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University of Regensburg Working Papers in Business, Economics and Management Information Systems

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December 5, 2012

Nr. 470

JEL Classification: C32, E32

Keywords: unobserved component, trend, cycle, identification, subprime crisis

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Trend-Cycle Interactions and the Subprime Crisis: Analysis of US and Canadian Output

Max Soloschenko[*] Enzo Weber[†]

ABSTRACT

In the following paper a simultaneous unobserved components model is applied to US-American and Canadian output data in order to examine the causal structure of trend and cycle shocks and the way it changes over time. The main focus is placed on the analysis of the subprime crisis impact on the trend and cycle components. The structural model is identified by means of heteroscedasticity. During the subprime crisis for both countries we determine the strong increase of the structural trend variance compared to the previous period. This underlines the permanent effect and, thus, structural problems as a potential cause. Moreover, the both components are more volatile in the USA than in Canada. A further similarity between both countries is the complete disappearance of the structural cycle shock volatility.

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1 INTRODUCTION

The subprime crisis led to the most severe slump in the world economy since the Great Depression of the 1930s. On the empirical side, it would be of particular interest to ascertain which shocks led to a near worldwide economic collapse. This paper takes up Weber's (2011) structural framework, and augments and applies it to US-American and Canadian output data. The main focus lies on an examination of the trend and cycle components as well as their causal structure. For this purpose, the aggregate outputs of both countries are decomposed into cyclical and trend components and the interaction between their structural innovations is determined. Another important point constitutes the analysis of the course of the subprime crisis in both countries and its effect on the trend and cycle. By including Canada, it will be interesting to see whether the US results can be confirmed, given the country's traditionally strong economic integration with the USA. The following questions will be addressed: were the two components, trend and cycle, driven by permanent or transitory shocks, or indeed both? Do the same innovations in the USA and Canada influence trend and cycle? In addition, it will also be clarified whether the respective components are affected purely by their own shocks or if spillovers also play a significant role.

It will be shown that during the subprime crisis trend and cycle were driven in both countries by permanent shock alone, but that different explanations for this are required. Moreover, the strong negative correlation of output components for Canada and the USA will be confirmed. Furthermore, with regards to trend and cycle, the USA has a higher volatility than Canada.

The underlying paper makes use of the class of unobserved components (UC) models in its empirical analysis. In the first UC models, uncorrelated trend and cycle components were assumed (Harvey 1985, Clark 1987). In later developments, such as those by Balke and Wohar (2002) and Morley et al. (2003), this assumption was relaxed and subsequently extended by Weber (2011) in the framework of simultaneous unobserved components (simultUC) models, which capture the concurrent causality structure of trend and cycle shocks. These authors have established that it is possible to take into account the correlation between the permanent trend and transitory cycle innovations, while maintaining the identifiability of the structural model. In this paper the identification of the simultUC model is achieved through heteroscedasticity, i.e. the necessary information is taken from the differing variances of the structural shocks. Additionally, in the following paper, drift breaks will be introduced to the structural model in accordance with criticism levelled by Basistha (2007). Moreover, the existence and number of breaks will be endogenously determined and statistically verified.

In their influential work, Stock and Watson (1988) comment on the interconnection between trend and cycle as follows: „*Multivariate empirical analysis suggests that trend variations and business cycle movements appear to be related. One interpretation of this link is that business cycle fluctuations might be caused by innovations in growth. An alternative explanation – equally consistent with the empirical results – is that cyclical fluctuations cause changes in long run growth*." In the first case (that is, if causality goes from trend to cycle) RBC theory can be taken as a plausible explanation. This theory regards business cycles as a reaction to changes in the prospects for long-term economic growth (see Prescott 1987). The causal effect from cycle to trend cannot, however, be ruled out in any case. As an explanation, one can suggest e.g. an expansive fiscal policy, which leads to a positive demand effect in the short-run, but has a negative effect (because of the raising tax and interest rates) on the potential output in the long-run (see Clark 1987). Furthermore, the simultUC model makes it possible to distinguish empirically between the respective components as well as causality directions. As will be shown later, the impact direction can change with time or even run in both directions.

