 election, but succeeded in the subsequent election in 2006. Baker (2011) presents data from surveys conducted in Latin America between 1996 and 1999. They indicate that the vast majority of Latin Americans had strong support for trade liberalization at that time. This picture has changed afterwards. Jäkel and Smolka (2013) find that by 2007, Latin Americas were on average already substantially less pro-trade than people from Asian and East-Asian emerging economies. Then, more recently, Rodrik (2016) names Bolivia, Ecuador and Venezuela alongside Brazil as Latin American countries experiencing a populist backlash that stems from a trade and foreign investment shock. In 2018, only around 30% of Mexicans believed that trade creates more jobs or increases wages. Only 20% believed that it reduces consumer prices (see Davenport et al., 2021). In sum, there are some signs of a trade-driven globalization backlash in Latin

1 Poland and Hungary are classified as high-income countries by the World Bank. Within Europe, however, they can certainly be viewed as middle-income countries.

American middle-income countries. The general acceptance of free trade in Asian and East-Asian middle-income countries, however, is still very high. It is an open task to study more in detail people's attitudes towards trade liberalization in middle-income economies. From the viewpoint of the low-wage competition model presented in this work, it would not be surprising if in the future a newly (in the case of Asia and East Asia) or continuously (in the case of Latin America) declining support for deeper trade integration would be observed in middle-income countries. This, in particular, because the emergence of low-wage competitors has begun only recently (see Figures 1.3 and 1.4), and the welfare effects may manifest with some delay.

Estimating the pains from trade is surely a worthwhile task for future research, too. One way to do so is the sufficient statistics approach proposed by Arkolakis et al. (2012). They show that for a certain class of models, the real income change, i.e., the gains (or pains) from trade related shocks can be computed based on only two variables: the share of expenditure on domestic goods and the so-called trade elasticity, which the authors define as the elasticity of imports with respect to trade costs. The share of domestic expenditure is directly observable, and the trade elasticity can be estimated via a structural gravity equation. The approach is applicable to models that exhibit the following features: (i) Dixit-Stiglitz preferences, (ii) one factor of production, (iii) a linear cost function, and (iv) perfect or monopolistic competition. Three macro-level restrictions need to be fulfilled as well: (i) trade is balanced, (ii) aggregate profits are a constant share of aggregate revenues, and (iii) constant elasticity of import demand. A famous model belonging to this class is Krugman's monopolistic competition model (1980). As already explained in Section 3.1, the Krugman technology transfer model (1979a) is closely related to Krugman (1980). It builds on the same assumptions, only that firms operate under perfect competition and the number of varieties is exogenously given. Hence, the sufficient statistics approach should work with the static variant of Krugman (1979a), too. It allows to quantify the welfare effects of a low-wage competitor's entry (trade shock), thereby serving as a tool for political decision makers in middle-income countries. In trade negotiations, this tool could give them a notion of whether to favor the integration of a low-wage country into the global economy or not.

Two further promising directions for future research are FTA formation under optimal tariffs and imperfect competition. My analysis of two-country FTAs assumes exogenous outside tariffs (prohibitive in Chapter 3, non-prohibitive in Chapter 4). It would be interesting to construct examples of pains from trade and exclusion of the middle-income country from an FTA in the three-country model with optimal tariffs. As already mentioned in Section 4.3, this failed so far because of the limitations of Mathematica. Admittedly, the Krugman technology transfer model (1979a) is not tailor-made for this type of analysis. Missios et al. (2016) and Nken and Yildiz (2021) develop a more flexible trade model that encompasses both FTA formation and optimum tariffs. Utilizing an alternative programming platform may still deliver numerical results. Ossa (2016) e.g., provides

a MATLAB toolkit for computing optimal tariffs, Nash tariffs, and cooperative tariffs in multi-country settings. The author claims that it can be modified to be applicable to various theoretical frameworks. It may be worth a trial in the future.
With imperfect competition, producers in the medium-wage country can reap part of the benefits due to entry of a low-wage newcomer by outsourcing to the low-wage country and repatriating the profits (cf. Arnold and Trepl, 2015). This raises the question under which circumstances this is sufficient to rule out pains from trade. Combining optimum tariffs and imperfect competition would raise further interesting questions, related to the issue of production shifting (see Baldwin and Venables 1995, Subsection 2.2.1). The analysis of tariff wars while allowing for international investment could unveil unexpected implications as in Takatsuka and Zeng (2022): With internationally mobile capital and increasing returns to scale, small countries can win tariff wars, although they may set lower optimal tariff rates than the larger countries.
Lastly, the Krugman model with international cost differentials (1979a) can be augmented to a multi-country (more than three countries) model of global value chains to explain global patterns of vertical specialization (cf. Costinot et al., 2013), and to investigate the effects of global unbundling of production on world income and welfare inequality (cf. Basco and Mestieri, 2019). Utility function (3.1) can be re-interpreted as the production function of a final good, and the varieties as intermediate goods.

To wrap this thesis up, I would like to make a case for the theoretical approach I use. Even on this high level of abstraction, I think the model captures a salient feature of the world economy, viz. the successive emergence of low-wage competitors, and provides an important insight into the economics of middle-income countries: The entry of a low-wage country into global trade puts the gains from trade of former low-wage and then medium-wage countries under pressure. This result offers a new explanation of the middle-income trap. It is derived from a simple and stylized model. It is theoretically robust in that it carries over to standard model extensions, like tariffs and international investment. Thus, as Korobeinikov (2009) puts it, my theoretical approach is truly ‘akin to Ockham’s razor’.

# A. Proofs

## Proof of Proposition 1:

From (3.14), $U^E_{ESN} > U^E_{SN}$ if

$$\frac{1}{a^E}\left[(\bar{A}^N-\bar{A}^S)\left(\frac{w^Ea^E}{w^Na^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}+(\bar{A}^S-\bar{A}^E)\left(\frac{w^Ea^E}{w^Sa^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}+\bar{A}^E\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^E}(\bar{A}^E)^{\frac{1-\alpha}{\alpha}}.$$

Validity follows from $\bar{A}^N-\bar{A}^S>0$, $\bar{A}^S-\bar{A}^E>0$, and terms of trade being positive.

From (3.14), $U^S_{SN} < U^S_{ESN}$ if

$$\frac{1}{a^S}\left[\bar{A}^S+(\bar{A}^N-\bar{A}^S)\left(\frac{w^Sa^S}{w^Na^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}$$
$$< \frac{1}{a^S}\left[(\bar{A}^S-\bar{A}^E)+\bar{A}^E\left(\frac{w^Sa^S}{w^Ea^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}+(\bar{A}^N-\bar{A}^S)\left(\frac{w^Sa^S}{w^Na^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying yields

$$\bar{A}^S+(\bar{A}^N-\bar{A}^S)\left(\frac{w^Sa^S}{w^Na^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}} < (\bar{A}^S-\bar{A}^E)+\bar{A}^E\left(\frac{w^Sa^S}{w^Ea^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}+(\bar{A}^N-\bar{A}^S)\left(\frac{w^Sa^S}{w^Na^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}},$$

and rearranging terms gives us

$$(\bar{A}^N-\bar{A}^S)\left[\left(\frac{w^Sa^S}{w^Na^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}}-\left(\frac{w^Sa^S}{w^Na^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right] < \bar{A}^E\left[\left(\frac{w^Sa^S}{w^Ea^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}-1\right].$$

The fact that $U^S_{ESN} > U^S_{SN}$ exactly if (3.15) holds follows from (3.1).

From (3.14), $U^N_{ESN} > U^N_{SN}$ if

$$\frac{1}{a^N}\left[(\bar{A}^N-\bar{A}^S)+(\bar{A}^S-\bar{A}^E)\left(\frac{w^Na^N}{w^Sa^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}+\bar{A}^E\left(\frac{w^Na^N}{w^Ea^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}$$
$$> \frac{1}{a^N}\left[(\bar{A}^N-\bar{A}^S)+\bar{A}^S\left(\frac{w^Na^N}{w^Sa^S}\right)_{SN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying and rearranging terms yields

$$\bar{A}^E\left[\left(\frac{w^N a^N}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}-\left(\frac{w^N a^N}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]>\bar{A}^S\left[\left(\frac{w^N a^N}{w^S a^S}\right)_{SN}^{\frac{\alpha}{1-\alpha}}-\left(\frac{w^N a^N}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right].$$

From (3.12), the North's terms of trade with the South are higher in the equilibrium of $ESN$ than in the equilibrium of $SN$, and the terms of trade with the East are higher still:

$$\left(\frac{w^N a^N}{w^E a^E}\right)_{ESN}>\left(\frac{w^N a^N}{w^S a^S}\right)_{ESN}>\left(\frac{w^N a^N}{w^S a^S}\right)_{SN}.$$

This implies that the left-hand side of the inequality is positive, and the right-hand side is negative. q.e.d.

## Proof of Proposition 2:

That Pareto optimality requires that the proportion of total output a consumer gets is uniform across varieties follows from homotheticity of (3.1).
From (3.13), the outputs in the proposition satisfy $Y^E > Y^S > Y^N$.
If country $i$ produces positive amounts of different varieties, then the worldwide outputs of these varieties must be identical. Otherwise, given symmetry of (3.13) and uniform input coefficients within each country, the consumers' utility could be increased by shifting labor to the low-output high-marginal utility variety in $i$. It follows that the total output of the set of varieties that East produces is uniform and no less than $Y^E$, and that North produces a uniform amount of the varieties in $(\bar{A}^S, \bar{A}^N]$ (that no other country can produce) which is no greater than $Y^N$. From $Y^E > Y^N$, it follows that the sets of varieties produced in East and North are disjoint.
Suppose South produces a positive mass of varieties also produced in East. Then the total output of all varieties South produces is no less than $Y^E$. Since the labor supplies in East and South are just sufficient to produce $Y^E$ of varieties $j \in [0, \bar{A}^E]$ and $Y^S$ $(< Y^E)$ of $j \in (\bar{A}^E, \bar{A}^S]$, this implies that North produces positive amounts of some varieties $j \in [0, \bar{A}^S]$. However, since the uniform output per variety in North is no greater than $Y^N$ $(< Y^E)$, consumers' utility increases if South shifts labor from varieties also produced in East to varieties in $[0, \bar{A}^S]$ produced in North. This contradicts Pareto optimality, so the sets of varieties produced in East and South must be disjoint.
From (3.13), the Southern output per variety $L^S/(a^S\bar{A}^S)$ exceeds $Y^N$ if the South produces a uniform amount of all varieties in $[0, \bar{A}^S]$. Given that East produces some of these varieties (which are not produced in South), the total output of the remaining varieties exceeds $Y^N$. This is incompatible with positive output in North, so the sets of varieties produced in South and North are also disjoint.
Taken together, it follows that consumer $k$'s utility is

$$U_k = \lambda_k \left[ \left(A^E\right)^{1-\alpha} \left(\frac{L^E}{a^E}\right)^{\alpha} + \left(A^S\right)^{1-\alpha} \left(\frac{L^S}{a^S}\right)^{\alpha} + \left(A^N\right)^{1-\alpha} \left(\frac{L^N}{a^N}\right)^{\alpha} \right]^{\frac{1}{\alpha}}.$$

Differentiating $U_k$, holding $A^E$ constant, yields

$$dU_k = \frac{1-\alpha}{\alpha} U_k^{1-\alpha} \left[ \left(\frac{a^S}{L^S} A^S\right)^{-\alpha} dA^S + \left(\frac{a^N}{L^N} A^N\right)^{-\alpha} dA^N \right].$$

From (3.13),

$$\frac{a^S}{L^S} A^S \leq \frac{a^S}{L^S} \bar{A}^S < \frac{a^N}{L^N} (\bar{A}^N - \bar{A}^S) \leq \frac{a^N}{L^N} A^N$$

for all $A^S \leq \bar{A}^S$ and $A^N \geq \bar{A}^N - \bar{A}^S$. It follows that $dU_k > 0$ for $dA^S = -A^N > 0$. So Pareto optimality requires that, given the mass of varieties East produces ($A^E$), South produces all other varieties it is able to produce: $A^S = \bar{A}^S - A^E$. This implies that North produces only those varieties South cannot produce: $A^N = \bar{A}^N - A^E - A^S = \bar{A}^N - \bar{A}^S$. Differentiating $U_k$, holding $A^N$ constant, yields

$$dU_k = \frac{1-\alpha}{\alpha} U_k^{1-\alpha} \left[ \left(\frac{a^E}{L^E} A^E\right)^{-\alpha} dA^E + \left(\frac{a^S}{L^S} A^S\right)^{-\alpha} dA^S \right].$$

From (3.13),

$$\frac{a^E}{L^E} A^E \leq \frac{a^E}{L^E} \bar{A}^E < \frac{a^S}{L^S} (\bar{A}^S - \bar{A}^E) \leq \frac{a^S}{L^S} (\bar{A}^S - A^E) = \frac{a^S}{L^S} A^S$$

for all $A^E \leq \bar{A}^E$. Thus, $dU^k > 0$ for $dA^E = -dA^S > 0$, so that $A^E = \bar{A}^E$.

All consumers are assumed to have identical preferences. So, from individual demand for a variety $j$ (3.2), global demand for a variety $j$ is

$$\sum_k y(j) = \sum_k \frac{p(j)^{-\frac{1}{1-\alpha}} w^k}{\int_0^{\bar{A}^N} p(j')^{-\frac{\alpha}{1-\alpha}} dj'} = \frac{p(j)^{-\frac{1}{1-\alpha}}}{\int_0^{\bar{A}^N} p(j')^{-\frac{\alpha}{1-\alpha}} dj'} \sum_k w^k,$$

where $\sum_k w^k$ is world income. Hence,

$$\frac{y(j)}{\sum_k y(j)} = \frac{w^k}{\sum_k w^k} \equiv \lambda_k.$$

With global demand for variety $j$ being equal to global supply of variety $j$ (goods market clearing), each consumer $k$ buys a fraction $\lambda_k$ of the output of each variety (left-hand side) that is equal to her share in world income (right-hand side). q.e.d.

## Proof of Proposition 3 continued:

It is to be proved that condition (3.20) holds. In autarky, the South produces $L^S/(a^S \bar{A}^S)$ units of each variety in $[0, \bar{A}^S]$. From (3.1), the South's autarky social welfare is

$$\bar{U}^S_{EN} = x_S^{\frac{1}{\alpha}},$$

where

$$x_S = \left(\bar{A}^S\right)^{1-\alpha}\left(\frac{L^S}{a^S}\right)^{\alpha}.$$

Similarly, social welfare in a set of countries that form an FTA is given by (3.1) evaluated the outputs of the varieties produced in the FTA:

$$\begin{aligned}
\bar{U}^E_{ES} + \bar{U}^S_{ES} &= (x_E + x_{ES})^{\frac{1}{\alpha}} \\
\bar{U}^S_{SN} + \bar{U}^N_{SN} &= (x_S + x_{SN})^{\frac{1}{\alpha}} \\
\bar{U}^E_{ESN} + \bar{U}^S_{ESN} + \bar{U}^N_{ESN} &= (x_E + x_{ES} + x_{SN})^{\frac{1}{\alpha}},
\end{aligned}$$

where

$$\begin{aligned}
x_E &= \left(\bar{A}^E\right)^{1-\alpha}\left(\frac{L^E}{a^E}\right)^{\alpha} \\
x_{ES} &= \left(\bar{A}^S - \bar{A}^E\right)^{1-\alpha}\left(\frac{L^S}{a^S}\right)^{\alpha} \\
x_{SN} &= \left(\bar{A}^N - \bar{A}^S\right)^{1-\alpha}\left(\frac{L^N}{a^N}\right)^{\alpha}.
\end{aligned}$$

Condition (3.20) can then be rewritten as

$$(x_E + x_{ES} + x_{SN})^{\frac{1}{\alpha}} + x_S^{\frac{1}{\alpha}} \geq (x_E + x_{ES})^{\frac{1}{\alpha}} + (x_S + x_{SN})^{\frac{1}{\alpha}}.$$

From convexity of the power function with exponent $1/\alpha$ ($> 1$), it follows that this inequality is satisfied for $x_S < x_E + x_{ES}$.[1] Using the definitions of the $x$'s and rearranging terms, $x_S < x_E + x_{ES}$ can be rewritten as

$$\frac{\left(\bar{A}^S\right)^{1-\alpha} - \left(\bar{A}^S - \bar{A}^E\right)^{1-\alpha}}{\left(\bar{A}^E\right)^{1-\alpha}} < \left(\frac{\frac{L^E}{a^E}}{\frac{L^S}{a^S}}\right)^{\alpha}.$$

From (3.13),

$$\frac{\bar{A}^E}{\bar{A}^S - \bar{A}^E} < \frac{\frac{L^E}{a^E}}{\frac{L^S}{a^S}}.$$

So the validity of the preceding inequality is implied by

$$\frac{\left(\bar{A}^S\right)^{1-\alpha} - \left(\bar{A}^S - \bar{A}^E\right)^{1-\alpha}}{\left(\bar{A}^E\right)^{1-\alpha}} < \left(\frac{\bar{A}^E}{\bar{A}^S - \bar{A}^E}\right)^{\alpha}.$$

1 A differentiable function $f(x)$ with $f''(x) > 0$ satisfies $f(a+c) < f(a) + [f(b) - f(a)]c/(b-a)$ and $f(b-c) < f(b) - [f(b) - f(a)]c/(b-a)$ and, therefore, $f(a+c) + f(b-c) < f(a) + f(b)$ for $a + c < b$ and $c > 0$. Setting $f(x) = x^{1/\alpha}$, $a = x_S$, $b = x_E + x_{ES} + x_{SN}$, and $c = x_{SN}$ yields the result. The inequality $a + c < b$ becomes $x_S < x_E + x_{ES}$.

Simplifying yields

$$0 < \bar{A}^E.$$

$\bar{A}^E$ is positive by definition. q.e.d.

## Proof of Proposition 4:

The comparisons of individual utilities conducted in Subsection 3.2.3 imply that every country unequivocally prefers $ESN$ over $ES$, i.e.,

$$U^i_{ESN} > U^i_{ES}, \quad i \in \{E, S, N\}, \tag{A.1}$$

and East and South unequivocally prefer $ESN$ over $EN$:

$$U^i_{ESN} > U^i_{EN}, \quad i \in \{E, S\}. \tag{A.2}$$

From Proposition 1, East and North unequivocally prefer $ESN$ over $SN$:

$$U^i_{ESN} > U^i_{SN}, \quad i \in \{E, N\}. \tag{A.3}$$

The autarky equilibrium is blocked by the set of all three countries. From (A.1) the same holds true for $ES$. (A.1), (A.2), and (A.3) together imply that no coalition of two countries blocks $ESN$. So, $ESN$ is always in the core.