This paper is organised as follows: The second section presents the model specifications and deals with the identification problem. Section three then applies the theoretical framework to the industrial production (IP) of the selected countries, interprets the results and examines robustness. Lastly, a short overview of the key findings is provided.

2 THEORETICAL PART

2.1 MODEL SPECIFICATION

The starting point is a simultUC model, Weber (2011), which represents the seasonally adjusted log output y_t as the sum of a stochastic trend τ_t and a cyclical component c_t:

(1) $$y_t = \tau_t + c_t \, .$$

The individual components can be represented as follows:

$$(2) \qquad \tau_t = \tau_{t-1} + \mu + \sum\nolimits_{q=1}^{Q} \mu^q D_t^q + \overbrace{k_{11}\tilde{\eta}_t + k_{12}\tilde{\varepsilon}_t}^{\eta_t} , \qquad \eta_t \sim N(0, \sigma_\eta^2),$$

$$(3) \qquad c_t = b_1 c_{t-1} + ... + b_p c_{t-p} + \underbrace{k_{21}\tilde{\eta}_t + k_{22}\tilde{\varepsilon}_t}_{\varepsilon_t} , \qquad \varepsilon_t \sim N(0, \sigma_\varepsilon^2).$$

Thus, the trend is a random walk with drift and the cycle is an AR(p) process. The latter can be regarded as a stationary transitory deviation from the stochastic trend. Hereafter, the term "cycle" will be used as a synonym for the transitory part of the output fluctuations. The drift term μ represents the steady-state growth rate of the economy. Moreover, we introduce the possibility of a (or if need be several) drift break(s) (see Perron and Wada 2005). For this purpose, a dummy variable, D_t^q, is employed, being equal to one after the break in time T and zero before. Q denotes the number of drift breaks. For the empirical analysis, the potential break date is determined endogenously.

The decomposition of the composite shocks (η_t and ε_t) in equations (2) and (3) was first introduced by Weber (2011) and facilitates capturing the causality structure between the two components. Thus, $\tilde{\eta}_t$ and $\tilde{\varepsilon}_t$ denote structurally uncorrelated trend and cycle shocks (henceforth: structural shocks). Accordingly, trend and cycle innovations (η_t and ε_t) and, thus, trend and cycle can be hit by trend- as well as cycle-specific shocks. The parameters k_{12} and k_{21} are spillover coefficients, which describe the simultaneous interaction between the two unobserved components, τ_t and c_t. The simultaneous system is normalised by $E(\tilde{\eta}_t^2) = 1$ and $E(\tilde{\varepsilon}_t^2) = 1$, as well as $k_{11} \geq 0$ and $k_{22} \geq 0$.

2.2 REDUCED-FORM AND IDENTIFICATION

In order to verify the identification of the simultUC model, the reduced-form must be deduced. Those is calculated by substituting the equations (2) and (3) into equation (1) and solving for the endogenous variable. Thus, an autoregressive integrated moving average (ARIMA(p,d,q)) process is obtained. The ARIMA representation in the conventional form and notation takes the following form:

$$(4) \qquad B(L)\Delta y_t = c + \sum\nolimits_{q=1}^{Q} c^q D_t^q + A(L)u_t , \qquad u_t \sim N(0, \sigma_u^2),$$

where u_t consists of both structural shocks. $A(L)$ is a p-dimensional lag polynomial. Its coefficients a_i, where $i = 1,\dots,p$, as well as its variance σ_u^2 can be calculated from the theoretical autocovariance equations. The AR-coefficients from the cycle equation, b_i, $i = 1,\dots,p$, are directly identified by the autoregressive parameters from (4). Furthermore, the MA part delivers exactly $p+1$ nonzero autocovariances $\gamma(0),\dots,\gamma(p)$. The necessary condition for identification is fulfilled when the number of unknown parameters from the structural form is equal to the number of equations in the system.