$EN$ is also in the core if the following conditions hold:

$$U^N_{EN} > U^N_{ESN}, \tag{A.4}$$

$$U^N_{EN} > U^N_{SN}, \tag{A.5}$$

$$U^E_{EN} > U^E_{ES}. \tag{A.6}$$

If North prefers $EN$ over $ESN$, which is implied by (A.4), $EN$ not blocked by $ESN$. Condition (A.5) ensures that North has no incentive to block $EN$ by forming a coalition with South. With East preferring $EN$ over $ES$, which is implied by (A.6), there is no trading system that blocks $EN$.

$SN$ may also be in the core together with $ESN$. This occurs if

$$U^S_{SN} > U^S_{ESN}, \tag{A.7}$$

$$U^N_{SN} > U^N_{EN}, \tag{A.8}$$

$$U^S_{SN} > U^S_{ES}. \tag{A.9}$$

The three inequalities imply that $SN$ is not blocked by $ESN$, $EN$, or $ES$. From (A.5) and (A.8), it follows that $EN$ and $SN$ cannot be in the core simultaneously. This completes the proof. q.e.d.

## Proof of Proposition 5:

Dividing relative demand of a Northern consumer (4.3) by relative demand of a Southern consumer (4.4) yields

$$\frac{\frac{Y_N^N}{Y_S^N}}{\frac{Y_N^S}{Y_S^S}} = \frac{\left[\frac{P^N}{(1+t_S^N)P^S}\right]^{-\frac{1}{1-\alpha}}}{\left[\frac{(1+t_N^S)P^N}{P^S}\right]^{-\frac{1}{1-\alpha}}}.$$

Simplifying and rearranging terms gives us

$$\frac{Y_S^N}{Y_S^S} = \frac{Y_N^N}{Y_N^S}\left[\frac{1}{(1+t_S^N)(1+t_N^S)}\right]^{\frac{1}{1-\alpha}}. \tag{A.10}$$

In free trade equilibrium, $t_S^N = t_N^S = 0$, so that (A.10) simplifies to $Y_S^N/Y_S^S = Y_N^N/Y_N^S$, and hence $Y_N^S/Y_S^S = Y_N^N/Y_S^N \equiv Y^N/Y^S$ (relative demand is uniform across countries). In a tariff Nash equilibrium, $t_S^N$ and $t_N^S$ are positive, so that $1/[(1+t_S^N)(1+t_N^S)]$ is smaller than one. With the exponent $1/1-\alpha > 0$, it must be that $Y_N^N/Y_N^S > Y_S^N/Y_S^S$ for equality (A.10) to hold. From Proposition 1, we know that in free trade equilibrium, a consumer buys a fraction of global output of each good that is equal to her share in world income. In a trade equilibrium with tariffs, a consumer's expenditure share is not equal to her income share, but income and expenditure shares are positively correlated. So, in a tariff trade equilibrium in which a Northern consumer earns a higher income than a Southern consumer, a Northern consumer buys a larger fraction of each good than a Southern consumer. Thus, both $Y_N^N/Y_N^S$ and $Y_S^N/Y_S^S$ are greater than one. This together with $Y_N^N/Y_N^S > Y_S^N/Y_S^S$ implies that $Y_S^N/Y_S^S > Y_N^S/Y_N^N$. Then, from (4.25) and (4.26), it follows that $(t_S^N)^* > (t_N^S)^*$. q.e.d.

## Proof of gains from trade in FTE with international wage differentials:

The general formulation of gains from trade for country $i$ is the following:

$$\frac{1}{a^i}\left[A^i + A^{i'}\left(\frac{w^i a^i}{w^{i'}a^{i'}}\right)^{\frac{\alpha}{1-\alpha}} + A^{i''}\left(\frac{w^i a^i}{w^{i''}a^{i''}}\right)^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^i}(\bar{A}^i)^{\frac{1-\alpha}{\alpha}}.$$

Simplifying yields

$$A^i + A^{i'}\left(\frac{w^i a^i}{w^{i'}a^{i'}}\right)^{\frac{\alpha}{1-\alpha}} + A^{i''}\left(\frac{w^i a^i}{w^{i''}a^{i''}}\right)^{\frac{\alpha}{1-\alpha}} > \bar{A}^i.$$

For $i = N$, $A^i + A^{i'} + A^{i''} = \bar{A}^i$. With $(w^i a^i)/(w^{i'}a^{i'}) > 1$ and $(w^i a^i)/(w^{i''}a^{i''}) > 1$ (wage differentials), the left-hand side is greater than the right-hand side, irrespective of whether $A^{i''}$ is positive (global free trade) or zero (only one trading partner).

For $i = S$, the proof is two-part. First, assume South only trades with North, so that $A^{i''} = 0$ and $A^i = \bar{A}^i$. Hence, $\bar{A}^i$ cancels out and the right-hand side is zero. With $(w^i a^i)/(w^{i'} a^{i'}) > 0$, the left-hand side is positive. Second, assume South only trades with East, so that $A^{i''} = 0$ and $A^i = \bar{A}^i - A^{i'}$. Again, $\bar{A}^i$ cancels out and the right-hand is zero. With $(w^i a^i)/(w^{i'} a^{i'}) > 1$ (wage differential), the left-hand side is positive. If North was also part of the trading system, the same line of argument applies but with an additional positive summand on the left-hand side.

For $i = E$, $A^i = \bar{A}^i$ in every trading system. Hence, $\bar{A}^i$ cancels out and the right-hand is zero. With $(w^i a^i)/(w^{i'} a^{i'}) > 0$ and $(w^i a^i)/(w^{i''} a^{i''}) > 0$, the left-hand side is positive. q.e.d.

# B. Technical Appendix

### Derivation of the demand function for good $j$ (3.2):

A consumer's utility maximization problem is given by

$$\max_{\{y(j)\}_0^{\bar{A}^N}} \quad U^i = \left[\int_0^{\bar{A}^N} y^i(j)^\alpha dj\right]^{\frac{1}{\alpha}} \quad \text{s.t.} \quad w^i = \int_0^{\bar{A}^N} p(j)y(j)dj.$$

The first-order conditionis

$$y(j') = \left[\frac{p(j)}{p(j')}\right]^{\frac{1}{1-\alpha}} y(j).$$

Inserting the first-order condition into the budget constraint and solving for $y(j)$ yields

$$y(j) = \frac{p(j)^{-\frac{1}{1-\alpha}} w^i}{\int_0^{\bar{A}^N} p(j')^{-\frac{\alpha}{1-\alpha}} dj'}.$$

### Showing linear homogeneity of the price index:

A function $\mathcal{P}(\vec{p})$ is linearly homogenous in the vector of arguments $\vec{p}$ if $\mathcal{P}(\lambda\vec{p}) = \lambda\mathcal{P}(\vec{p})$:

$$\begin{aligned}\mathcal{P}(\lambda\vec{p}) = \left[\int_0^{\bar{A}^N} (\lambda p(j))^{-\frac{\alpha}{1-\alpha}} dj\right]^{-\frac{1-\alpha}{\alpha}} &= \left[\int_0^{\bar{A}^N} \lambda^{-\frac{\alpha}{1-\alpha}} p(j)^{-\frac{\alpha}{1-\alpha}} dj\right]^{-\frac{1-\alpha}{\alpha}} \\ = \left[\lambda^{-\frac{\alpha}{1-\alpha}} \int_0^{\bar{A}^N} p(j)^{-\frac{\alpha}{1-\alpha}} dj\right]^{-\frac{1-\alpha}{\alpha}} &= \lambda \left[\int_0^{\bar{A}^N} p(j)^{-\frac{\alpha}{1-\alpha}} dj\right]^{-\frac{1-\alpha}{\alpha}} = \lambda\mathcal{P}.\end{aligned}$$

### Steps to derive (3.3) from (3.2):

$$y^i(j) = \frac{p(j)^{-\frac{1}{1-\alpha}} w^i}{\int_0^{\bar{A}^N} p(j')^{-\frac{\alpha}{1-\alpha}} dj'} = \frac{p(j)^{-\frac{1}{1-\alpha}} w^i}{\mathcal{P}^{-\frac{\alpha}{1-\alpha}}} = \frac{p(j)^{-\frac{1}{1-\alpha}} w^i}{\mathcal{P}^{-\frac{1}{1-\alpha}+1}} = \left[\frac{p(j)}{\mathcal{P}}\right]^{-\frac{1}{1-\alpha}} \frac{w^i}{\mathcal{P}}.$$

## Derivation of the elasticity of substitution in consumption:

The elasticity of substitution in consumption is defined as the percentage reduction of the relative demand for two goods, $j$ and $j'$, given a one percent increase of the relative price of the two goods:

$$-\frac{d\left(\frac{y(j)}{y(j')}\right)/\left(\frac{y(j)}{y(j')}\right)}{d\left(\frac{p(j)}{p(j')}\right)/\left(\frac{p(j)}{p(j')}\right)}=-\frac{d\left(\frac{y(j)}{y(j')}\right)}{d\left(\frac{p(j)}{p(j')}\right)}\frac{\left(\frac{p(j)}{p(j')}\right)}{\left(\frac{y(j)}{y(j')}\right)}.$$

From utility maximization, relative demand is

$$\frac{y(j)}{y(j')}=\left[\frac{p(j)}{p(j')}\right]^{-\frac{1}{1-\alpha}}.$$

Hence,

$$\frac{d\left(\frac{y(j)}{y(j')}\right)}{d\left(\frac{p(j)}{p(j')}\right)}=-\frac{1}{1-\alpha}\left[\frac{p(j)}{p(j')}\right]^{-\frac{2-\alpha}{1-\alpha}},$$

and

$$-\frac{d\left(\frac{y(j)}{y(j')}\right)}{d\left(\frac{p(j)}{p(j')}\right)}\frac{\left(\frac{p(j)}{p(j')}\right)}{\left(\frac{y(j)}{y(j')}\right)}=\frac{1}{1-\alpha}\left[\frac{p(j)}{p(j')}\right]^{-\frac{2-\alpha}{1-\alpha}}\frac{p(j)}{p(j')}\left[\frac{p(j)}{p(j')}\right]^{\frac{1}{1-\alpha}}=\frac{1}{1-\alpha}.$$

## Derivation of the pricing rule (3.4):

The profit maximization problem of a firm in country $i$ producing variety $j$ is given by

$$\max_{\{y(j)\}}\pi(j)=p(j)y(j)-w^i l(j),$$

where $l(j)$ is the amount of labor employed by firm $j$. With $l(j)=y(j)a^i$, taking the derivative of $\pi(j)$ with respect to $y(j)$, setting it equal to zero, and solving yields

$$p(j)=w^i a^i.$$

## Derivation of relative demand (3.5):

This immediately follows from the first-order condition for utility maximization (see above).

## Derivation of the equilibrium terms of trade (3.7):

$$\frac{w^N a^S}{w^S a^S}=\frac{P^N}{P^S}=\left(\frac{Y^S}{Y^N}\right)^{1-\alpha}=\left(\frac{\frac{L^S}{A^S a^S}}{\frac{L^N}{A^N a^N}}\right)^{1-\alpha}=\left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{1-\alpha}.$$

## Derivation of the equilibrium allocation of production when (3.8) is reversed:

If (3.8) is reversed, there is cost equalization between South and North:

$$\frac{w^N a^S}{w^S a^S} = \left(\frac{\frac{a^N}{L^N}A^N}{\frac{a^S}{L^S}A^S}\right)^{1-\alpha} = 1.$$

Simplifying and rearranging terms yields

$$a^S L^N A^N = a^N L^S A^S.$$

North produces all varieties the South does not produce:

$$a^S L^N(\bar{A}^N - A^S) = a^N L^S A^S.$$

By expanding and solving we obtain the equilibrium number of varieties produced in the South:

$$A^S = \frac{a^S L^N}{a^N L^S + a^S L^N}\bar{A}^N.$$

Using this in $A^N = \bar{A}^N - A^S$ and solving yields the equilibrium number of varieties produced in the North:

$$A^N = \frac{a^N L^S}{a^N L^S + a^S L^N}\bar{A}^N.$$

## Derivation of indirect utility (3.11):

Inserting (3.10) into (3.9) yields

$$U^i = \left\{A^N\left[\frac{(P^i)^{-\frac{1}{1-\alpha}}w^{i'}}{A^N(P^N)^{-\frac{\alpha}{1-\alpha}} + A^S(P^S)^{-\frac{\alpha}{1-\alpha}}}\right]^\alpha + A^S\left[\frac{(P^{i'})^{-\frac{1}{1-\alpha}}w^{i'}}{A^N(P^N)^{-\frac{\alpha}{1-\alpha}} + A^S(P^S)^{-\frac{\alpha}{1-\alpha}}}\right]^\alpha\right\}^{\frac{1}{\alpha}}.$$

Factoring out the denominator and $w^{i'}$ yields

$$U^i = w^{i'}\left\{\frac{A^i(P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'}(P^{i'})^{-\frac{\alpha}{1-\alpha}}}{\left[A^N(P^N)^{-\frac{\alpha}{1-\alpha}} + A^S(P^S)^{-\frac{\alpha}{1-\alpha}}\right]^\alpha}\right\}^{\frac{1}{\alpha}}.$$

With $N = i$ and $S = i'$, or $S = i$ and $N = i'$, either way simplifying yields

$$U^i = w^{i'} \left[ A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} \right]^{\frac{1-\alpha}{\alpha}}.$$

Using the pricing rule (3.4), factoring out $1/a^i$, and multiplying $w^{i'}$ back into the bracket gives

$$U^i = \frac{1}{a^i} \left[ A^i + A^{i'} \left( \frac{w^i a^i}{w^{i'} a^{i'}} \right)^{\frac{\alpha}{1-\alpha}} \right]^{\frac{1-\alpha}{\alpha}}.$$

## Functional form that plots $U_{SN}^N$ in Figure 3.2:

$$U_{SN}^N = \frac{1}{a^N} \left[ A^N + A^S \left( \frac{w^N a^N}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}} \right]^{\frac{1-\alpha}{\alpha}}.$$

Using (3.7), and setting $A^N = \bar{A}^N - \bar{A}^S$ and $A^S = \bar{A}^S$, we get

$$U_{SN}^N = \frac{1}{a^N} \left[ \bar{A}^N - \bar{A}^S + \bar{A}^S \left( \frac{\frac{a^N}{L^N}(\bar{A}^N - \bar{A}^S)}{\frac{a^S}{L^S}\bar{A}^S} \right)^{\alpha} \right]^{\frac{1-\alpha}{\alpha}}.$$

With $\alpha = 0.5, \bar{A}^N = 110, L^S = 200, L^N = 100, a^S = a^N = 1$, we get

$$U_{SN}^N = 110 - \bar{A}^S + \bar{A}^S \left( 2\frac{110 - \bar{A}^S}{\bar{A}^S} \right)^{0.5}.$$

Rearranging yields

$$U_{SN}^N = 110 + \bar{A}^S \left[ \left( \frac{220}{\bar{A}^S} - 2 \right)^{0.5} - 1 \right].$$

## Derivation of indirect utility (3.14):

In the three-country model, direct utility of a consumer in country $i$ is

$$U^i = \left[ A^i (Y^i)^\alpha + A^{i'} (Y^{i'})^\alpha + A^{i''} (Y^{i''})^\alpha \right]^{\frac{1}{\alpha}}. \tag{B.1}$$

Demand of a consumer from country $i$ for a good produced in country $i'$ is

$$Y^{i'} = \frac{(P^{i'})^{-\frac{1}{1-\alpha}} w^i}{A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}}}. \tag{B.2}$$

Inserting (B.2) into (B.1) yields

$$U^i = \left\{ A^i \left[ \frac{(P^i)^{-\frac{1}{1-\alpha}} w^i}{A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}}} \right]^{\alpha} + A^{i'} \left[ \frac{(P^{i'})^{-\frac{1}{1-\alpha}} w^i}{A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}}} \right]^{\alpha} + A^{i''} \left[ \frac{(P^{i''})^{-\frac{1}{1-\alpha}} w^i}{A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}}} \right]^{\alpha} \right\}^{\frac{1}{\alpha}}. \quad \text{(B.3)}$$

Factoring out the denominator and $w^i$ yields

$$U^i = w^i \left\{ \frac{A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}}}{\left[ A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}} \right]^{\alpha}} \right\}^{\frac{1}{\alpha}}.$$

Simplifying gives us

$$U^i = w^i \left[ A^i (P^i)^{-\frac{\alpha}{1-\alpha}} + A^{i'} (P^{i'})^{-\frac{\alpha}{1-\alpha}} + A^{i''} (P^{i''})^{-\frac{\alpha}{1-\alpha}} \right]^{\frac{1-\alpha}{\alpha}}.$$

With $P^i = w^i a^i$, factoring out $1/a^i$ and multiplying $w^i$ back into the bracket yields

$$U^i = \frac{1}{a^i} \left[ A^i + A^{i'} \left( \frac{w^i a^i}{w^{i'} a^{i'}} \right)^{\frac{\alpha}{1-\alpha}} + A^{i''} \left( \frac{w^i a^i}{w^{i''} a^{i''}} \right)^{\frac{\alpha}{1-\alpha}} \right]^{\frac{1-\alpha}{\alpha}}.$$

## Derivation of the condition for $U^E_{ESN} > U^E_{ES}$:

From (3.14), $U^E_{ESN} > U^E_{ES}$ if

$$\frac{1}{a^E} \left[ (\bar{A}^N - \bar{A}^S) \left( \frac{w^E a^E}{w^N a^N} \right)^{\frac{\alpha}{1-\alpha}}_{ESN} + (\bar{A}^S - \bar{A}^E) \left( \frac{w^E a^E}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}}_{ESN} + \bar{A}^E \right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^E} \left[ (\bar{A}^S - \bar{A}^E) \left( \frac{w^E a^E}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}}_{ES} + \bar{A}^E \right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying yields

$$(\bar{A}^N - \bar{A}^S) \left( \frac{w^E a^E}{w^N a^N} \right)^{\frac{\alpha}{1-\alpha}}_{ESN} + (\bar{A}^S - \bar{A}^E) \left( \frac{w^E a^E}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}}_{ESN} > (\bar{A}^S - \bar{A}^E) \left( \frac{w^E a^E}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}}_{ES},$$

and rearranging terms gives us

$$(\bar{A}^N - \bar{A}^S) \left( \frac{w^E a^E}{w^N a^N} \right)^{\frac{\alpha}{1-\alpha}}_{ESN} > (\bar{A}^S - \bar{A}^E) \left[ \left( \frac{w^E a^E}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}}_{ES} - \left( \frac{w^E a^E}{w^S a^S} \right)^{\frac{\alpha}{1-\alpha}}_{ESN} \right].$$