If we take AR(2) as an example, the equation comparison shows that the simultaneous structure is not identified, because, for the identification of four k_{ij} (where $i, j = 1,2$), one equation is missing (see Morley et al. 2003). Furthermore, as Weber (2011) has shown, in this case, raising the AR order would not help, because an AR(3) model does not fulfil the sufficient rank condition. In the aforementioned paper, this problem is solved by means of heteroscedasticity. This approach considers several regimes (with different volatility) for the data generating process of the structural simultUC shocks ($\tilde{\eta}_t$ and $\tilde{\varepsilon}_t$). The structural variances (say, those of the first regime) are normalised to 1, so that $\sigma_{\tilde{\eta}1}^2 = E\left(\tilde{\eta}_t^2 \mid \mathrm{I}_1\right) = 1$ and $\sigma_{\tilde{\varepsilon}1}^2 = E\left(\tilde{\varepsilon}_t^2 \mid \mathrm{I}_1\right) = 1$ holds. I_r denotes the set of information belonging to the rth regime (where $r = 1,\dots,s$) and s indicates the number of volatility regimes. The variances of the further regimes $\sigma_{\tilde{\eta}l}^2 = E\left(\tilde{\eta}_t^2 \mid \mathrm{I}_l\right)$ and $\sigma_{\tilde{\varepsilon}l}^2 = E\left(\tilde{\varepsilon}_t^2 \mid \mathrm{I}_l\right)$, where $l = 2,\dots,s$, are parameters that need to be estimated. If variance breaks have indeed taken place, these estimations will be different from one.

As one can see, this separation into several regimes increases the number of the unknown coefficients by two at each step: $\sigma_{\tilde{\eta}l}^2$ and $\sigma_{\tilde{\varepsilon}l}^2$ (where $l = 2,\dots,s$). However, $p+1$ additional autocovariances for each further variance regime can be obtained from the MA part of the reduced form.[1] It follows logically from this that for $p \geq 2$, the necessary summing-up condition for the identification of four k_{ij} and the two additional variances $\sigma_{\tilde{\eta}l}^2$ and $\sigma_{\tilde{\varepsilon}l}^2$ per regime is fulfilled.

At this point the heteroscedasticity implications of the reduced-form parameters should be briefly addressed. As can be seen from equation (4), a change in the variance of the structural

[1] The proportional break in the structural shocks ($\sigma_{\tilde{\eta}l}^2 = \sigma_{\tilde{\varepsilon}l}^2$) implies the following: the "new" autocovariances $\gamma_l(0),\dots,\gamma_l(p)$ (l denotes regime) are linearly dependent from their first-regime counterparts and consequently deliver no additional information to identify the simultaneity. On top of that, these "new" autocovariances will be only present if the variance breaks are disproportionate to one another.

shocks implies a break in the MA parameters (a_i) as well as in the residual variance (σ_u^2), but not in the constant (c) or in the AR coefficients (b_i). Had these been affected, a change in the drift and in the AR cycle coefficients would have been observed as a consequence.[2]

3 EMPIRICAL PART

3.1 DATA

We selected the USA and Canada (CA) for the empirical analysis. While US output has already been analysed closely by Weber (2011), we add the perspective on the subprime crisis. An empirical study of Canadian aggregate output represents entirely new terrain. This paper, as well as the above one, uses IP as a measure of output.

3.2 TECHNICAL ASPECTS OF THE ESTIMATION

First of all, IP indices are logged and multiplied by 100. In the next step, the ADF-Test is applied to the modified series in order to check for the presence of unit roots. With the help of an ARIMA(p,1,p) model for each country, the lag length is specified and the initial values for the optimisation of the simultUC likelihood are determined. The optimal lag length is selected using Akaike (AIC) and Schwarz (SC) criteria. Subsequently, the residuals are examined for the presence of autocorrelation. Given the complexity of the structural model under consideration, only lag lengths from 1 to 4 were taken into account. [3]

The exact date of the change in variance regimes is determined as follows: first of all, we look at historical events that could potentially explain a break. This economic analysis is bolstered by a visual inspection of the first differences. Then an endogenous search is carried out by looking for the specification with the largest likelihood. On top of that, the presence of breaks in the MA coefficients and variances is also tested. The estimation of the ARIMA models and the subsequent tests were performed using R 2.10.1 statistical software, while the simultUC models were estimated in GAUSS 9. [4]

[2] See Weber (2011) for details.