**Derivation of the condition for $U_{ESN}^S > U_{ES}^S$:**

From (3.14), $U_{ESN}^S > U_{ES}^S$ if

$$\frac{1}{a^S}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + (\bar{A}^S - \bar{A}^E) + \bar{A}^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}$$
$$> \frac{1}{a^S}\left[(\bar{A}^S - \bar{A}^E) + \bar{A}^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ES}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > \bar{A}^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ES}^{\frac{\alpha}{1-\alpha}},$$

and rearranging terms gives us

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > \bar{A}^E\left[\left(\frac{w^S a^S}{w^E a^E}\right)_{ES}^{\frac{\alpha}{1-\alpha}} - \left(\frac{w^S a^S}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right].$$

**Derivation of the condition for $U_{ESN}^E > U_{EN}^E$:**

From (3.14), $U_{ESN}^E > U_{EN}^E$ if

$$\frac{1}{a^E}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + (\bar{A}^S - \bar{A}^E)\left(\frac{w^E a^E}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E\right]^{\frac{1-\alpha}{\alpha}}$$
$$> \frac{1}{a^E}\left[(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + (\bar{A}^S - \bar{A}^E)\left(\frac{w^E a^E}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > \frac{1}{a^E}(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}}.$$

Adding $\bar{A}^E\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}$ on both sides and rearranging terms gives us

$$(\bar{A}^S - \bar{A}^E)\left[\left(\frac{w^E a^E}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} - \left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right] > (\bar{A}^N - \bar{A}^E)\left[\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} - \left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right].$$

**Derivation of the condition for $U^N_{ESN} > U^N_{EN}$:**

From (3.14), $U^N_{ESN} > U^N_{EN}$ if

$$\frac{1}{a^N}\left[(\bar{A}^N-\bar{A}^S)+(\bar{A}^S-\bar{A}^E)\left(\frac{w^Na^N}{w^Sa^S}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}+\bar{A}^E\left(\frac{w^Na^N}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}\right]^{\frac{1-\alpha}{\alpha}}$$
$$>\frac{1}{a^N}\left[(\bar{A}^N-\bar{A}^E)+\bar{A}^E\left(\frac{w^Na^N}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN}\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying yields

$$-\bar{A}^S+(\bar{A}^S-\bar{A}^E)\left(\frac{w^Na^N}{w^Sa^S}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}+\bar{A}^E\left(\frac{w^Na^N}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}>-\bar{A}^E+\bar{A}^E\left(\frac{w^Na^N}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN},$$

and rearranging terms gives us

$$(\bar{A}^S-\bar{A}^E)\left[\left(\frac{w^Na^N}{w^Sa^S}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}-1\right]>\bar{A}^E\left[\left(\frac{w^Na^N}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN}-\left(\frac{w^Na^N}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{ESN}\right].$$

**Derivation of the condition for $U^E_{EN} > U^E_{ES}$:**

From (3.14), $U^E_{EN} > U^E_{ES}$ if

$$\frac{1}{a^E}\left[(\bar{A}^N-\bar{A}^E)\left(\frac{w^Ea^E}{w^Na^N}\right)^{\frac{\alpha}{1-\alpha}}_{EN}+\bar{A}^E\right]^{\frac{1-\alpha}{\alpha}}>\frac{1}{a^E}\left[(\bar{A}^S-\bar{A}^E)\left(\frac{w^Ea^E}{w^Sa^S}\right)^{\frac{\alpha}{1-\alpha}}_{ES}+\bar{A}^E\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying, and rearranging on the right-hand side yields

$$(\bar{A}^N-\bar{A}^E)\left(\frac{w^Ea^E}{w^Na^N}\right)^{\frac{\alpha}{1-\alpha}}_{EN}>\bar{A}^E\left[\left(\frac{w^Ea^E}{w^Sa^S}\right)^{\frac{\alpha}{1-\alpha}}_{ES}-1\right].$$

**Derivation of the condition for $U^S_{SN} > U^S_{ES}$:**

From (3.14), $U^S_{SN} > U^S_{ES}$ if

$$\frac{1}{a^S}\left[(\bar{A}^N-\bar{A}^S)\left(\frac{w^Sa^S}{w^Na^N}\right)^{\frac{\alpha}{1-\alpha}}_{SN}+\bar{A}^S\right]^{\frac{1-\alpha}{\alpha}}>\frac{1}{a^S}\left[(\bar{A}^S-\bar{A}^E)+\bar{A}^E\left(\frac{w^Sa^S}{w^Ea^E}\right)^{\frac{\alpha}{1-\alpha}}_{ES}\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying, and rearranging on the right-hand side yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}} > \bar{A}^E\left[\left(\frac{w^S a^S}{w^E a^E}\right)_{ES}^{\frac{\alpha}{1-\alpha}} - 1\right].$$

## Derivation of the condition for $U_{EN}^N > U_{SN}^N$:

From (3.14), $U_{EN}^N > U_{SN}^N$ if

$$\frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^E) + \bar{A}^E\left(\frac{w^N a^N}{w^E a^E}\right)_{EN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^N a^N}{w^S a^S}\right)_{SN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^S\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying and rearranging on both sides yields

$$\bar{A}^E\left[\left(\frac{w^N a^N}{w^E a^E}\right)_{EN}^{\frac{\alpha}{1-\alpha}} - 1\right] > \bar{A}^S\left[\left(\frac{w^N a^N}{w^S a^S}\right)_{SN}^{\frac{\alpha}{1-\alpha}} - 1\right].$$

## Derivation of import demand functions (4.5) and (4.6) with non-prohibitive tariffs:

From (4.1), a Northern consumer's import demand is

$$Y_S^N = \left[\frac{(1+t_S^N)w^S a^S}{\mathcal{P}^N}\right]^{-\frac{1}{1-\alpha}} \frac{w^N + t_S^N A^S w^S a^S Y_S^N}{\mathcal{P}^N}.$$

Isolating $w^N/\mathcal{P}^N$ yields

$$\left\{\left[\frac{(1+t_S^N)w^S a^S}{\mathcal{P}^N}\right]^{\frac{1}{1-\alpha}} - \frac{t_S^N A^S w^S a^S}{\mathcal{P}^N}\right\} Y_S^N = \frac{w^N}{\mathcal{P}^N}.$$

Isolating $Y_S^N$ and factoring out $\left[\frac{w^N a^N}{(1+t_S^N)w^S a^S}\right]^{\frac{1}{1-\alpha}}$ yields

$$Y_S^N = \left[\frac{w^N a^N}{(1+t_S^N)w^S a^S}\right]^{\frac{1}{1-\alpha}}\left\{\left(\frac{w^N a^N}{\mathcal{P}^N}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^N} t_S^N A^S w^S a^S \left[\frac{w^N a^N}{(1+t_S^N)w^S a^S}\right]^{\frac{1}{1-\alpha}}\right\}^{-1} \frac{w^N}{\mathcal{P}^N}.$$

Derivation of a Southern consumer's import demand (4.6) works analogously.

## Alternative way of determining the two-country trade equilibrium with tariffs:

From labor market clearing conditions (4.9) and (4.10),

$$Y_N^N = \frac{1}{A^N a^N} - \frac{L^S}{L^N} Y_N^S, \tag{B.4}$$

$$Y_S^S = \frac{1}{A^S a^S} - \frac{L^N}{L^S} Y_S^N. \tag{B.5}$$

Using (B.4) and (B.5) in (4.16) and (4.17) respectively yields

$$Y_S^N = \left(Y_N^N\right)^{-\frac{1-\alpha}{\alpha}} \left[\frac{L^S}{L^N}\frac{A^N}{A^S} Y_N^S (1 + t_S^N)\right]^{\frac{1}{\alpha}}, \tag{B.6}$$

$$Y_N^S = \left(Y_S^S\right)^{-\frac{1-\alpha}{\alpha}} \left[\frac{L^N}{L^S}\frac{A^S}{A^N} Y_S^N (1 + t_N^S)\right]^{\frac{1}{\alpha}}. \tag{B.7}$$

Equations (B.4)-(B.7) uniquely determine consumption quantities $Y_N^S$, $Y_S^N$, $Y_N^N$, and $Y_S^S$. These consumption quantities determine producer prices $P^N$ and $P^S$, and thus terms of trade, via (4.3) and (4.4). Utility of a Northern consumer is determined by

$$U^N = \left[A^N (Y_N^N)^\alpha + A^S (Y_S^N)^\alpha\right]^{\frac{1}{\alpha}}.$$

Utility of a Southern consumer is determined by

$$U^S = \left[A^N (Y_N^S)^\alpha + A^S (Y_S^S)^\alpha\right]^{\frac{1}{\alpha}}.$$

## Derivation of demand function (4.14) in the three-country trade equilibrium with tariffs:

Demand of a consumer in country $i$ for a good produced in $i''$ relative to a good produced in $i'$ is

$$Y_{i''}^i = \left[\frac{(1 + t_{i''}^i) w^{i''} a^{i''}}{(1 + t_{i'}^i) w^{i'} a^{i'}}\right]^{-\frac{1}{1-\alpha}} Y_{i'}^i.$$

Inserting this into her income $e^i = w^i + \sum_{i'} t_{i'}^i A^{i'} w^{i'} a^{i'} Y_{i'}^i$ yields

$$e^i = w^i + \left\{ t_{i'}^i A^{i'} w^{i'} a^{i'} + t_{i''}^i A^{i''} w^{i''} a^{i''} \left[\frac{(1 + t_{i''}^i) w^{i''} a^{i''}}{(1 + t_{i'}^i) w^{i'} a^{i'}}\right]^{-\frac{1}{1-\alpha}} \right\} Y_{i'}^i.$$

Using this in demand function (4.13) yields

$$Y^i_{i'} = \left[\frac{(1+t^i_{i'})w^{i'}a^{i'}}{\mathcal{P}^i}\right]^{-\frac{1}{1-\alpha}} \frac{1}{\mathcal{P}^i}\left(w^i + \left\{t^i_{i'}A^{i'}w^{i'}a^{i'} + t^i_{i''}A^{i''}w^{i''}a^{i''}\left[\frac{(1+t^i_{i''})w^{i''}a^{i''}}{(1+t^i_{i'})w^{i'}a^{i'}}\right]^{-\frac{1}{1-\alpha}}\right\}Y^i_{i'}\right).$$

Solving for $Y^i_{i'}$ and rearranging terms yields

$$\begin{aligned} Y^i_{i'} &= \left[\frac{w^i a^i}{(1+t^i_{i'})w^{i'}a^{i'}}\right]^{\frac{1}{1-\alpha}} \left(\left(\frac{w^i a^i}{\mathcal{P}^i}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^i}\left\{t^i_{i'}A^{i'}w^{i'}a^{i'}\left[\frac{w^i a^i}{(1+t^i_{i'})w^{i'}a^{i'}}\right]^{\frac{1}{1-\alpha}}\right.\right. \\ &\quad \left.\left. + \, t^i_{i''}A^{i''}w^{i''}a^{i''}\left[\frac{w^i a^i}{(1+t^i_{i''})w^{i''}a^{i''}}\right]^{\frac{1}{1-\alpha}}\right\}\right)^{-1} \frac{w^i}{\mathcal{P}^i}. \end{aligned}$$

Demand of consumer $i$ for a domestically produced good is thus given by

$$\begin{aligned} Y^i_i &= \left(\left(\frac{w^i a^i}{\mathcal{P}^i}\right)^{\frac{1}{1-\alpha}} - \frac{1}{\mathcal{P}^i}\left\{t^i_{i'}A^{i'}w^{i'}a^{i'}\left[\frac{w^i a^i}{(1+t^i_{i'})w^{i'}a^{i'}}\right]^{\frac{1}{1-\alpha}}\right.\right. \\ &\quad \left.\left. + \, t^i_{i''}A^{i''}w^{i''}a^{i''}\left[\frac{w^i a^i}{(1+t^i_{i''})w^{i''}a^{i''}}\right]^{\frac{1}{1-\alpha}}\right\}\right)^{-1} \frac{w^i}{\mathcal{P}^i}. \end{aligned}$$

## Getting rid of the price index in (4.14):

From (4.11),

$$\frac{1}{\mathcal{P}^i} = \frac{1}{w^i a^i}\left\{A^i + A^{i'}\left[\frac{(1+t^i_{i'})w^{i'}a^{i'}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}} + A^{i''}\left[\frac{(1+t^i_{i''})w^{i''}a^{i''}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}}\right\}^{\frac{1-\alpha}{\alpha}}.$$

Substitution into (4.14) yields

$$\begin{aligned} Y^i_{i'} &= \left[\frac{w^i a^i}{(1+t^i_{i'})w^{i'}a^{i'}}\right]^{\frac{1}{1-\alpha}} \left(\left\{A^i + A^{i'}\left[\frac{(1+t^i_{i'})w^{i'}a^{i'}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}} + A^{i''}\left[\frac{(1+t^i_{i''})w^{i''}a^{i''}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}}\right\}^{\frac{1}{\alpha}}\right. \\ &\quad -\frac{w^{i'}a^{i'}}{w^i a^i}\left\{A^i + A^{i'}\left[\frac{(1+t^i_{i'})w^{i'}a^{i'}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}} + A^{i''}\left[\frac{(1+t^i_{i''})w^{i''}a^{i''}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}}\right\}^{\frac{1-\alpha}{\alpha}} \\ &\quad \left.\left\{t^i_{i'}A^{i'}\left[\frac{w^i a^i}{(1+t^i_{i'})w^{i'}a^{i'}}\right]^{\frac{1}{1-\alpha}} + t^i_{i''}A^{i''}\frac{w^{i''}a^{i''}}{w^{i'}a^{i'}}\left[\frac{w^i a^i}{(1+t^i_{i''})w^{i''}a^{i''}}\right]^{\frac{1}{1-\alpha}}\right\}\right)^{-1} \\ &\quad \frac{1}{a^i}\left\{A^i + A^{i'}\left[\frac{(1+t^i_{i'})w^{i'}a^{i'}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}} + A^{i''}\left[\frac{(1+t^i_{i''})w^{i''}a^{i''}}{w^i a^i}\right]^{-\frac{\alpha}{1-\alpha}}\right\}^{\frac{1-\alpha}{\alpha}}. \end{aligned} \tag{B.8}$$

The way of determining the equilibrium values presented in the main text requires to determine two of the three relative producer prices in a first step. This is achieved by substitution of the $Y^i_{i'}$'s from (B.8) into two of the three labor market clearing conditions. The resulting two relative producer prices determine the third one. In a second step, the three relative producer prices determine the nine $Y^i_{i'}$'s via (B.8). Translating this - especially (B.8) - into Mathematica code for numerical analysis is inconvenient. An alternative, much more convenient, way for numerical analysis is the following.

## Alternative way of determining the three-country trade equilibrium with tariffs:

From the three labor market clearing conditions, $\sum_{i'} L^{i'} Y^{i'}_i = L^i/(a^i A^i)$, we get demand in country $i$ for a domestically produced good, $Y^i_i$, as a function of foreign demand for a domestically produced good, $Y^{i'}_i$:

$$Y^i_i = \frac{1}{A^i a^i} - \sum_{i'} \frac{L^{i'}}{L^i} Y^{i'}_i. \tag{B.9}$$

Analogous to (B.6) and (B.7) from the two-country model, import demand of a consumer located in country $i$ for a good produced in country $i'$ as a function of demand for a domestically produced good, and import demand of a consumer located in country $i'$ for a good produced in country $i$, takes the general form

$$Y^i_{i'} = \left(Y^i_i\right)^{-\frac{1-\alpha}{\alpha}} \left[\frac{L^{i'}}{L^i} \frac{A^i}{A^{i'}} Y^{i'}_i (1 + t^i_{i'})\right]^{\frac{1}{\alpha}}. \tag{B.10}$$

The set of equations (B.9) and (B.10) uniquely determine the nine consumption quantities ($Y^i_i$, $Y^i_{i'}$ and $Y^i_{i''}$ for each of the three countries). These consumption quantities determine the three relative producer prices via

$$\frac{Y^i_i}{Y^i_{i'}} = \left[\frac{w^i a^i}{(1 + t^i_{i'}) w^{i'} a^{i'}}\right]^{-\frac{1}{1-\alpha}}. \tag{B.11}$$

Substitution of $Y^i_i$, $Y^i_{i'}$ and $Y^i_{i''}$ into (3.1) yields utility of a representative consumer from country $i$:

$$U^i = \left[\sum_{i' \in \{E,S,N\}} A^{i'} \left(Y^i_{i'}\right)^{\alpha}\right]^{\frac{1}{\alpha}}.$$

This way of determining the equilibrium is used for numerical analysis in Mathematica (see Appendix E for the code).