[3] Both the information criterion and the residual analysis found the lag length of 4 redundant.

[4] In the first step of the Kalman filter, the initial values for the conditional expectation and the conditional variance are required. In this case, the trend starts with the first observation of the series, while the cycle is initialised at zero. The starting point for the cycle variance is the variance of the IP growth rates. The trend variance starts at 10.000, which represents an extremely large variance, as is expected of a random walk process.

3.3 EMPIRICAL ANALYSIS: USA

3.3.1 SPECIFICATION

The framework constructed by Weber (2011) is taken as a starting point for the US estimation and extended for the specific purposes of this paper. The applied time series runs from 1947:1 to 2011:3. Furthermore, a drift break is included so as to avoid possible distortions. Log IP multiplied by 100 (hereinafter referred to as “IP”) and its first differences are plotted in Fig. 1.

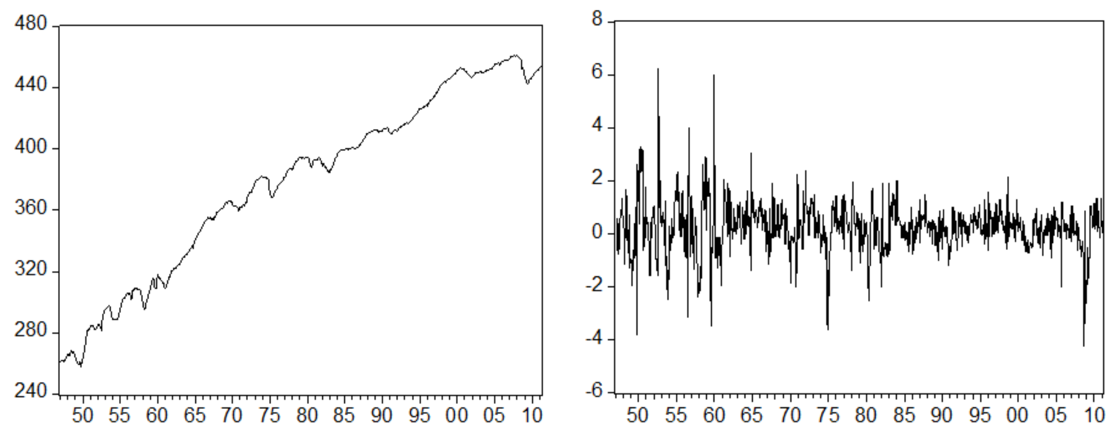

FIG. 1: US log real IP (x100) and the first differences

As the first differences in Fig. 1 show, there are at least two possible break points that could be eligible for the USA: the early 60s and the mid-1980s. The third one – that is, the beginning of the subprime crisis – constitutes a novel element of this paper. The substantial fluctuations, which start at the end of the forties and last until the beginning of the sixties, indicate several consecutive recessions: 1948(I)-1949(IV), 1953(II)-1954(II), 1957(III)-1958(II), 1960(II)-1961(I).[5] Labonte und Makinen (2002) trace these economic slumps back to overly restrictive monetary policy: *"In all of these episodes, monetary policy can be characterized in hindsight as following a pattern of too much tightening of policy before the recession, followed by an easing of policy during the recession. The over tightening of monetary policy is clearest in the three cases (1953-1954, 1957-1958, 1960) where inflation was already low."* The recession of 1960-1961 plays an important role in that respect. The Fed's decision to increase the rate of interest in 1959, combined with restrictive fiscal policy, are viewed as a cause for this economic slowdown. However, the central bank's immediate move towards expansionary policy subsequently led to a quick economic recovery. This recession was followed by the second largest economic boom ever measured by the NBER

[5] NBER recessions

and is clearly visible in the first differences. The search for the best likelihood value indicated January 1961 as a potential break point. This is very close to the break point suggested for the US GDP growth by Keating and Valcarcel (2011). February 1984 is taken as the second most likely break point. This date is also commonly used as the beginning of the Great Moderation for the US GDP series in the relevant econometric literature (see McConnell and Perez-Quiros 2000 / Kim and Nelson 1999). As previously mentioned, the beginning of the subprime crisis, that is, spring/summer 2007, is taken as marking the third break. Given that this paper examines IP (a real variable), the actual starting point should reflect the moment when the real sector succumbed to the crisis. As can be seen from the first differences, strong fluctuations start in summer 2008 and peak in September of the same year (at the same time as the bankruptcy of Lehman Brothers). This supports the value suggested by the largest likelihood, and thus June 2008 was selected as the exact date of the change in regimes. As Rigobon (2003) has pointed out, a slight misspecification of volatility regimes would not impair identification and consistency.

Before the actual simultUC estimation, the selected break points were verified in an ARIMA(2,1,2) model by the Wald tests of the null hypothesis of the stability of the variances and MA coefficients. All three of the break points are clearly significant, meaning that the necessary identification condition is indeed fulfilled. Aside from that, a drift break was integrated in January 1974, in keeping with the largest likelihood value, as can also be seen from the IP time-series in Fig. 1. From an economic perspective, the drift break can be explained by the oil crisis, which began in the fourth quarter of 1973 and is in line with the drift break points suggested for the US real GNP and GDP (see Perron 1989 / Perron and Wada 2005). It should also be noted that the specification with two drift breaks could not be corroborated. The second potential date of the break in drift was set at the end of the "dot-com" bubble (November 2001). The recovery phase after the Internet bubble is the largest economic boom that has been measured by the NBER to date.

3.3.2 ESTIMATION AND RESULTS

The estimated parameters from the trend and cycle equations, as well as the respective six variances of the three additional regimes, are presented in equations (5) to (9). Standard errors from the inverse Hessian are given in parentheses. Additionally, due to the potential distortion of the Wald test (e.g. Dufour 1997 / Nelson and Startz 2007), LR tests were performed for the relevant coefficients.

(5) $$\tau_t = \tau_{t-1} + \underset{(0.109)}{0.396} - \underset{(0.121)}{0.214} + \underset{(0.266)}{1.860}\tilde{\eta}_t - \underset{(0.557)}{2.097}\tilde{\varepsilon}_t$$

(6) $$c_t = \underset{(0.091)}{1.086}c_{t-1} - \underset{(0.084)}{0.269}c_{t-2} - \underset{(0.272)}{1.013}\tilde{\eta}_t + \underset{(0.545)}{2.685}\tilde{\varepsilon}_t$$

(7) $$\sigma^2_{\tilde{\eta}2} = \underset{(0.114)}{0.433} \quad , \quad \sigma^2_{\tilde{\varepsilon}2} = \underset{(0.068)}{0.237}$$

(8) $$\sigma^2_{\tilde{\eta}3} = \underset{(0.078)}{0.270} \quad , \quad \sigma^2_{\tilde{\varepsilon}3} = \underset{(0.020)}{0.030}$$

(9) $$\sigma^2_{\tilde{\eta}4} = \underset{(0.514)}{1.396} \quad , \quad \sigma^2_{\tilde{\varepsilon}4} = \underset{(-)}{0}$$

The standard errors clearly indicate that all coefficients – except $\sigma^2_{\tilde{\varepsilon}3}$ – are significant. The high significance of the spillover parameters k_{12} and k_{21} from the equations (5) and (6) deserves particular attention, for it confirms the strength of the applied identification approach. At the same time, the model with three breaks is over-identified with two degrees of freedom, which is due to the fact that the covariance matrices deliver twelve determining equations for ten unknown parameters. Thus, using the LR test, it is possible to test both spillover coefficients for breaks directly in the simultUC model. In this case, the null hypothesis of no break finds clear support for all three break points. Hence, it is obvious that only the variances and the MA coefficients display breaks, but not the spillovers.