## Determining a hub-and-spoke trade equilibrium with tariffs:

In a hub-and-spoke trading system there are two countries (the spokes) that do not trade with each other but with the third country (the hub). Hence, two of the six import demand functions (B.10) are dropped. The remaining four import demand functions are unchanged because the hub country trades the same set of varieties with the spoke countries as with global trade. Demand for a domestically produced variety is still represented by (B.9) for the hub country. For the two spoke countries the sum (B.9) is replaced by a single summand:

$$Y_i^i = \frac{1}{A^i a^i} - \frac{L^{i'}}{L^i} Y_i^{i'}.$$

Four import demand functions and three labor market clearing conditions determine the three $Y_i^i$'s and the four $Y_{i'}^i$'s. These consumption quantities again determine the now two relative producer prices via

$$\frac{Y_i^i}{Y_{i'}^i} = \left[ \frac{w^i a^i}{(1+t_{i'}^i) w^{i'} a^{i'}} \right]^{-\frac{1}{1-\alpha}}.$$

Substitution of the $Y_{i'}^i$'s and $Y_i^i$'s into (3.1) yields utility of a representative consumer from country $i$ with one $A^{i'}$ being zero for each spoke country:

$$U^i = \left[ \sum_{i' \in \{E,S,N\}} A^{i'} \left( Y_{i'}^i \right)^{\alpha} \right]^{\frac{1}{\alpha}}.$$

## Intermediate steps from (4.24) to (4.25):

Inserting (4.22), (4.23), and relative demand (4.3) into (4.24) yields

$$\frac{d[(U^N)^\alpha]}{dt_S^N} = \frac{A^N}{A^S} (det\mathbf{A})^{-1} \left\{ \frac{P^S}{P^N} \left[ 1 - (\alpha - 1) \frac{Y_S^N}{Y_S^S} \right] \frac{P^S}{P^N} Y_S^N \right\} + \left[ \frac{P^S}{P^N} (1 + t_S^N) \right] (det\mathbf{A})^{-1} \left( -\alpha \frac{A^N}{A^S} \frac{P^S}{P^N} Y_S^N \right) = 0.$$

$A^N/A^S$, $(det\mathbf{A})^{-1}$, $P^S/P^N$, and $Y_S^N$ cancel out, which leaves

$$1 - (\alpha - 1) \frac{Y_S^N}{Y_S^S} - \alpha (1 + t_S^N) = 0.$$

Isolating $t_S^N$ yields

$$t_S^N = \frac{1}{\alpha} - \frac{\alpha - 1}{\alpha} \frac{Y_S^N}{Y_S^S} - 1.$$

Rearranging terms gives us

$$t_S^N = \frac{1-\alpha}{\alpha}\left(1+\frac{Y_S^N}{Y_S^S}\right).$$

## Derivation of South's optimal tariff:

By solving the labor market clearing conditions (4.9) and (4.10) for $Y_S^N$ and $Y_N^N$, and substituting them into import demand functions (4.16) and (4.17), the latter can be written as

$$\frac{(Y_N^S)^\alpha}{(Y_S^S)^{\alpha-1}} - \frac{L^N}{L^S}\frac{A^S}{A^N}\left(\frac{Y^S}{L^N} - \frac{L^S}{L^N}Y_S^S\right)(1+t_N^S) = 0 \qquad \text{(B.12)}$$

and

$$(1+t_S^N)Y_N^S\frac{\left(\frac{Y^N}{L^N} - \frac{L^S}{L^N}Y_N^S\right)^{\alpha-1}}{\left(\frac{Y^S}{L^N} - \frac{L^S}{L^N}Y_S^S\right)^{\alpha}} - \frac{L^N}{L^S}\frac{A^S}{A^N} = 0, \qquad \text{(B.13)}$$

respectively.
The total differentials of (B.12) and (B.13), and the latter multiplied with $Y_S^N$ yield

$$(1-\alpha)\left(\frac{Y_N^S}{Y_S^S}\right)^\alpha dY_S^S + \frac{A^S}{A^N}(1+t_N^S)dY_S^S + \alpha\left(\frac{Y_S^S}{Y_N^S}\right)^{1-\alpha} dY_N^S - \frac{L^N}{L^S}\frac{A^S}{A^N}Y_S^N dt_N^S = 0 \quad \text{(B.14)}$$

and

$$\begin{aligned}\alpha(1+t_S^N)Y_N^S\frac{(Y_N^N)^{\alpha-1}}{(Y_S^N)^\alpha}dY_S^S \\ + \left[(1+t_S^N)\left(\frac{Y_N^N}{Y_S^N}\right)^{\alpha-1} - (1+t_S^N)(\alpha-1)Y_N^S\left(\frac{Y_N^N}{Y_S^N}\right)^{\alpha-1}(Y_N^N)^{-1}\right]dY_N^S \\ + Y_N^S\left(\frac{Y_N^N}{Y_S^N}\right)^{\alpha-1}dt_S^N = 0, \quad \text{(B.15)}\end{aligned}$$

where use is made of $\frac{Y^S}{L^N} - \frac{L^S}{L^N}Y_S^S = Y_S^N$ and $\frac{Y^S}{L^N} - \frac{L^S}{L^N}Y_S^S = Y_N^N$ after differentiation.
Using (4.3) and (4.4), (B.14) and (B.15) can be written in matrix form $\mathbf{Ay} = \mathbf{x}$:

$$\underbrace{\begin{bmatrix} \frac{A^S}{A^N}(1+t_N^S)+(1-\alpha)\left[\frac{P^N}{P^S}(1+t_N^S)\right]^{\frac{\alpha}{\alpha-1}} & \alpha\frac{P^N}{P^S}(1+t_N^S) \\ \alpha\frac{A^S}{A^N} & \frac{P^N}{P^S}\left[1-\frac{(\alpha-1)Y_N^S}{Y_N^N}\right] \end{bmatrix}}_{\mathbf{A}} \underbrace{\begin{bmatrix} dY_S^S \\ dY_N^S \end{bmatrix}}_{\mathbf{y}} =$$

$$= \underbrace{\begin{bmatrix} \frac{P^N}{P^S}Y_N^S dt_N^S \\ -\frac{P^N}{P^S}Y_N^S\frac{1}{1+t_S^N}dt_S^N \end{bmatrix}}_{\mathbf{x}}$$

Assuming that the South does not retaliate ($dt_S^N = 0$), this system of equations can be solved for $dY_S^S/dt_N^S$ and $dY_N^S/dt_N^S$:

$$\frac{dY_S^S}{dt_N^S} = (det\mathbf{A})^{-1}\left\{\frac{P^N}{P^S}\left[1-(\alpha-1)\frac{Y_N^S}{Y_N^N}\right]\frac{P^N}{P^S}Y_N^S\right\} \tag{B.16}$$

$$\frac{dY_N^S}{dt_N^S} = (det\mathbf{A})^{-1}\left(-\alpha\frac{A^S}{A^N}\frac{P^N}{P^S}Y_N^S\right). \tag{B.17}$$

The first-order condition for the utility maximizing tariff is

$$\frac{d[(U^S)^\alpha]}{dt_N^S} = \frac{A^S}{A^N}\frac{dY_S^S}{dt_N^S} + \left(\frac{Y_N^S}{Y_S^S}\right)^{\alpha-1}\frac{dY_N^S}{dt_N^S} = 0 \tag{B.18}$$

Substitution of (B.16), (B.17), and (4.3) into (B.18) yields the optimal tariff for the South:

$$(t_N^S)^* = \frac{1-\alpha}{\alpha}\left(1+\frac{Y_N^S}{Y_N^N}\right). \tag{B.19}$$

Intermediate steps from B.18 to B.19 are analogous to the steps from (4.24) to (4.25) in the derivation of North's optimal tariff.

## System of equations that determines the three-country Nash equilibrium with tariffs:

For each country $i \in \{E, S, N\}$, we have two optimal tariffs,

$$(t_{i'}^i)^* = \frac{1-\alpha}{\alpha}\left(1+\frac{Y_{i'}^i}{Y_{i'}^{i'}}\right) \tag{B.20}$$

and

$$(t^i_{i''})^* = \frac{1-\alpha}{\alpha}\left(1 + \frac{Y^i_{i''}}{Y^{i''}_{i''}}\right). \tag{B.21}$$

Together with the three $Y^i_i$'s from (B.9) and the six $Y^i_{i'}$'s from (B.10), we have a system of fifteen equations that uniquely determines the nine consumption quantities and the six optimal tariffs. Consumption quantities and optimal tariffs determine the three relative consumer prices via (B.11). Substitution of $Y^i_i$, $Y^i_{i'}$ and $Y^i_{i''}$ into (3.1) yields utility of a representative consumer from country $i$.

## Derivation of the equilibrium relative capital stock (5.4):

Substitution of $Y^S = (\gamma^S/A^S)(L^S)^\beta(K^S)^{1-\beta}$ and $Y^N = (\gamma^N/A^N)(L^N)^\beta(K^N)^{1-\beta}$ into (5.3) yields

$$\frac{P^N}{P^S} = \left(\frac{\gamma^S}{\gamma^N}\right)^{1-\alpha}\left(\frac{A^N}{A^S}\right)^{1-\alpha}\left(\frac{L^S}{L^N}\right)^{\beta-\alpha\beta}\left(\frac{K^S}{K^N}\right)^{1-\beta-\alpha+\alpha\beta}.$$

Equating this with (5.2) yields

$$\frac{\gamma^S}{\gamma^N}\left(\frac{L^S}{L^N}\right)^{\beta}\left(\frac{K^S}{K^N}\right)^{-\beta} = \left(\frac{\gamma^S}{\gamma^N}\right)^{1-\alpha}\left(\frac{A^N}{A^S}\right)^{1-\alpha}\left(\frac{L^S}{L^N}\right)^{\beta-\alpha\beta}\left(\frac{K^S}{K^N}\right)^{1-\beta-\alpha+\alpha\beta}.$$

Collecting $K^N/K^S$ on the left-hand side and all other terms on the right-hand side gives us

$$\left(\frac{K^N}{K^S}\right)^{1-\alpha+\alpha\beta} = \left(\frac{\gamma^N}{\gamma^S}\right)^{\alpha}\left(\frac{A^N}{A^S}\right)^{1-\alpha}\left(\frac{L^N}{L^S}\right)^{\alpha\beta}.$$

By raising both sides to $1/(1-\alpha+\alpha\beta)$ we obtain

$$\frac{K^N}{K^S} = \left(\frac{\gamma^N}{\gamma^S}\right)^{\frac{\alpha}{1-\alpha+\alpha\beta}}\left(\frac{L^N}{L^S}\right)^{\frac{\alpha\beta}{1-\alpha+\alpha\beta}}\left(\frac{A^N}{A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}.$$

## Derivation of the equilibrium terms of trade (5.5):

Inserting (5.4) into (5.2) yields

$$\frac{P^N}{P^S} = \frac{\gamma^S}{\gamma^N}\left(\frac{L^S}{L^N}\right)^{\frac{(1-\alpha+\alpha\beta)\beta}{1-\alpha+\alpha\beta}}\left(\frac{\gamma^S}{\gamma^N}\right)^{\frac{-\alpha\beta}{1-\alpha+\alpha\beta}}\left(\frac{L^S}{L^N}\right)^{\frac{-\alpha\beta^2}{1-\alpha+\alpha\beta}}\left(\frac{A^N}{A^S}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}.$$

Simplifying gives us

$$\frac{P^N}{P^S} = \left(\frac{\gamma^S}{\gamma^N}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}}\left(\frac{L^S}{L^N}\frac{A^N}{A^S}\right)^{\frac{(1-\alpha)\beta}{1-\alpha+\alpha\beta}}.$$

## Derivation of the equilibrium relative wage (5.6):

Using (5.4) in $w^N/w^S = (K^N/K^S)(L^S/L^N)$ and rearranging the exponents yields

$$\frac{w^N}{w^S} = \left(\frac{L^S}{L^N}\right)^{\frac{1-\alpha+\alpha\beta}{1-\alpha+\alpha\beta}} \left(\frac{L^S}{L^N}\right)^{\frac{-\alpha\beta}{1-\alpha+\alpha\beta}} \left(\frac{\gamma^N}{\gamma^S}\right)^{\frac{\alpha}{1-\alpha+\alpha\beta}} \left(\frac{A^N}{A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}} .$$

Simplifying gives us

$$\frac{w^N}{w^S} = \left(\frac{\gamma^N}{\gamma^S}\right)^{\frac{\alpha}{1-\alpha+\alpha\beta}} \left(\frac{L^S}{L^N}\frac{A^N}{A^S}\right)^{\frac{1-\alpha}{1-\alpha+\alpha\beta}} .$$

# C. Numerical Appendix

### Notes on finding numerical examples of *pains from trade* for South:

Pains from trade for the South, i.e., $U^S_{ESN} < U^S_{SN}$, arise if $\bar{A}^N$ is sufficiently large or if the terms of trade with East, $[(w^S a^S)/(w^E a^E)]_{ESN}$, are sufficiently close to unity. Thus, numerical Example 1 is not exceptional, as any other example with $\bar{A}^N > 110$, while holding all other parameters constant, yields pains from trade for South. The larger $\bar{A}^N$ the stronger the pains. Analogously, holding $\bar{A}^N$ constant any other example with $1 < [(w^S a^S)/(w^E a^E)]_{ESN} < 1.23$ also yields pains from trade for South. From (3.13), such examples can be constructed by raising $L^S$, $\bar{A}^E$, or $a^S$ c.p., or by reducing $L^E$, $\bar{A}^S$, or $a^E$ c.p.

### Additional example for no full compensation of South ($\mathbf{V^S < \bar{U}^S_{SN}}$):

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 9 | 15 | 110 | 200 | 100 | 500 | 1 | 1 | 1 |

$\bar{U}^i$, the ensuing social welfare levels before transfers:

| $\bar{U}^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 2,839 | 11,334 | 1,800 | 12,085 |
| South | 1,639 | 1,500 | 9,941 | 6,978 |
| North | 55,000 | 60,034 | 55,941 | 62,085 |
| Within FTA | 4,478 | 71,368 | 65,882 | 81,148 |

South suffers from a reduction in welfare after Easts's entry: $\bar{U}^S_{ESN} = 6{,}978 < 9{,}941 = \bar{U}^S_{SN}$. Global welfare in $ESN$ is 81,148. This can arbitrarily be distributed among the countries using transfer payments. Condition (3.16) requires $V^E + V^S + V^N = 81{,}148$. Condition (3.21) requires $V^E + V^N \geq 71{,}368 \bar{U}^E_{EN} + \bar{U}^N_{EN}$, so that East and North are at least indifferent between $ESN$ and $EN$. This leaves scope for transfers to South in the amount of $V^S = 81{,}148 - 71{,}368 = 9{,}780$. This is smaller than $9{,}941 = \bar{U}^S_{SN}$, South's social welfare before East's entry. Hence, South cannot be fully compensated.

## Notes on finding numerical examples of the *exclusion* of South:

Exclusion of the South ($EN$ in the core) arises if the following conditions hold simultaneously:

(i) $U^i_{aut} < U^i_{EN}$ for all $i \in \{E, N\}$
(ii) $U^i_{SN} < U^i_{EN}$ for one $i \in \{S, N\}$
(iii) $U^i_{ES} < U^i_{EN}$ for one $i \in \{E, S\}$
(iv) $U^i_{ESN} < U^i_{EN}$ for one $i \in \{E, S, N\}$

Consider first the case of **prohibitive tariffs** (free trade or no trade at all). Condition (i) is always fulfilled for $i = E, N$ due to gains from trade. For the same reason, conditions (ii) and (iii) are never fulfilled for $i = S$. For $i = N$, validity of condition (ii) immediately follows from validity of condition (iv). Hence, the problem boils down to finding parameter values such that two crucial conditions are fulfilled: $U^N_{ESN} < U^N_{EN}$ and $U^E_{ES} < U^E_{EN}$. The former is fulfilled exactly if inequality (3.26) holds, i.e., if the North's reduction in welfare from losing cheap access to varieties from South is more than compensated by the welfare gain from better terms of trade with the East. This is the case if parameter values are such that $[(w^N a^N)/(w^S a^S)]_{SN}$ is close enough to unity, i.e., varieties from South are only marginally cheaper than domestic ones, and $\bar{A}^S - \bar{A}^E$ is sufficiently large, i.e., producing these varieties domestically after switching from $ESN$ to $EN$ raises the terms of trade with East considerably. Three additional examples of the exclusion of South with prohibitive tariffs are the following:

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 40 | 66 | 100 | 400 | 200 | 100 | 1 | 1 | 1 |

Condition (3.13) is fulfilled: From (3.12), $[(w^S a^S)/(w^N a^N)]_{SN} = 0.99$ and $[(w^E a^E)/(w^S a^S)]_{SN} = 0.88$. The ensuing individual utility levels are:

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 62.84 | 64.50 | 40 | 81.24 |
| South | 71.61 | 66 | 99.50 | 92.63 |
| North | 100 | 157.98 | 100.99 | 149.80 |

$EN$ is in the core:

$$U^N_{ESN} = 149.80 < 157.98 = U^N_{EN}$$
$$U^E_{ES} = 62.84 < 64.50 = U^E_{EN}.$$

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| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 30 | 59 | 100 | 300 | 150 | 100 | 1 | 1 | 1 |

Condition (3.13) is fulfilled: From (3.12), $[(w^S a^S)/(w^N a^N)]_{SN} = 0.98$ and $[(w^E a^E)/(w^S a^S)]_{SN} = 0.72$. The ensuing individual utility levels are:

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 50.86 | 56.56 | 30 | 71.11 |
| South | 70.71 | 59 | 99.16 | 98.87 |
| North | 100 | 149.37 | 101.24 | 143.98 |

$EN$ is in the core:

$$U^N_{ESN} = 143.98 < 149.37 = U^N_{EN}$$
$$U^E_{ES} = 50.86 < 56.56 = U^E_{EN}.$$

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| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 15 | 54 | 110 | 200 | 100 | 100 | 1 | 1 | 1 |

Condition (3.13) is fulfilled: From (3.12), $[(w^S a^S)/(w^N a^N)]_{SN} = 0.98$ and $[(w^E a^E)/(w^S a^S)]_{ESN} = 0.78$. The ensuing individual utility levels are:

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 32.10 | 41.96 | 15 | 52.60 |
| South | 73.21 | 54 | 108.99 | 119.94 |
| North | 110 | 148.39 | 110.99 | 143.72 |

$EN$ is in the core:

$$U^N_{ESN} = 143.721 < 148.385 = U^N_{EN}$$
$$U^E_{ES} = 32.103 < 41.693 = U^E_{EN}.$$

South would gain from East's entry in this example: $U^S_{SN} = 108.991 < 119.939 = U^S_{ESN}$.

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If we allow for **non-prohibitive tariffs**, the reasoning is different. There are three instead of two crucial conditions: $U^N_{ESN} < U^N_{EN}$ and $U^E_{ES} < U^E_{EN}$, as before, plus $U^N_{SN} < U^N_{EN}$. With non-prohibitive tariffs, the latter inequality does not immediately follow from $U^N_{ESN} < U^N_{EN}$.

Before asking how parameter values must be set to fulfill these three conditions, it is worth noting that welfare effects of excluding a country are generally smaller than with prohibitive tariffs because with non-prohibitive tariffs exclusion means exclusion from *free* trade but not from any trade at all. Exclusion does not change the patterns of trade: East produces and exports $\bar{A}^E$, South produces and exports $\bar{A}^S - \bar{A}^E$, and North produces and exports $\bar{A}^N - \bar{A}^S$, regardless of which country is excluded. Welfare changes from exclusion are therefore only due to changes in consumed quantities of an unchanged mass of varieties. This means that country size matters, not only in terms of the number of produced varieties but also in terms of labor supply. Roughly speaking, a country is better off by forming a customs union with a relatively large country and imposing tariffs on imports from a relatively small country than by forming a customs union with a relatively small country and imposing tariffs on a relatively large country.

Analogous to the case with prohibitive tariffs, $[(1 + t^N_S)(w^S a^S)/(w^N a^N)]_{EN}$ needs to be close enough to unity. Contrary to the case with prohibitive tariffs, $\bar{A}^S - \bar{A}^E$ as well as $L^S$ must be sufficiently small. This is the reason why with non-prohibitive tariffs we don't find cases in which exclusion of South from any trade at all is in the core. If parameter values are set accordingly, the three crucial conditions hold simultaneously: $U^N_{ESN} < U^N_{EN}$ and $U^N_{SN} < U^N_{EN}$ hold because trade diversion from a small South, which produces low quantities of a small mass of varieties at relatively high cost, to a big East is beneficial for North, and $U^E_{ES} < U^E_{EN}$ holds because trade diversion from a small South to a large North is beneficial for East. Examples other than 3 and 6 in the main text include the following where the tariff rate $t^i_{ii} = t^{ii}_i$ indicated is approximately the highest tariff that is non-prohibitive for external trade of both FTA members in all three two-country FTAs ($SN$, $EN$, and $ES$). $EN$ is in the core for all positive values of $t^i_{ii} = t^{ii}_i$ below the indicated value.

| $t$ | $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 25% | 0.5 | 35 | 54 | 110 | 400 | 100 | 100 | 1 | 1 | 1 |

The tariff rate of 25% is non-prohibitive in all two-country FTAs: $[(1 + t^N_S)(w^S a^S)/(w^N a^N)]_{EN} = 0.64$, $[(1 + t^S_E)(w^E a^E)/(w^S a^S)]_{EN} = 0.97$, $[(1 + t^S_E)(w^E a^E)/(w^S a^S)]_{SN} = 0.85$, and $[(1 + t^N_S)(w^S a^S)/(w^N a^N)]_{ES} = 0.78$. The ensuing individual utility levels are:

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 71.00 | 71.32 | 69.17 | 70.03 |
| South | 104.63 | 92.05 | 101.94 | 103.19 |
| North | 166.58 | 180.43 | 175.01 | 177.16 |

$EN$ is the singleton core:

$$U^N_{ESN} = 177.16 < 180.43 = U^N_{EN}$$
$$U^N_{SN} = 175.01 < 180.43 = U^N_{EN}$$
$$U^E_{ES} = 71.00 < 71.32 = U^E_{EN}$$

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| $t$ | $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 35% | 0.5 | 30 | 50 | 110 | 400 | 100 | 100 | 1 | 1 | 1 |

The tariff rate of 35% is non-prohibitive in all two-country FTAs: $[(1+t^N_S)(w^S a^S)/(w^N a^N)]_{EN} = 0.66$, $[(1+t^S_E)(w^E a^E)/(w^S a^S)]_{EN} = 0.97$, $[(1+t^S_E)(w^E a^E)/(w^S a^S)]_{SN} = 0.82$, and $[(1+t^N_S)(w^S a^S)/(w^N a^N)]_{ES} = 0.85$. The ensuing individual utility levels are:

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 64.16 | 64.81 | 61.62 | 63.46 |
| South | 104.77 | 89.31 | 102.09 | 103.63 |
| North | 166.02 | 183.32 | 176.82 | 179.49 |

$EN$ is the singleton core:

$$U^N_{ESN} = 179.49 < 183.32 = U^N_{EN}$$
$$U^N_{SN} = 176.82 < 183.32 = U^N_{EN}$$
$$U^E_{ES} = 64.16 < 64.81 = U^E_{EN}$$

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| $t$ | $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 40% | 0.5 | 20 | 35 | 110 | 400 | 100 | 200 | 1 | 1 | 1 |

The tariff rate of 40% is non-prohibitive in all two-country FTAs: $[(1+t^N_S)(w^S a^S)/(w^N a^N)]_{EN} = 0.72$, $[(1+t^S_E)(w^E a^E)/(w^S a^S)]_{EN} = 0.99$, $[(1+t^S_E)(w^E a^E)/(w^S a^S)]_{SN} = 0.74$, and $[(1+t^N_S)(w^S a^S)/(w^N a^N)]_{ES} = 0.82$. The ensuing individual utility levels are:

| $U^i$ | $ES$ | $EN$ | $SN$ | $ESN$ |
|---|---|---|---|---|
| East | 54.71 | 57.27 | 51.78 | 56.05 |
| South | 94.76 | 79.99 | 97.65 | 97.08 |
| North | 148.83 | 156.84 | 154.39 | 153.49 |

$EN$ is the singleton core:

$$U^N_{ESN} = 153.49 < 156.84 = U^N_{EN}$$
$$U^N_{SN} = 154.39 < 156.84 = U^N_{EN}$$
$$U^E_{ES} = 54.71 < 57.27 = U^E_{EN}$$

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## Example 6 individual utility with tariffs including hub-and-spoke trading systems:

| $t^{ii'}_{i''} = t^{i''}_{ii'}$ | 0 | 10% | 20% | 25% | 30% | 45% | 55% | 155% |
|---|---|---|---|---|---|---|---|---|
| $U^N_{SN}$ | 182.43 | 182.12 | 181.13 | 180.44 | 179.65 | 171.22 | 167.46 | **117.08** |
| $U^S_{SN}$ | 103.20 | 103.02 | 102.46 | 102.07 | 101.63 | **61.46** | **61.67** | **104.72** |
| $U^E_{SN}$ | 72.97 | 72.76 | 72.29 | 71.98 | 71.64 | 53.71 | 53.38 | 36 |
| $U^N_{EN}$ | 182.43 | 184.27 | 185.41 | 185.76 | 187.02 | 184.93 | 183.50 | **183.49** |
| $U^S_{EN}$ | 103.20 | 99.22 | 95.68 | 94.03 | 65.78 | 67.50 | 68.35 | 60 |
| $U^E_{EN}$ | 72.97 | 73.71 | 74.16 | 74.30 | **54.51** | **54.74** | **54.87** | **60.33** |
| $U^N_{ES}$ | 182.43 | 176.72 | 171.47 | 168.97 | 166.56 | 159.73 | 130.18 | 110 |
| $U^S_{ES}$ | 103.20 | 104.21 | 104.77 | 104.92 | 105.00 | 104.88 | **71.16** | **74.91** |
| $U^E_{ES}$ | 72.97 | 73.69 | 74.08 | 74.19 | 74.24 | 74.16 | 73.61 | **52.97** |

Figures in gray refer to the country excluded from the respective FTA. A country's utility level in bold implies that for this country the corresponding tariff rate is prohibitive for trade with the excluded country. The fact that in the final column all values (except the ones for the excluded country) are bold, implies that the applied tariff rate of 155% is overall prohibitive. There is no external trade.
A tariff rate of 55% is still prohibitive for South-East trade in $EN$ and $SN$. Consumer price of a Eastern good relative to a Southern good is greater than one. It costs a Southern consumer more to import the goods in $[0, \bar{A}^E]$ from East than purchasing them domestically: $[(1 + t^S_E)(w^E a^E)/(w^S a^S)]_{EN} = 1.33$ and $[(1 + t^S_E)(w^E a^E)/(w^S a^S)]_{SN} =$

1.09. Nonetheless, the 55% tariff rate is non-prohibitive for North-South and North-East trade in $EN$ and $SN$. Then again, it is still prohibitive for North-South trade in $ES$: $[(1+t_S^N)(w^S a^S)/(w^N a^N)]_{ES} = 1.03$. So, in either of the three trading systems a hub-and-spoke trading system emerges. One country is the hub, trading with both other countries. The two other countries (in bold or gray) are the spokes, not trading among each other. Hence, in the table's penultimate column, $SN$ denotes a customs union with no trade of South with outsider East, $EN$ denotes a customs union with no trade of East with outsider South, and $ES$ denotes a customs union with no trade of South with outsider North.

A tariff rate of 45% is still prohibitive for South-East trade in $EN$ and $SN$: $[(1+t_E^S)(w^E a^E)/(w^S a^S)]_{EN} = 1.21$ and $[(1+t_E^S)(w^E a^E)/(w^S a^S)]_{SN} = 1.02$. It is non-prohibitive for North-South trade in $ES$. So a hub-and-spoke trading system does not emerge in $ES$ anymore but only in $EN$ and $SN$. Thus, in the third last column of the table, $SN$ denotes a customs union with no trade of South with outsider East, $EN$ denotes a customs union with no trade of East with outsider South, and $ES$ denotes a customs union with trade between all countries.

A tariff rate of 30% is only prohibitive for trade between East and South in $EN$: $[(1+t_E^S)(w^E a^E)/(w^S a^S)]_{EN} = 1.04$. For all other trade relations in any of the three customs unions it is non-prohibitive.

Tariff rates of 25% and below are overall non-prohibitive in all trading systems.

## Additional example of pain from (two-way) capital drain:

**Example 2 (extd.):**

| $\alpha$ | $\beta$ | $\bar{K}_{SN}$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 0.5 | 100 | 5 | 11 | 100 | 100 | 100 | 800 | 1 | 1 | 1 |

The following table contrasts the equilibrium allocation of capital in $SN$ with the equilibrium allocation of capital in $ESN$ for different values of $K_{SN}^E$:

| $\bar{K}_{ESN}$ | $K_{SN}^E$ | $K_{ESN}^E$ | $K_{SN}^S$ | $K_{ESN}^S$ | $K_{SN}^N$ | $K_{ESN}^N$ |
|---|---|---|---|---|---|---|
| 102 | 2 | **6.47** | | 7.31 | | 88.22 |
| 103 | 3 | **6.53** | | 7.38 | | **89.09** |
| 107 | 7 | 6.79 | 11.04 | 7.66 | 88.96 | **92.55** |
| 150 | 50 | 9.52 | | 10.75 | | **129.74** |
| 155 | 55 | 9.83 | | **11.10** | | **134.06** |

From (5.12), North's terms of trade with South in $ESN$ are $(P^N/P^S)_{ESN} = 1.29$. South's terms of trade with East are $(P^S/P^E)_{ESN} = 1.06$. Since $P^i/P^{i'} = (w^i a^i / w^{i'} a^{i'})^\beta$ and $0 < \beta < 1$, the corresponding relative wages are higher. So it is ensured that in $ESN$, East is the low-wage country and South is the medium-wage country. If East enters contributing two additional units of internationally mobile capital ($\bar{K}_{ESN} = 102$) or less, there is a downstream flow of capital from North and South to East. With $3 \leq K^E_{SN} \leq 6$, there is a two-way capital drain away from South to East and North. As soon as $K^E_{SN} \geq 7$, East's capital-to-labor ratio is not sufficiently small anymore to attract capital from South and North. East is a net exporter of capital then. For a relatively wide range of East's initial capital stock, i.e., $7 \leq K^E_{SN} \leq 50$, capital moves one-way upstream from East and South to North. This is due to the fact that North has a relatively large labor force, and it produces a relatively large mass of goods. South is a net importer of capital only if the global capital stock is 155 or larger after East's entry.

# D. Social Welfare Maximization

Suppose countries which form an FTA agree, behind the Rawlsian 'veil of ignorance', on a social welfare functional that is a symmetric, increasing, and quasi-concave function of the individual utility levels $U_k$ as their common objective.

Consider first the case with international transfers. If the social welfare functional is strictly increasing in at least one argument, then maximization of social welfare implies global free trade. As noted above, maximization of global social welfare is consistent with arbitrary distributions of fractions of total production across consumers. If the social welfare functional is strictly quasi-concave, then it calls for an equal distribution of the outputs of all varieties across consumers, i.e., $\lambda_k = 1/(L^E + L^S + L^N)$. The same holds true for the Rawlsian maximin social welfare functional. Because of grand-coalition superadditivity, entry of the East raises the sum of the individual utilities. Yet, if the same social welfare functional is maximized both before and after the entry of the East, then the expansion of the FTA reduces the incumbents' welfare.

Next, consider the formation of the equilibrium FTA in the absence of international transfers. The maximin principle potentially leads to the exclusion of the South from free trade then if one gives up condition (3.13). To see this, assume now

$$\frac{a^E}{L^E}\bar{A}^E > \frac{a^S}{L^S}(\bar{A}^S - \bar{A}^E), \tag{D.1}$$

whereas the inequality in (3.13) continues to hold for $(i, i') \in \{(E, N), (S, N)\}$. Under these conditions, if the East and the South are in an FTA (in $ES$ or $ESN$), unit cost equalizes (i.e., $w^E a^E = w^S a^S$) and the two countries produce fractions $(a^S L^E)/(a^S L^E + a^E L^S)$ and $(a^E L^S)/(a^S L^E + a^E L^S)$ of the varieties in $[0, \bar{A}^S]$, respectively. Let's further assume that $a^E > a^S$. Then, $w^S > w^E$ needs to hold, so that $w^E a^E = w^S a^S$. This implies that South is still the medium-wage country compared to East despite cost equalization. The South unequivocally prefers not to have the East in an FTA with the North: $U^S_{SN} > U^S_{ESN}$ (the calculations of the equilibrium utilities if (D.1) is satisfied are collected at the end of this appendix). This is because its terms of trade with the North deteriorate and, given cost equalization, it does not benefit from cheap imports from the East. Suppose the FTA is determined by the Rawlsian maximin criterion, i.e., from the set of trading systems the one with the highest level of utility for the least well-off country is chosen.

**Proposition D.1:** *Let (D.1) hold and $a^E > a^S$. If*

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^S < (\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E < \left(\frac{a^E}{a^S}\right)^{\frac{\alpha}{1-\alpha}} \bar{A}^S,$$

*then $EN$ is the maximin trading system.*

*Proof:* Autarky and $ES$ are not maximin because they are Pareto inferior to $ESN$. $SN$ is not maximin because East fares better with any other trading system. So maximin picks either $EN$ or $ESN$. The conditions of the proposition imply $U^E_{ESN} < U^E_{EN} < U^S_{EN}$. So the least well-off country's welfare is higher in $EN$ than in $ESN$. q.e.d.

The conditions of the proposition imply $U^E_{ESN} < U^E_{EN} < U^S_{EN}$. That is, the East is the poorest country and prefers not to have the South in an FTA with the North. The Rawlsian maximin criterion then selects the FTA $EN$ as the equilibrium trading system. As an example, let:

| $\alpha$ | $\bar{A}^E$ | $\bar{A}^S$ | $\bar{A}^N$ | $L^E$ | $L^S$ | $L^N$ | $a^E$ | $a^S$ | $a^N$ |
|---|---|---|---|---|---|---|---|---|---|
| 0.5 | 20 | 25 | 50 | 300 | 200 | 50 | 4 | 2 | 1 |

Condition (D.1) is satisfied: $0.27 > 0.05$. Relative cost terms are $[(w^E a^E)/(w^N a^N)]_{ESN} = 0.54$ and $[(w^E a^E)/(w^N a^N)]_{EN} = 0.67$. The condition of Proposition D.1 holds: $38.38 < 40 < 50$.

In the following, I list the comparisons of all equilibrium utilities among the two-country FTAs $SN$, $EN$ and $ES$, and global free trade $ESN$ if (D.1) is satisfied (cost equalization between East and South). Recall that different to the case with a cost *differential* between East and South, the number of varieties produced by East and South in $ES$ and $ESN$ are not $A^E = \bar{A}^E$ and $A^S = \bar{A}^S - \bar{A}^E$ but $A^E = [(a^S L^E)/(a^S L^E + a^E L^S)]\bar{A}^S$ and $A^S = [(a^E L^S)/(a^S L^E + a^E L^S)]\bar{A}^S$, respectively. The number of varieties produced by North remains $A^N = \bar{A}^N - \bar{A}^S$ in $SN$ and $ESN$, and $A^N = \bar{A}^N - \bar{A}^E$ in $EN$.

**Comparison of $ESN$ and $SN$:**

**$\mathbf{U^S_{ESN}}$ vs. $\mathbf{U^S_{SN}}$:**
From (3.14), $U^S_{ESN} < U^S_{SN}$ if

$$\frac{1}{a^S}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^S + A^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} < \frac{1}{a^S}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^S\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^S a^S)/(w^E a^E)]_{ESN} = 1$ and $A^S + A^E = \bar{A}^S$, simplifying and rearranging terms yields

$$(\bar{A}^N - \bar{A}^S)\left[\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} - \left(\frac{w^S a^S}{w^N a^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}}\right] < 0.$$

The inequality holds. South's terms of trade with North are lower in $ESN$ than in $SN$. Thus, the left-hand side is negative.

**$\mathbf{U^N_{ESN}}$ vs. $\mathbf{U^N_{SN}}$:**
From (3.14), $U^N_{ESN} > U^N_{SN}$ exactly if

$$\frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^S) + A^S\left(\frac{w^N a^N}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^E\left(\frac{w^N a^N}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^S) + \bar{A}^S\left(\frac{w^N a^N}{w^S a^S}\right)_{SN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^N a^N)/(w^S a^S)]_{ESN} = [(w^N a^N)/(w^E a^E)]_{ESN}$ and $A^S + A^E = \bar{A}^S$, simplifying yields

$$\left(\frac{w^N a^N}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > \left(\frac{w^N a^N}{w^S a^S}\right)_{SN}^{\frac{\alpha}{1-\alpha}}.$$

The validity of this inequality follows from the fact that North's terms of trade with South are higher in $ESN$ than in $SN$.

**Comparison of $ESN$ and $ES$:**

**$\mathbf{U^E_{ESN}}$ vs. $\mathbf{U^E_{ES}}$:**
From (3.14), $U^E_{ESN} > U^E_{ES}$ exactly if

$$\frac{1}{a^E}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^S\left(\frac{w^E a^E}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^E\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^E}\left[A^S\left(\frac{w^E a^E}{w^S a^S}\right)_{ES}^{\frac{\alpha}{1-\alpha}} + A^E\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^E a^E)/(w^S a^S)]_{ESN} = [(w^E a^E)/(w^S a^S)]_{ES} = 1$, simplifying yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > 0$$

The inequality holds because from $\bar{A}^N > \bar{A}^S$ and terms of trade being positive, the left-hand side is positive. The economic intuition is that the terms of trade for varieties in $[0, \bar{A}^S]$ are the same for East in $ESN$ and in $ES$. $U^E_{ESN} > U^E_{ES}$ thus follows from revealed preference.