In the first regime – where both variances are normalized to 1 – the simultUC system is strongly influenced by the structural cycle shock ($\tilde{\varepsilon}_t$). It hits the cycle more than twice as strongly as the structural trend innovation does, and even prevails in its effect on the trend component ($k_{12} = -2.097$). Hence, the negative correlation (-0.934) between η_t and ε_t can be explained primarily through k_{12}. The second spillover coefficient $k_{21} = -1.013$ reflects the conventional approach, which sees the correlation as a causal effect from trend to cycle. Therefore, it can be interpreted as the real persistent shock, which drives business cycles, just as the RBC theory postulates. It should be noted here that k_{12} denotes the permanent effect of the structural cycle shock, while k_{21} describes the transitory influence of the structural trend innovation. The volatility of the composite shocks, η_t and ε_t, is approximately equal. According to the estimated results, the drift levelled off from 0.396 (before the break) to 0.182 (after the break, $\mu^1 = -0.214$) and is also in line with the pattern from the IP series. The LR test has shown that μ^1 is marginally insignificant on the 5% level. Nonetheless, the current specification was preserved, because of the criticism levelled by Perron and Wada (2005) and Basistha (2007).[6]

In the second regime the variance of the structural cycle shock dropped by 75% and that of the structural trend shock by 56%. In the third regime the variances declined even further. Compared to the first regime, the variability of the structural trend shock sank by more than 70%, and for the structural cycle shock by 97%. The variance reduction of almost one hundred percent in the case of the structural cycle disturbance has the following implications for the system. The dominant position in the system has shifted to $\tilde{\eta}_t$. Consequently, the negative correlation between the composite shocks can be attributed to $k_{21} = -1.013$ and must be seen as a causal effect from trend to cycle. Taking an economic interpretation into consideration, the business cycles in the third regime can be mostly explained by real permanent shocks. This idea is reflected in a range of economic theories, such as the RBC theory. In the fourth regime, the variance of the structural trend innovation rises fivefold, while the volatility of the structural cycle shock remains immaterial. This is in line with the theory, according to which the subprime crisis was caused (in the case of real estate and the financial sector) or exacerbated (in the case of labour market) by structural problems in system-relevant sections. It should be noted that the current estimation is in line with Weber's (2011) results, despite the inclusion of the highly volatile Global Financial Crisis, which certainly confirms the robustness of the applied model.

In contrast to previous studies, which focussed on composite shock analysis, the structural framework used in this paper makes it possible to determine and investigate the source of these disturbances. The following can be said regarding the volatility reduction of η_t and ε_t with respect to one another. The relation of standard deviations amounted to 0.98 within the first regime (see Table 1 in the appendix). Hence, despite the fact that before the first break the variance of each component was mostly driven by structural cycle innovations, both composite shocks displayed equal volatility in relation to one another. In the second regime, the variances of the structural shocks declined, with the result that the volatility of each component also decreased. However, the relation of standard deviations remains almost equal. In the third regime, the almost complete disappearance of structural cycle variance led to further decline of the η_t and ε_t variances, which were driven almost entirely by the structural trend shock. After the third break (that is, during the subprime crisis) the structural trend

[6] Moreover, the omission of the parameter would not have led to any noteworthy changes.

variance increased fivefold, and thus the relation of composite standard deviations rose even further. In essence, the increase of the relation from 0.98 to 1.84 can be interpreted as "moderate", because the spillover coefficients in both equations prevent the variances from drifting further apart. The reduction of $\sigma^2_{\tilde{\varepsilon}l}$ (where $l = 2,3,4.$) decreased (through k_{12}) its contribution to the trend variance. At the same time, the slight drop/rise found in $\sigma^2_{\tilde{\eta}l}$ (where $l = 2,3,4.$) moderated the reduction of cycle variance (through k_{21}). In sum, it is clear that there is a decrease in the volatility of both composite shocks due to the considerable reduction in the variability of the structural cycle shock ($\sigma^2_{\tilde{\varepsilon}l}$). However, the drop in cycle volatility was by far less sharp than that of the structural cycle innovation.