**$\mathbf{U^S_{ESN}}$ vs. $\mathbf{U^S_{ES}}$:**
From (3.14), $U^S_{ESN} > U^S_{ES}$ exactly if

$$\frac{1}{a^S}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^S + A^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^S}\left[A^S + A^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ES}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^S a^S)/(w^E a^E)]_{ESN} = [(w^S a^S)/(w^E a^E)]_{ES} = 1$, simplifying yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} > 0.$$

The inequality holds because from $\bar{A}^N > \bar{A}^S$ and terms of trade being positive, the left-hand side is positive. The economic intuition is the same as for East: $U^S_{ESN} > U^S_{ES}$ follows from revealed preference because South can buy varieties in $[0, \bar{A}^S]$ in $ESN$ at the same terms of trade as in $ES$.

**Comparison of $ESN$ and $EN$:**

**$\mathbf{U^E_{ESN}}$ vs. $\mathbf{U^E_{EN}}$:**
From (3.14), $U^E_{ESN} < U^E_{EN}$ exactly if

$$\frac{1}{a^E}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^S\left(\frac{w^E a^E}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^E\right]^{\frac{1-\alpha}{\alpha}} < \frac{1}{a^E}\left[(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^N a^N)/(w^S a^S)]_{ESN} = [(w^N a^N)/(w^E a^E)]_{ESN}$ and $A^S + A^E = \bar{A}^S$, simplifying yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^E a^E}{w^N a^N}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^S < (\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E.$$

This is the first inequality in the formula in Proposition D.1.

$\mathbf{U^N_{ESN}}$ **vs.** $\mathbf{U^N_{EN}}$**:**
From (3.14), $U^N_{ESN} > U^N_{EN}$ exactly if

$$\frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^S) + A^S\left(\frac{w^N a^N}{w^S a^S}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} + A^E\left(\frac{w^N a^N}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^E) + \bar{A}^E\left(\frac{w^N a^N}{w^E a^E}\right)_{EN}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^N a^N)/(w^S a^S)]_{ESN} = [(w^N a^N)/(w^E a^E)]_{ESN}$ and $A^S + A^E = \bar{A}^S$, simplifying and rearranging terms yields

$$\bar{A}^S\left[\left(\frac{w^N a^N}{w^E a^E}\right)_{ESN}^{\frac{\alpha}{1-\alpha}} - 1\right] > \bar{A}^E\left[\left(\frac{w^N a^N}{w^E a^E}\right)_{EN}^{\frac{\alpha}{1-\alpha}} - 1\right].$$

**Comparison of** $EN$ **and** $ES$**:**

$\mathbf{U^E_{EN}}$ **vs.** $\mathbf{U^E_{ES}}$**:**
From (3.14), $U^E_{EN} > U^E_{ES}$ exactly if

$$\frac{1}{a^E}\left[(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^E\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^E}\left[A^S\left(\frac{w^E a^E}{w^S a^S}\right)_{ES}^{\frac{\alpha}{1-\alpha}} + A^E\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^E a^E)/(w^S a^S)]_{ES} = 1$ and $A^S + A^E = \bar{A}^S$, simplifying yields

$$(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)_{EN}^{\frac{\alpha}{1-\alpha}} > \bar{A}^S - \bar{A}^E.$$

**Comparison of** $SN$ **and** $ES$**:**

$\mathbf{U^S_{SN}}$ **vs.** $\mathbf{U^S_{ES}}$**:**
From (3.14), $U^S_{SN} > U^S_{ES}$ exactly if

$$\frac{1}{a^S}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}} + \bar{A}^S\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^S}\left[A^S + A^E\left(\frac{w^S a^S}{w^E a^E}\right)_{ES}^{\frac{\alpha}{1-\alpha}}\right]^{\frac{1-\alpha}{\alpha}}.$$

With $[(w^E a^E)/(w^S a^S)]_{ES} = 1$ and $A^S + A^E = \bar{A}^S$, simplifying yields

$$(\bar{A}^N - \bar{A}^S)\left(\frac{w^S a^S}{w^N a^N}\right)_{SN}^{\frac{\alpha}{1-\alpha}} > 0.$$

The inequality holds. From $\bar{A}^N > \bar{A}^S$ and terms of trade being positive, the left-hand side is positive.

**Comparison of $EN$ and $SN$:**

**$\mathbf{U^N_{EN}}$ vs. $\mathbf{U^N_{SN}}$:**
From (3.14), $U^N_{EN} > U^N_{SN}$ exactly if

$$\frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^E) + \bar{A}^E\left(\frac{w^N a^N}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN}\right]^{\frac{1-\alpha}{\alpha}} > \frac{1}{a^N}\left[(\bar{A}^N - \bar{A}^S)\left(\frac{w^N a^N}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}_{SN} + \bar{A}^S\right]^{\frac{1-\alpha}{\alpha}}.$$

Simplifying and rearranging terms on both sides yields

$$\bar{A}^E\left[\left(\frac{w^N a^N}{w^E a^E}\right)^{\frac{\alpha}{1-\alpha}}_{EN} - 1\right] > \bar{A}^S\left[\left(\frac{w^N a^N}{w^S a^S}\right)^{\frac{\alpha}{1-\alpha}}_{SN} - 1\right].$$

**Comparison of East's and South's utilities in $EN$:**

**$\mathbf{U^E_{EN}}$ vs. $\mathbf{U^S_{EN}}$:**
$U^E_{EN} < U^S_{EN}$ exactly if

$$\frac{1}{a^E}\left[\bar{A}^E + (\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{EN}\right]^{\frac{1-\alpha}{\alpha}} < \frac{1}{a^S}\left(\bar{A}^S\right)^{\frac{1-\alpha}{\alpha}}.$$

Simplifying and rearranging terms yields

$$(\bar{A}^N - \bar{A}^E)\left(\frac{w^E a^E}{w^N a^N}\right)^{\frac{\alpha}{1-\alpha}}_{EN} + \bar{A}^E < \left(\frac{a^E}{a^S}\right)^{\frac{\alpha}{1-\alpha}}\bar{A}^S.$$

This is the second inequality in the formula in Proposition D.1.

# E. Mathematica Code

This appendix contains the Mathematica Code used to numerically solve the models presented in the main text. Assigning names to systems of equations, variables, and parameters, follows certain rules:
The name of a system of equations denotes the trading systems for which the equilibrium values shall be derived. An uppercase letter in that name denotes a country that is a member of the corresponding FTA. Outsider countries are indicated by either a lowercase letter or omitting the letter at all. For example, $SN$ is the name of the system of equations that determines the equilibrium values of an FTA composed of South and North with no trade with outsider East. $EsN$ is the name of the system of equations that determines the equilibrium values of a customs union composed of East and North with a common non-prohibitive tariff imposed on imports from outsider South.
The first letter(s) of a variable's name denote(s) the variable's type, i.e., consumption quantity, utility, terms of trade, consumer price ratio, or capital stock. The following two lowercase letters denote the countries the variable refers to. The subsequent letters refer to the corresponding FTA. For example, $YnsESn$ is the quantity of a good produced in the South and consumed by an individual in the North, in a customs union composed of East and South with outsider North. $UnESn$ denotes a Northern consumer's utility in $ES$ with non-prohibitive external tariffs. Terms of trade are named *tot*, consumer price ratio is named *cpr*, the capital stock $K$, and the exogenous uniform tariff factor $T$ (the corresponding value of the tariff rate $t^i_{i'}$ is hence $T - 1$). For example, $totseeSN$ and $cprseeSN$ denote South's terms of trade and consumer price ratio with East in a customs union composed of South and North with outsider East.
The parameter values' names are self-explaining. Occasional exceptions from these rules are indicated in-text below.

**Setting parameter values:**

alpha = 0.5

an = 1

as = 1

ae = 1

Ln = 100

$Ls = 150$

$Le = 450$

$An = 110$

$As = 60$

$Ae = 36$

$T = 1.25$

### Determining equilibrium consumption quantities:

**SN** = Solve[{Yns==Ynn^((alpha − 1)/alpha) ∗ ((Ls/Ln) ∗ ((An − As)/As) ∗ Ysn)^(1/alpha),

Ysn == Yss^((alpha − 1)/alpha) ∗ ((Ln/Ls) ∗ (As/(An − As)) ∗ Yns)^(1/alpha),

Ln ∗ Ynn + Ls ∗ Ysn == Ln/(an ∗ (An − As)),

Ln ∗ Yns + Ls ∗ Yss == Ls/(as ∗ As)&&Ynn > 0&&Yns > 0&& *textYsn* > 0&&Yss > 0},

{Ynn, Yns, Ysn, Yss}, Reals]

YnnSN = Ynn/.SN[[1, 1]]

YnsSN = Yns/.SN[[1, 2]]

YsnSN = Ysn/.SN[[1, 3]]

YssSN = Yss/.SN[[1, 4]]

{{Ynn → 0.00854102, Yns → 0.0106763, Ysn → 0.00763932, Yss → 0.00954915}}

**EN** = Solve[{Yne==Ynn^((alpha − 1)/alpha) ∗ ((Le/Ln) ∗ ((An − Ae)/Ae) ∗ Yen)^(1/alpha),

Yen == Yee^((alpha − 1)/alpha) ∗ ((Ln/Le) ∗ (Ae/(An − Ae)) ∗ Yne)^(1/alpha),

Ln ∗ Ynn + Le ∗ Yen == Ln/(an ∗ (An − Ae)),

Ln ∗ Yne + Le ∗ Yee == Le/(ae ∗ Ae)&&Ynn > 0&&Yne > 0&&Yen > 0&&Yee > 0},

{Ynn, Yne, Yen, Yee}, Reals]

YnnEN = Ynn/.EN[[1, 1]]

YneEN = Yne/.EN[[1, 2]]

YenEN = Yen/.EN[[1, 3]]

YeeEN = Yee/.EN[[1, 4]]

{{Ynn → 0.0054499, Yne → 0.0504115, Yen → 0.00179191, Yee → 0.0165752}}

**ES** = Solve[{Yse==Yss^((alpha − 1)/alpha) ∗ ((Le/Ls) ∗ ((As − Ae)/Ae) ∗ Yes)^(1/alpha),

Yes == Yee^((alpha − 1)/alpha) ∗ ((Ls/Le) ∗ (Ae/(As − Ae)) ∗ Yse)^(1/alpha),

Ls ∗ Yss + Le ∗ Yes == Ls/(as ∗ (As − Ae)),

Ls ∗ Yse + Le ∗ Yee == Le/(ae ∗ Ae)&&Yss > 0&&Yse > 0&&Yes > 0&&Yee > 0}, {Yss, Yse, Yes, Yee}, Reals]

YssES = Yss/.ES[[1, 1]]

YseES = Yse/.ES[[1, 2]]

YesES = Yes/.ES[[1, 3]]

YeeES = Yee/.ES[[1, 4]]

{{Yss → 0.0133491, Yse → 0.0266981, Yes → 0.0094392, Yee → 0.0188784}}

**ESN** = Solve[{Yns==Ynn^((alpha − 1)/alpha) ∗ ((Ls/Ln) ∗ ((An − As)/(As − Ae)) ∗ Ysn)^(1/alpha),

Ysn == Yss^((alpha − 1)/alpha) ∗ ((Ln/Ls) ∗ ((As − Ae)/(An − As)) ∗ Yns)^(1/alpha),

Yne==Ynn^((alpha − 1)/alpha) ∗ ((Le/Ln) ∗ ((An − As)/Ae) ∗ Yen)^(1/alpha),

Yen == Yee^((alpha − 1)/alpha) ∗ ((Ln/Le) ∗ (Ae/(An − As)) ∗ Yne)^(1/alpha),

Yse==Yss^((alpha − 1)/alpha) ∗ ((Le/Ls) ∗ ((As − Ae)/Ae) ∗ Yes)^(1/alpha),

Yes == Yee^((alpha − 1)/alpha) ∗ ((Ls/Le) ∗ (Ae/(As − Ae)) ∗ Yse)^(1/alpha),

Ln ∗ Ynn + Ls ∗ Ysn + Le ∗ Yen == Ln/(an ∗ (An − As)),

Ln ∗ Yns + Ls ∗ Yss + Le ∗ Yes == Ls/(as ∗ (As − Ae)),

Ln ∗ Yne + Ls ∗ Yse + Le ∗ Yee == Le/(ae ∗ Ae)&&Ynn > 0&&Yns > 0&&Yne > 0&&Ysn > 0&&

Yss > 0&&Yse > 0&&Yen > 0&&Yes > 0&&Yee > 0},

{Ynn, Yns, Yne, Ysn, Yss, Yse, Yen, Yes, Yee}, Reals]

YnnESN = Ynn/.ESN[[1, 1]]

YnsESN = Yns/.ESN[[1, 2]]

YneESN = Yne/.ESN[[1, 3]]

YsnESN = Ysn/.ESN[[1, 4]]

YssESN = Yss/.ESN[[1, 5]]

YseESN = Yse/.ESN[[1, 6]]

YenESN = Yen/.ESN[[1, 7]]

YesESN = Yes/.ESN[[1, 8]]

YeeESN = Yee/.ESN[[1, 9]]

{{Ynn → 0.00548166, Yns → 0.0171302, Yne → 0.0342604, Ysn → 0.0031009, Yss → 0.0096903, Yse → 0.0193806, Yen → 0.00219267, Yes → 0.00685208, Yee → 0.0137042}}

**EsN** = Solve[{Yns==Ynn^((alpha − 1)/alpha) ∗ ((Ls/Ln) ∗ ((An − As)/(As − Ae)) ∗ Ysn ∗ *T*)^(1/alpha),

Ysn == Yss^((alpha − 1)/alpha) ∗ ((Ln/Ls) ∗ ((As − Ae)/(An − As)) ∗ Yns ∗ *T*)^(1/alpha),

Yne==Ynn^((alpha − 1)/alpha) ∗ ((Le/Ln) ∗ ((An − As)/Ae) ∗ Yen)^(1/alpha),

```
Yen == Yee^((alpha − 1)/alpha) ∗ ((Ln/Le) ∗ (Ae/(An − As)) ∗ Yne)^(1/alpha),
Yse==Yss^((alpha − 1)/alpha) ∗ ((Le/Ls) ∗ ((As − Ae)/Ae) ∗ Yes ∗ T)^(1/alpha),
Yes == Yee^((alpha − 1)/alpha) ∗ ((Ls/Le) ∗ (Ae/(As − Ae)) ∗ Yse ∗ T)^(1/alpha),
Ln ∗ Ynn + Ls ∗ Ysn + Le ∗ Yen == Ln/(an ∗ (An − As)),
Ln ∗ Yns + Ls ∗ Yss + Le ∗ Yes == Ls/(as ∗ (As − Ae)),
Ln ∗ Yne + Ls ∗ Yse + Le ∗ Yee == Le/(ae ∗ Ae)&&Ynn > 0&&Yns > 0&&Yne > 0&&Ysn > 0&&
Yss > 0&&Yse > 0&&Yen > 0&&Yes > 0&&Yee > 0},
{Ynn, Yns, Yne, Ysn, Yss, Yse, Yen, Yes, Yee}, Reals]

YnnEsN = Ynn/.EsN[[1, 1]]
YnsEsN = Yns/.EsN[[1, 2]]
YneEsN = Yne/.EsN[[1, 3]]
YsnEsN = Ysn/.EsN[[1, 4]]
YssEsN = Yss/.EsN[[1, 5]]
YseEsN = Yse/.EsN[[1, 6]]
YenEsN = Yen/.EsN[[1, 7]]
YesEsN = Yes/.EsN[[1, 8]]
YeeEsN = Yee/.EsN[[1, 9]]
```

{{Ynn → 0.00587263, Yns → 0.0146076, Yne → 0.036704, Ysn → 0.00237108, Yss → 0.0143991, Yse → 0.0148193, Yen → 0.00234905, Yes → 0.00584306, Yee → 0.0146816}}

```
eSN = Solve[{Yns==Ynn^((alpha − 1)/alpha) ∗ ((Ls/Ln) ∗ ((An − As)/(As − Ae)) ∗ Ysn)^(1/alpha),
Ysn == Yss^((alpha − 1)/alpha) ∗ ((Ln/Ls) ∗ ((As − Ae)/(An − As)) ∗ Yns)^(1/alpha),
Yne==Ynn^((alpha − 1)/alpha) ∗ ((Le/Ln) ∗ ((An − As)/Ae) ∗ Yen ∗ T)^(1/alpha),
Yen == Yee^((alpha − 1)/alpha) ∗ ((Ln/Le) ∗ (Ae/(An − As)) ∗ Yne ∗ T)^(1/alpha),
Yse==Yss^((alpha − 1)/alpha) ∗ ((Le/Ls) ∗ ((As − Ae)/Ae) ∗ Yes ∗ T)^(1/alpha),
Yes == Yee^((alpha − 1)/alpha) ∗ ((Ls/Le) ∗ (Ae/(As − Ae)) ∗ Yse ∗ T)^(1/alpha),
Ln ∗ Ynn + Ls ∗ Ysn + Le ∗ Yen == Ln/(an ∗ (An − As)),
Ln ∗ Yns + Ls ∗ Yss + Le ∗ Yes == Ls/(as ∗ (As − Ae)),
Ln ∗ Yne + Ls ∗ Yse + Le ∗ Yee == Le/(ae ∗ Ae)&&Ynn > 0&&Yns > 0&&Yne > 0&&Ysn > 0&&
Yss > 0&&Yse > 0&&Yen > 0&&Yes > 0&&Yee > 0},
{Ynn, Yns, Yne, Ysn, Yss, Yse, Yen, Yes, Yee}, Reals]

YnneSN = Ynn/.eSN[[1, 1]]
YnseSN = Yns/.eSN[[1, 2]]
```

YneeSN = Yne/.eSN[[1, 3]]

YsneSN = Ysn/.eSN[[1, 4]]

YsseSN = Yss/.eSN[[1, 5]]

YseeSN = Yse/.eSN[[1, 6]]

YeneSN = Yen/.eSN[[1, 7]]

YeseSN = Yes/.eSN[[1, 8]]

YeeeSN = Yee/.eSN[[1, 9]]

{{Ynn → 0.00665876, Yns → 0.0208086, Yne → 0.0267756, Ysn → 0.00376676, Yss → 0.0117711, Yse → 0.0151465, Yen → 0.00170913, Yes → 0.00534104, Yee → 0.0167788}}

**ESn** = Solve[{Yns==Ynn^((alpha − 1)/alpha) * ((Ls/Ln) * ((An − As)/(As − Ae)) * Ysn * $T$)^(1/alpha),
Ysn == Yss^((alpha − 1)/alpha) * ((Ln/Ls) * ((As − Ae)/(An − As)) * Yns * $T$)^(1/alpha),
Yne==Ynn^((alpha − 1)/alpha) * ((Le/Ln) * ((An − As)/Ae) * Yen * $T$)^(1/alpha),
Yen == Yee^((alpha − 1)/alpha) * ((Ln/Le) * (Ae/(An − As)) * Yne * $T$)^(1/alpha),
Yse==Yss^((alpha − 1)/alpha) * ((Le/Ls) * ((As − Ae)/Ae) * Yes)^(1/alpha),
Yes == Yee^((alpha − 1)/alpha) * ((Ls/Le) * (Ae/(As − Ae)) * Yse)^(1/alpha),
Ln * Ynn + Ls * Ysn + Le * Yen == Ln/(an * (An − As)),
Ln * Yns + Ls * Yss + Le * Yes == Ls/(as * (As − Ae)),
Ln * Yne + Ls * Yse + Le * Yee == Le/(ae * Ae)&&Ynn > 0&&Yns > 0&&Yne > 0&&Ysn > 0&&
Yss > 0&&Yse > 0&&Yen > 0&&Yes > 0&&Yee > 0},
{Ynn, Yns, Yne, Ysn, Yss, Yse, Yen, Yes, Yee}, Reals]

YnnESn = Ynn/.ESn[[1, 1]]

YnsESn = Yns/.ESn[[1, 2]]

YneESn = Yne/.ESn[[1, 3]]

YsnESn = Ysn/.ESn[[1, 4]]

YssESn = Yss/.ESn[[1, 5]]

YseESn = Yse/.ESn[[1, 6]]

YenESn = Yen/.ESn[[1, 7]]

YesESn = Yes/.ESn[[1, 8]]

YeeESn = Yee/.ESn[[1, 9]]

{{Ynn → 0.0078519, Yns → 0.0130829, Yne → 0.0261658, Ysn → 0.00259465, Yss → 0.0105547, Yse → 0.0211095, Yen → 0.0018347, Yes → 0.00746333, Yee → 0.0149267}}

### Calculating individual direct (and indirect) utilities:

$UnAut = (1/an) * (An\verb|^|((1 - alpha)/alpha))$

110.