Figure 2 plots the filtered unobserved trend and cycle components:

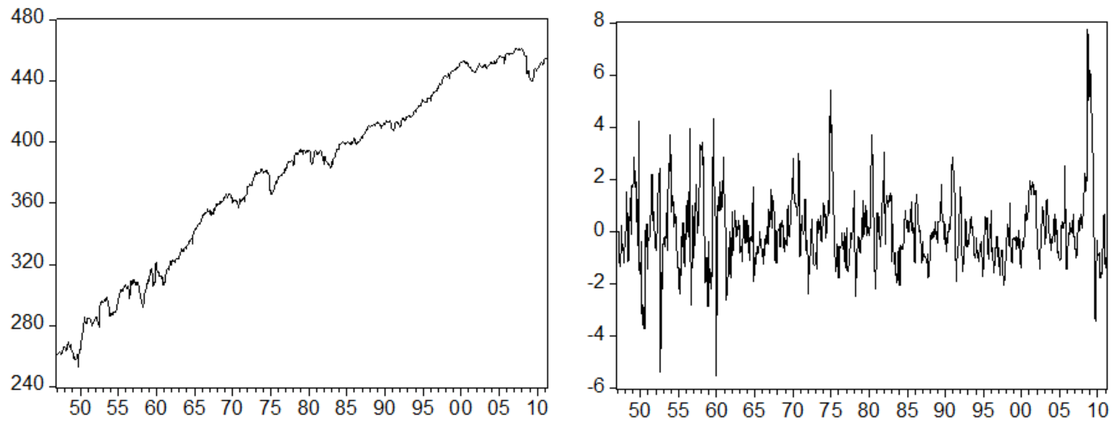

FIG. 2: Filtered IP trend and cycle (USA)

As shown in Fig. 2, the filtered trend remained very volatile until the beginning of the sixties. Moreover, it can be seen that each recession had an obvious effect on its course. In the second regime, where the variance of the structural cycle shock has declined by 75%, the trend becomes less noisy. Nonetheless, one can still see strong variations induced by both oil crises. From the year 1985 onwards, the trend becomes smoother and the "dot-com" bubble represents the sole volatile period. After that, one can see the severe drop in the trend induced by the subprime crisis. All of this makes a convincing case for the suggested break points.

The filtered cycle is shown on the right-hand side of Fig. 2. As the lag polynomial has no complex roots, the cycle shows no typical "periodic" behaviour. The moderation of the cycle between the first regime and the subprime crisis reflects the drop in the volatility of the structural cycle shock. The cycle behaviour also clearly demonstrates that the recent financial crisis has affected its course more strongly than all previous crises. A closer look at both components shows that they display opposite movements, which can be seen especially during the subprime crisis. It can be explained as follows. A negative shock causes a sharp decline in the potential output. However, due to rigidities, the production itself does not immediately follow this development. The "positive" cycle only partially counterbalances the negative trend and the net effect is a decrease in output. The abrupt plummet of the cycle a few periods later implies that production follows potential output. That steep drop shows the effect of the crisis on the cycle component, while the previous increase indicates a gap between the trend and the actual production, just as the RBC theory postulates. As will become apparent later, the explanations put forward above are equally valid for Canada.