$UsAut = (1/as) * (As\verb|^|((1 - alpha)/alpha))$

60.

$UeAut = (1/ae) * (Ae\verb|^|((1 - alpha)/alpha))$

36.

$UnSN = ((An - As) * YnnSN\verb|^|alpha + As * YnsSN\verb|^|alpha)\verb|^|(1/alpha)$

117.082

$UsSN = ((An - As) * YsnSN\verb|^|alpha + As * YssSN\verb|^|alpha)\verb|^|(1/alpha)$

104.721

$UnEN = ((An - Ae) * YnnEN\verb|^|alpha + Ae * YneEN\verb|^|alpha)\verb|^|(1/alpha)$

183.49

$UeEN = ((An - Ae) * YenEN\verb|^|alpha + Ae * YeeEN\verb|^|alpha)\verb|^|(1/alpha)$

60.3311

$UsES = ((As - Ae) * YssES\verb|^|alpha + Ae * YseES\verb|^|alpha)\verb|^|(1/alpha)$

74.9117

$UeES = ((As - Ae) * YesES\verb|^|alpha + Ae * YeeES\verb|^|alpha)\verb|^|(1/alpha)$

52.9706

$UnESN = ((An - As) * YnnESN\verb|^|alpha + (As - Ae) * YnsESN\verb|^|alpha + Ae * YneESN\verb|^|alpha)\verb|^|(1/alpha)$

182.426

$UsESN = ((An - As) * YsnESN\verb|^|alpha + (As - Ae) * YssESN\verb|^|alpha + Ae * YseESN\verb|^|alpha)\verb|^|(1/alpha)$

103.196

$UeESN = ((An - As) * YenESN\verb|^|alpha + (As - Ae) * YesESN\verb|^|alpha + Ae * YeeESN\verb|^|alpha)\verb|^|(1/alpha)$

72.9706

$indUnSN = (1/an) * ((An - As) + As * ((Ls/Ln) * (an * (An - As)/(as * As)))\verb|^|alpha)\verb|^|((1 - alpha)/alpha)$

117.082

indUsSN = (1/as) ∗ ((An − As) ∗ ((Ln/Ls) ∗ (as ∗ As/(an ∗ (An − As))))^alpha + As)^((1 − alpha)/alpha)

104.721

indUnEN = (1/an) ∗ ((An − Ae) + Ae ∗ ((Le/Ln) ∗ (an ∗ (An − Ae)/(ae ∗ Ae)))^alpha)^((1 − alpha)/alpha)

183.49

indUeEN = (1/ae) ∗ ((An − Ae) ∗ ((Ln/Le) ∗ (ae ∗ Ae/(an ∗ (An − Ae))))^alpha + Ae)^((1 − alpha)/alpha)

60.3311

indUsES = (1/as) ∗ ((As − Ae) + Ae ∗ ((Le/Ls) ∗ (as ∗ (As − Ae)/(ae ∗ Ae)))^alpha)^((1 − alpha)/alpha)

74.9117

indUeES = (1/ae) ∗ ((As − Ae) ∗ ((Ls/Le) ∗ (ae ∗ Ae/(as ∗ (As − Ae))))^alpha + Ae)^((1 − alpha)/alpha)

52.9706

indUnESN =

(1/an)∗

((An − As) + (As − Ae) ∗ ((Ls/Ln) ∗ (an ∗ (An − As)/(as ∗ (As − Ae))))^alpha+

Ae ∗ ((Le/Ln) ∗ (an ∗ (An − As)/(ae ∗ Ae)))^alpha)^((1 − alpha)/alpha)

182.426

indUsESN =

(1/as)∗

((An − As) ∗ ((Ln/Ls) ∗ (as ∗ (As − Ae)/(an ∗ (An − As))))^alpha + (As − Ae)+

Ae ∗ ((Le/Ls) ∗ (as ∗ (As − Ae)/(ae ∗ Ae)))^alpha)^((1 − alpha)/alpha)

103.196

indUeESN =

(1/ae)∗

((An − As) ∗ ((Ln/Le) ∗ (ae ∗ Ae/(an ∗ (An − As))))^alpha+

(As − Ae) ∗ ((Ls/Le) ∗ (ae ∗ Ae/(as ∗ (As − Ae))))^alpha + Ae)^((1 − alpha)/alpha)

72.9706

UnEsN = ((An − As) ∗ YnnEsN^alpha + (As − Ae) ∗ YnsEsN^alpha + Ae ∗ YneEsN^alpha)^(1/alpha)

185.759

$UsEsN = ((An - As) * YsnEsN\hat{}alpha + (As - Ae) * YssEsN\hat{}alpha + Ae * YseEsN\hat{}alpha)\hat{}(1/alpha)$

94.0324

$UeEsN = ((An - As) * YenEsN\hat{}alpha + (As - Ae) * YesEsN\hat{}alpha + Ae * YeeEsN\hat{}alpha)\hat{}(1/alpha)$

74.3034

$UneSN = ((An - As) * YnneSN\hat{}alpha + (As - Ae) * YnseSN\hat{}alpha + Ae * YneeSN\hat{}alpha)\hat{}(1/alpha)$

180.442

$UseSN = ((An - As) * YsneSN\hat{}alpha + (As - Ae) * YsseSN\hat{}alpha + Ae * YseeSN\hat{}alpha)\hat{}(1/alpha)$

102.073

$UeeSN = ((An - As) * YeneSN\hat{}alpha + (As - Ae) * YeseSN\hat{}alpha + Ae * YeeeSN\hat{}alpha)\hat{}(1/alpha)$

71.9825

$UnESn = ((An - As) * YnnESn\hat{}alpha + (As - Ae) * YnsESn\hat{}alpha + Ae * YneESn\hat{}alpha)\hat{}(1/alpha)$

168.973

$UsESn = ((An - As) * YsnESn\hat{}alpha + (As - Ae) * YssESn\hat{}alpha + Ae * YseESn\hat{}alpha)\hat{}(1/alpha)$

104.92

$UeESn = ((An - As) * YenESn\hat{}alpha + (As - Ae) * YesESn\hat{}alpha + Ae * YeeESn\hat{}alpha)\hat{}(1/alpha)$

74.1895

## Calculating terms of trade and consumer price ratios:

$totnsSN = (YnnSN/YnsSN)\hat{}(alpha - 1)$

1.11803

$totnsESN = (YnnESN/YnsESN)\hat{}(alpha - 1)$

1.76777

$totneESN = (YnnESN/YneESN)\hat{}(alpha - 1)$

2.5

$totseESN = (YssESN/YseESN)\hat{}(alpha - 1)$

1.41421

$\text{totnsEsN} = T * (\text{YnnEsN}/\text{YnsEsN})\char`^(\text{alpha} - 1)$

1.97144

$\text{cprnsEsN} = \text{totnsEsN}/T$

1.57715

$\text{totneEsN} = (\text{YnnEsN}/\text{YneEsN})\char`^(\text{alpha} - 1)$

2.5

$\text{totseEsN} = T * (\text{YssEsN}/\text{YseEsN})\char`^(\text{alpha} - 1)$

1.26811

$\text{cprseEsN} = \text{totseEsN}/T$

1.01449

$\text{totneeSN} = T * (\text{YnneSN}/\text{YneeSN})\char`^(\text{alpha} - 1)$

2.50659

$\text{cprneeSN} = \text{totneeSN}/T$

2.00527

$\text{totnseSN} = (\text{YnneSN}/\text{YnseSN})\char`^(\text{alpha} - 1)$

1.76777

$\text{totseeSN} = T * (\text{YsseSN}/\text{YseeSN})\char`^(\text{alpha} - 1)$

1.41794

$\text{cprseeSN} = \text{totseeSN}/T$

1.13435

$\text{totneESn} = T * (\text{YnnESn}/\text{YneESn})\char`^(\text{alpha} - 1)$

2.28186

$\text{cprneESn} = \text{totneESn}/T$

1.82549

$\text{totnsESn} = T * (\text{YnnESn}/\text{YnsESn})\char`^(\text{alpha} - 1)$

1.61352

cprnsESn = totnsESn/$T$

1.29082

totseESn = (YssESn/YseESn)^(alpha − 1)

1.41421

### Determining the hub-and-spoke trade equilibrium with tariffs prohibitive (denoted $tp$) for trade between East and South in $EN$ ($tpeseSN = 1$) and $SN$ ($tpesEsN = 1$):

tpesEsN = 1

tpeseSN = 1.55

**eNs =**

Solve[

{Yns==Ynn^((alpha − 1)/alpha) * ((Ls/Ln) * ((An − As)/(As − Ae)) * Ysn * tpesEsN)^(1/alpha),

Ysn == Yss^((alpha − 1)/alpha) * ((Ln/Ls) * ((As − Ae)/(An − As)) * Yns * tpesEsN)^(1/alpha),

Yne==Ynn^((alpha − 1)/alpha) * ((Le/Ln) * ((An − As)/Ae) * Yen * tpeseSN)^(1/alpha),

Yen == Yee^((alpha − 1)/alpha) * ((Ln/Le) * (Ae/(An − As)) * Yne * tpeseSN)^(1/alpha),

Ln * Ynn + Ls * Ysn + Le * Yen == Ln/(an * (An − As)),

Ln * Yns + Ls * Yss == Ls/(as * As),

Ln * Yne + Le * Yee == Le/(ae * Ae)&&Ynn > 0&&Yns > 0&&Yne > 0&&Ysn > 0&&Yss > 0&&

Yen > 0&&Yee > 0},

{Ynn, Yns, Yne, Ysn, Yss, Yen, Yee}, Reals]

YnneNs = Ynn/.eNs[[1, 1]]

YnseNs = Yns/.eNs[[1, 2]]

YneeNs = Yne/.eNs[[1, 3]]

YsneNs = Ysn/.eNs[[1, 4]]

YsseNs = Yss/.eNs[[1, 5]]

YeneNs = Yen/.eNs[[1, 6]]

YeeeNs = Yee/.eNs[[1, 7]]

{{Ynn → 0.00825152, Yns → 0.0151482, Yne → 0.0228759, Ysn → 0.00357765, Yss → 0.00656787, Yen → 0.00141822, Yee → 0.0226942}}

totnseNs = tpesEsN * (YnneNs/YnseNs)^(alpha − 1)

1.35492

cprnseNs = totnseNs/tpesEsN

1.35492

totneeNs = tpeseSN * (YnneNs/YneeNs)^(alpha − 1)

2.5808

cprneeNs = totneeNs/tpeseSN

1.66503

UneNs = ((An − As) * YnneNs^alpha + (As − Ae) * YnseNs^alpha + Ae * YneeNs^alpha)^(1/alpha)

167.461

UseNs = ((An − As) * YsneNs^alpha + As * YsseNs^alpha)^(1/alpha)

61.673

UeeNs = ((An − As) * YeneNs^alpha + Ae * YeeeNs^alpha)^(1/alpha)

53.3809

### Determining the hub-and-spoke trade equilibrium with tariffs prohibitive (denoted $tp$) for trade between South and North $ES$:

tpsnESn = 1.55

**nEs** = Solve[{Yne==Ynn^((alpha − 1)/alpha) * ((Le/Ln) * ((An − As)/Ae) * Yen * tpsnESn)^(1/alpha),

Yen == Yee^((alpha − 1)/alpha) * ((Ln/Le) * (Ae/(An − As)) * Yne * tpsnESn)^(1/alpha),

Yse==Yss^((alpha − 1)/alpha) * ((Le/Ls) * ((As − Ae)/Ae) * Yes)^(1/alpha),

Yes == Yee^((alpha − 1)/alpha) * ((Ls/Le) * (Ae/(As − Ae)) * Yse)^(1/alpha),

Ln * Ynn + Le * Yen == Ln/(an * (An − Ae)),

Ls * Yss + Le * Yes == Ls/(as * (As − Ae)),

Ln * Yne + Ls * Yse + Le * Yee == Le/(ae * Ae)&&Ynn > 0&&Yne > 0&&Yss > 0&&Yse > 0&&

Yen > 0&&Yes > 0&&Yee > 0},

{Ynn, Yne, Yss, Yse, Yen, Yes, Yee}, Reals]

YnnnEs = Ynn/.nEs[[1, 1]]

YnenEs = Yne/.nEs[[1, 2]]

YssnEs = Yss/.nEs[[1, 3]]

YsenEs = Yse/.nEs[[1, 4]]

YennEs = Yen/.nEs[[1, 5]]

YesnEs = Yes/.nEs[[1, 6]]

YeenEs = Yee/.nEs[[1, 7]]

{{Ynn → 0.00798194, Yne → 0.0177659, Yss → 0.0140538, Yse → 0.0241127, Yen → 0.00122924, Yes → 0.00920429, Yee → 0.0157922}}

totnenEs = tpsnESn ∗ (YnnnEs/YnenEs)^(alpha − 1)

2.31245

cprnenEs = totnenEs/tpsnESn

1.4919

totesnEs = (YssnEs/YsenEs)^(alpha − 1)

1.30986

cpresnEs = totesnEs

1.30986

UnnEs = ((An − Ae) ∗ YnnnEs^alpha + Ae ∗ YnenEs^alpha)^(1/alpha)

130.181

UsnEs = ((As − Ae) ∗ YssnEs^alpha + Ae ∗ YsenEs^alpha)^(1/alpha)

71.1551

UenEs = ((An − As) ∗ YennEs^alpha + (As − Ae) ∗ YesnEs^alpha + Ae ∗ YeenEs^alpha)^(1/alpha)

73.6091

## Determining the equilibrium of $EN$ with non-prohibitive tariffs (denoted $xEsN$ here) as stated in the main text:

**xEsN** = Solve[{

Ln∗

(((An − As) + (As − Ae) ∗ ($T$/totns)^(−alpha/(1 − alpha))+

Ae ∗ (1/totne)^(−alpha/(1 − alpha)))^(1/alpha)

−(1/totns) ∗ ((An − As) + (As − Ae) ∗ ($T$/totns)^(−alpha/(1 − alpha))+

Ae ∗ (1/totne)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)

∗(($T$ − 1) ∗ (As − Ae) ∗ ((1/$T$) ∗ totns)^(1/(1 − alpha))+

0 ∗ Ae ∗ (1/totse) ∗ (totne)^(1/(1 − alpha))))^(−1)

$*(1/\mathrm{an})*$

$((\mathrm{An}-\mathrm{As})+(\mathrm{As}-\mathrm{Ae})*(T/\mathrm{totns})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$\mathrm{Ae}*(1/\mathrm{totne})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}((1-\mathrm{alpha})/\mathrm{alpha})$

$+\mathrm{Ls}*((1/T)/\mathrm{totns})\hat{}(1/(1-\mathrm{alpha}))*$

$(((\mathrm{As}-\mathrm{Ae})+(\mathrm{An}-\mathrm{As})*(T*\mathrm{totns})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$\mathrm{Ae}*(T/\mathrm{totse})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}(1/\mathrm{alpha})$

$-\mathrm{totns}*((\mathrm{As}-\mathrm{Ae})+(\mathrm{An}-\mathrm{As})*(T*\mathrm{totns})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$\mathrm{Ae}*(T/\mathrm{totse})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}((1-\mathrm{alpha})/\mathrm{alpha})$

$*((T-1)*(\mathrm{An}-\mathrm{As})((1/T)/\mathrm{totns})\hat{}(1/(1-\mathrm{alpha}))+$

$(T-1)*\mathrm{Ae}*(1/\mathrm{totne})*((1/T)*\mathrm{totse})\hat{}(1/(1-\mathrm{alpha}))))\hat{}(-1)$

$*(1/\mathrm{as})*$

$((\mathrm{As}-\mathrm{Ae})+(\mathrm{An}-\mathrm{As})*(T*\mathrm{totns})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$\mathrm{Ae}*(T/\mathrm{totse})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}((1-\mathrm{alpha})/\mathrm{alpha})$

$+\mathrm{Le}*(1/\mathrm{totne})\hat{}(1/(1-\mathrm{alpha}))*$

$((\mathrm{Ae}+(\mathrm{An}-\mathrm{As})*\mathrm{totne}\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+(\mathrm{As}-\mathrm{Ae})*(T*\mathrm{totse})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}$

$(1/\mathrm{alpha})$

$-\mathrm{totne}*(\mathrm{Ae}+(\mathrm{An}-\mathrm{As})*(\mathrm{totne})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$(\mathrm{As}-\mathrm{Ae})*(T*\mathrm{totse})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}((1-\mathrm{alpha})/\mathrm{alpha})$

$*(0*(\mathrm{An}-\mathrm{As})*(1/\mathrm{totne})\hat{}(1/(1-\mathrm{alpha}))+$

$(T-1)*(\mathrm{As}-\mathrm{Ae})*(1/\mathrm{totns})*((1/T)/\mathrm{totse})\hat{}(1/(1-\mathrm{alpha}))))\hat{}(-1)*$

$(1/\mathrm{ae})*$

$(\mathrm{Ae}+(\mathrm{An}-\mathrm{As})*\mathrm{totne}\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+(\mathrm{As}-\mathrm{Ae})*(T*\mathrm{totse})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}$

$((1-\mathrm{alpha})/\mathrm{alpha})$

$==\mathrm{Ln}/(\mathrm{an}*(\mathrm{An}-\mathrm{As})),$

$\mathrm{Ln}*(\mathrm{totns}/T)\hat{}(1/(1-\mathrm{alpha}))*$

$(((\mathrm{An}-\mathrm{As})+(\mathrm{As}-\mathrm{Ae})*(T/\mathrm{totns})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$\mathrm{Ae}*(1/\mathrm{totne})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}(1/\mathrm{alpha})$

$-(1/\mathrm{totns})*((\mathrm{An}-\mathrm{As})+(\mathrm{As}-\mathrm{Ae})*(T/\mathrm{totns})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha}))+$

$\mathrm{Ae}*(1/\mathrm{totne})\hat{}(-\mathrm{alpha}/(1-\mathrm{alpha})))\hat{}((1-\mathrm{alpha})/\mathrm{alpha})$

$*((T-1)*(\mathrm{As}-\mathrm{Ae})*((1/T)*\mathrm{totns})\hat{}(1/(1-\mathrm{alpha}))+$

$0*\mathrm{Ae}*(1/\mathrm{totse})*(\mathrm{totne})\hat{}(1/(1-\mathrm{alpha}))))\hat{}(-1)$

$*(1/\mathrm{an})*$

```
((An − As) + (As − Ae) ∗ (T/totns)^(−alpha/(1 − alpha))+
Ae ∗ (1/totne)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)

+
Ls∗
(((As − Ae) + (An − As) ∗ (T ∗ totns)^(−alpha/(1 − alpha))+
Ae ∗ (T/totse)^(−alpha/(1 − alpha)))^(1/alpha)
−totns ∗ ((As − Ae) + (An − As) ∗ (T ∗ totns)^(−alpha/(1 − alpha))+
Ae ∗ (T/totse)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)
∗((T − 1) ∗ (An − As)((1/T)/totns)^(1/(1 − alpha))+
(T − 1) ∗ Ae ∗ (1/totne) ∗ ((1/T) ∗ totse)^(1/(1 − alpha))))^(−1)
∗(1/as)
∗((As − Ae) + (An − As) ∗ (T ∗ totns)^(−alpha/(1 − alpha))+
Ae ∗ (T/totse)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)

+Le ∗ ((1/T)/totse)^(1/(1 − alpha))∗
((Ae + (As − Ae) ∗ (T ∗ totse)^(−alpha/(1 − alpha)) + (An − As) ∗ (totne)^(−alpha/(1 − alpha)))^
(1/alpha)
−totse ∗ (Ae + (As − Ae) ∗ (T ∗ totse)^(−alpha/(1 − alpha))+
(An − As) ∗ (totne)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)
∗((T − 1) ∗ (As − Ae) ∗ ((1/T)/totse)^(1/(1 − alpha))+
0 ∗ (An − As) ∗ totns ∗ (1/totne)^(1/(1 − alpha))))^(−1)
∗(1/ae)∗(Ae + (As − Ae) ∗ (T ∗ totse)^(−alpha/(1 − alpha)) + (An − As) ∗ totne^(−alpha/(1 − alpha)))^
((1 − alpha)/alpha)
== Ls/(as ∗ (As − Ae)),
totse==totne/totns&&totns > 0&&totne > 0&&totse > 0},
{totns, totne, totse}, Reals]

xtotnsEsN = totns/.xEsN[[1, 1]]
xtotneEsN = totne/.xEsN[[1, 2]]
xtotseEsN = totse/.xEsN[[1, 3]]

{{totns → 1.97144, totne → 2.5, totse → 1.26811}}

xYnnEsN =
(((An − As) + (As − Ae) ∗ (T/xtotnsEsN)^(−alpha/(1 − alpha))+
Ae ∗ (1/xtotneEsN)^(−alpha/(1 − alpha)))^(1/alpha)
```

$-(1/\text{xtotnsEsN})*$

$((\text{An}-\text{As})+(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}((1-\text{alpha})/\text{alpha})$

$*((T-1)*(\text{As}-\text{Ae})*((1/T)*\text{xtotnsEsN})\hat{}(1/(1-\text{alpha}))+$

$0*\text{Ae}*(1/\text{xtotseEsN})*\text{xtotneEsN}\hat{}(1/(1-\text{alpha}))))\hat{}(-1)*$

$(1/\text{an})*$

$((\text{An}-\text{As})+(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}((1-\text{alpha})/\text{alpha})$

0.00587263

$\text{xYnsEsN} =$

$(\text{xtotnsEsN}/T)\hat{}(1/(1-\text{alpha}))*$

$(((\text{An}-\text{As})+(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}(1/\text{alpha})$

$-(1/\text{xtotnsEsN})*$

$((\text{An}-\text{As})+(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}((1-\text{alpha})/\text{alpha})$

$*((T-1)*(\text{As}-\text{Ae})*((1/T)*\text{xtotnsEsN})\hat{}(1/(1-\text{alpha}))+$

$0*\text{Ae}*(1/\text{xtotseEsN})*\text{xtotneEsN}\hat{}(1/(1-\text{alpha}))))\hat{}(-1)*$

$(1/\text{an})*$

$((\text{An}-\text{As})+(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}((1-\text{alpha})/\text{alpha})$

0.0146076

$\text{xYneEsN} =$

$\text{xtotneEsN}\hat{}(1/(1-\text{alpha}))*$

$(((\text{An}-\text{As})+\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}(1/\text{alpha})$

$-(1/\text{xtotneEsN})*$

$((\text{An}-\text{As})+\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}((1-\text{alpha})/\text{alpha})*$

$(0*\text{Ae}*\text{xtotneEsN}\hat{}(1/(1-\text{alpha}))+(T-1)*(\text{As}-\text{Ae})*\text{xtotseEsN}*$

$((1/T)*\text{xtotnsEsN})\hat{}(1/(1-\text{alpha}))))\hat{}(-1)*$

$(1/\text{an})*$

$((\text{An}-\text{As})+(\text{As}-\text{Ae})*(T/\text{xtotnsEsN})\hat{}(-\text{alpha}/(1-\text{alpha}))+$

$\text{Ae}*(1/\text{xtotneEsN})\hat{}(-\text{alpha}/(1-\text{alpha})))\hat{}((1-\text{alpha})/\text{alpha})$

0.036704

$xYsnEsN =$

$((1/T)/xtotnsEsN)\hat{}(1/(1-alpha))*$

$(((As-Ae)+(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha))+$

$Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha)))\hat{}(1/alpha)$

$-$

$xtotnsEsN*$

$((As-Ae)+(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha))+$

$Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha)))\hat{}((1-alpha)/alpha)$

$*((T-1)*(An-As)((1/T)/xtotnsEsN)\hat{}(1/(1-alpha))+$

$(T-1)*Ae*(1/xtotneEsN)*((1/T)*xtotseEsN)\hat{}(1/(1-alpha))))\hat{}(-1)*$

$(1/as)*$

$((As-Ae)+(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha))+$

$Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha)))\hat{}((1-alpha)/alpha)$

0.00237108

$xYssEsN =$

$(((As-Ae)+(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha))+$

$Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha)))\hat{}(1/alpha)$

$-$

$xtotnsEsN*$

$((As-Ae)+(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha))+$

$Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha)))\hat{}((1-alpha)/alpha)$

$*((T-1)*(An-As)((1/T)/xtotnsEsN)\hat{}(1/(1-alpha))+$

$(T-1)*Ae*(1/xtotneEsN)*((1/T)*xtotseEsN)\hat{}(1/(1-alpha))))\hat{}(-1)*$

$(1/as)*$

$((As-Ae)+(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha))+$

$Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha)))\hat{}((1-alpha)/alpha)$

0.0143991

$xYseEsN = ((1/T)*xtotseEsN)\hat{}(1/(1-alpha))*$

$(((As-Ae)+Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha))+$

$(An-As)*(T*xtotnsEsN)\hat{}(-alpha/(1-alpha)))\hat{}(1/alpha)-$

$(1/xtotseEsN)*$

$((As-Ae)+Ae*(T/xtotseEsN)\hat{}(-alpha/(1-alpha))+$

(An − As) ∗ (T ∗ xtotnsEsN)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)∗
((T − 1) ∗ Ae ∗ ((1/T) ∗ xtotseEsN)^(1/(1 − alpha))+
(T − 1) ∗ (An − As) ∗ xtotneEsN ∗ ((1/T)/xtotnsEsN)^(1/(1 − alpha))))^(−1)∗
(1/an)∗
((As − Ae) + Ae ∗ (T/xtotseEsN)^(−alpha/(1 − alpha))+
(An − As) ∗ (T ∗ xtotnsEsN)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)

0.0148193

xYenEsN = (1/xtotneEsN)^(1/(1 − alpha))∗
((Ae + (An − As) ∗ xtotneEsN^(−alpha/(1 − alpha))+
(As − Ae) ∗ (T ∗ xtotseEsN)^(−alpha/(1 − alpha)))^(1/alpha)−
xtotneEsN∗
(Ae + (An − As) ∗ xtotneEsN^(−alpha/(1 − alpha))+
(As − Ae) ∗ (T ∗ xtotseEsN)^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)∗
(0 ∗ (An − As) ∗ (1/xtotneEsN)^(1/(1 − alpha))+
(T − 1) ∗ (As − Ae) ∗ (1/xtotnsEsN) ∗ ((1/T)/xtotseEsN)^(1/(1 − alpha))))^(−1)∗
(1/ae)∗
(Ae + (An − As) ∗ xtotneEsN^(−alpha/(1 − alpha)) + (As − Ae) ∗ (T ∗ xtotseEsN)^(−alpha/(1 − alpha)))^
((1 − alpha)/alpha)

0.00234905

xYesEsN = ((1/T)/xtotseEsN)^(1/(1 − alpha))∗
((Ae + (As − Ae) ∗ (T ∗ xtotseEsN)^(−alpha/(1 − alpha))+
(An − As) ∗ xtotneEsN^(−alpha/(1 − alpha)))^(1/alpha)−
xtotseEsN∗
(Ae + (As − Ae) ∗ (T ∗ xtotseEsN)^(−alpha/(1 − alpha))+
(An − As) ∗ xtotneEsN^(−alpha/(1 − alpha)))^((1 − alpha)/alpha)∗
((T − 1) ∗ (As − Ae) ∗ ((1/T)/xtotseEsN)^(1/(1 − alpha))+
0 ∗ (An − As) ∗ xtotnsEsN ∗ (1/xtotneEsN)^(1/(1 − alpha))))^(−1)∗
(1/ae)∗
(Ae + (As − Ae) ∗ (T ∗ xtotseEsN)^(−alpha/(1 − alpha)) + (An − As) ∗ xtotneEsN^(−alpha/(1 − alpha)))^
((1 − alpha)/alpha)

0.00584306

xYeeEsN = 1/(ae ∗ Ae) − (Ln/Le) ∗ xYneEsN − (Ls/Le) ∗ xYseEsN

0.0146816

xUnEsN = ((An − As) ∗ (xYnnEsN)^alpha + (As − Ae) ∗ (xYnsEsN)^alpha + Ae ∗ (xYneEsN)^alpha)^(1/alpha)

185.759

xUsEsN = ((An − As) ∗ (xYsnEsN)^alpha + (As − Ae) ∗ (xYssEsN)^alpha + Ae ∗ (xYseEsN)^alpha)^(1/alpha)

94.0324

xUeEsN = ((An − As) ∗ (xYenEsN)^alpha + (As − Ae) ∗ (xYesEsN)^alpha + Ae ∗ (xYeeEsN)^alpha)^(1/alpha)

74.3034

### Determining the equilibrium capital stocks and terms of trade in $SN$ and $ESN$ with international investment (denoted $iiSN$ and $iiESN$):

alpha = 0.5

beta = 0.5

an = 1

as = 1

ae = 1

Ln = 100

Ls = 200

Le = 400

An = 110

As = 70

Ae = 40

KSN = 100

KESN = 130

**iiSN** =

Solve[

{Kn/Ks == ((Ln ∗ as)/(Ls ∗ an))^((beta ∗ alpha)/(1 − alpha + alpha ∗ beta))∗

((An − As)/As)^((1 − alpha)/(1 − alpha + alpha ∗ beta)),

KSN == Ks + Kn},

{Ks, Kn}, Reals]

KsSN = Ks/.iiSN[[1, 1]]

KnSN = Kn/.iiSN[[1, 2]]

{{Ks → 64.66, Kn → 35.34}}

**iiESN** =

Solve[

{Kn/Ks == ((Ln * as)/(Ls * an))^((beta * alpha)/(1 − alpha + alpha * beta))*

((An − As)/(As − Ae))^((1 − alpha)/(1 − alpha + alpha * beta)),

Ks/Ke == ((Ls * ae)/(Le * as))^((beta * alpha)/(1 − alpha + alpha * beta))*

((As − Ae)/Ae)^((1 − alpha)/(1 − alpha + alpha * beta)),

KESN == Ke + Ks + Kn},

{Ke, Ks, Kn}, Reals]

KeESN = Ke/.iiESN[[1, 1]]

KsESN = Ks/.iiESN[[1, 2]]

KnESN = Kn/.iiESN[[1, 3]]

{{Ke → 56.8891, Ks → 37.2729, Kn → 35.8379}}

iitotnsSN = ((an * Ls * (An − As))/(as * Ln * As))^(((1 − alpha) * beta)/(1 − alpha + alpha * beta))

1.04552

iitotnsESN = ((an * Ls * (An − As))/(as * Ln * (As − Ae)))^

(((1 − alpha) * beta)/(1 − alpha + alpha * beta))

1.38672

iitotseESN = ((an * Ls * (As − Ae))/(as * Ln * Ae))^(((1 − alpha) * beta)/(1 − alpha + alpha * beta))

1.14471

### Determining the tariff Nash equilibrium in the two-country model:

alpha = 0.5

an = 1

as = 1

Ln = 100

Ls = 100

Le = 400

An = 120

As = 10

**SNT** = Solve[{tns == (1/alpha) + ((1 − alpha)/alpha) * (Yns/Yss),

tsn == (1/alpha) + ((1 − alpha)/alpha) * (Ysn/Ynn),

Yns==Ynn^((alpha − 1)/alpha) * ((Ls/Ln) * ((An − As)/As) * Ysn * tns)^(1/alpha),

Ysn == Yss^((alpha − 1)/alpha) * ((Ln/Ls) * (As/(An − As)) * Yns * tsn)^(1/alpha), Ln ∗ Ynn + Ls ∗ Ysn == Ln/(an ∗ (An − As)),

Ln ∗ Yns + Ls ∗ Yss == Ls/(as ∗ As)&&Ynn > 0&&Yns > 0&&Ysn > 0&&Yss > 0&&tsn > 0&&tns > 0},

{Ynn, Yns, Ysn, Yss, tsn, tns}]

YnnSNT = Ynn/.SNT[[1, 1]]

YnsSNT = Yns/.SNT[[1, 2]]

YsnSNT = Ysn/.SNT[[1, 3]]

YssSNT = Yss/.SNT[[1, 4]]

Tsn = tsn/.SNT[[1, 5]]

Tns = tns/.SNT[[1, 6]]

{{Ynn → 0.0084779, Yns → 0.0338114, Ysn → 0.000613006, Yss → 0.0661886, tsn → 2.07231, tns → 2.51083}}

UnSN = (1/an) ∗ (As ∗ (an ∗ (An − As) ∗ Ls/(Ln ∗ as ∗ As))^alpha + (An − As))^((1 − alpha)/alpha)

143.166

UsSN = (1/as) ∗ ((An − As) ∗ (as ∗ As ∗ Ln/(Ls ∗ an ∗ (An − As)))^alpha + As)^((1 − alpha)/alpha)

43.1662

UnSNT = ((An − As) ∗ (YnnSNT)^alpha + As ∗ (YnsSNT)^alpha)^(1/alpha)

143.211

UsSNT = ((An − As) ∗ (YsnSNT)^alpha + As ∗ (YssSNT)^alpha)^(1/alpha)

28.0497

cprnSN = (Ls ∗ (An − As) ∗ an/(Ln ∗ As ∗ as))^(1 − alpha) ∗ (an/as)

3.31662

cprnSNT = (YnnSNT/YnsSNT)^(alpha − 1)

1.99704

cprsSNT = (YsnSNT/YssSNT)^(alpha − 1)

10.391

totnsSNT = cprnSNT ∗ Tsn

4.13848

### Plotting the graph in Figure 3.2:

alpha = 0.5

an = 1

as = 1

Ln = 100

Ls = 200

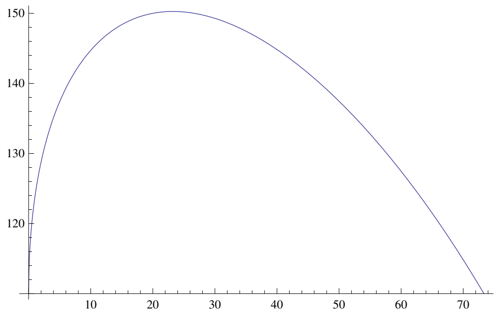
An = 110

```
F[As_]:=(1/an) * ((An − As) + As * (Ls * an * (An − As)/(Ln * as * As))^alpha)^((1 − alpha)/alpha)
```

```
G[As_]:=D[F[As], As]
Solve[{G[As]==0}, As]
```

```
{{As → 23.2457}}
```

```
Plot[F[As], {As, 0, 73.33}]
```



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