3.4 EMPIRICAL ANALYSIS: CANADA

3.4.1 SPECIFICATION

The monthly seasonally adjusted Canadian IP index was obtained from the International Financial Statistics (IMF) and runs from 1957:1 to 2011:5. It is presented on the left-hand side of Fig. 3

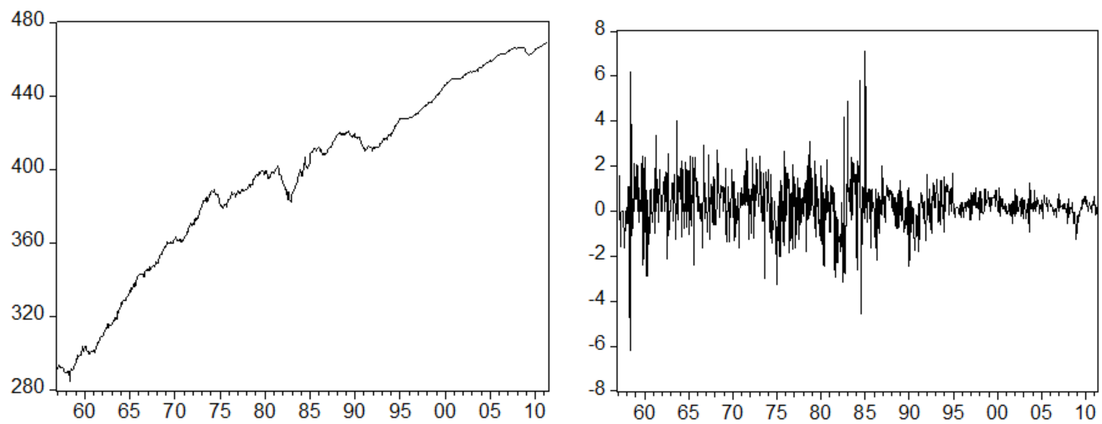

FIG. 3: Canadian log real IP (× 100) and first differences.

AIC and SC criteria from the ARIMA(p,1,p) model prefer a lag length of 2 for the cycle estimation. The AR and MA roots of the characteristic equation lie outside the unit circle. In the differences on the right-hand side of Fig. 3, two break points are visible: the beginning of 1985 and 1995. The first date when volatility undoubtedly decreased can be traced back to the Great Moderation and is very close to the break point suggested for the US GDP (see McConnell und Perez-Quiros 2000) and IP (see Weber 2011). For this estimation, the time points that provide the largest likelihood were selected: February 1985 and January 1995. Taking a closer look at the differences from the year 1985 onwards, one can recognise a drop in their amplitude in 1991/1992. This (rather) slight stabilisation of the variations is followed by a notable reduction in the volatility in 1995, which is congruent with the results from Stock und Watson (2003), who demonstrated that a strong decrease in volatility occurred in the mid-nineties. From an economic point of view, this is consistent with the decision made by the Bank of Canada and the Canadian government in February 1991 to set out a path for inflation reduction, which foresaw a decrease in inflation to 2% by the end of 1995. That led to lower inflationary expectations and, thus, to more security in the markets. In the first "Monetary Policy Report" produced by the Bank of Canada (1995), this issue was commented upon as follows: "*Since 1991, the Bank has been committed to specific inflation-control targets along a path to price stability, and this commitment has begun to bear fruit. The decline of underlying inflation to rates between 1 1/2 and 2 per cent during the last three years has been a key factor behind Canada's improved economic performance.*" As was the case for the US, June 2008 was selected as the third break in variance. In addition, a visual examination of the differences makes it possible to predict at the outset that the subprime crisis hit Canada markedly less severely than the USA.

As shown in Fig. 3, the drift break in the mid-seventies could also be relevant for Canada and, as in the case of the US, the first oil crisis could be considered a potential explanation. July 1974 was chosen for the estimation. This date is very close to the break point (April 1973) Basistha (2007) suggested for Canadian GDP.

3.4.2 ESTIMATION AND RESULTS

The estimated parameters from the simultUC model for Canada are given in equations (10) to (14). Due to the fact that the unrestricted estimation for the structural trend variance within the second regime was equal to 1.001, it was set to 1.

(10) $$\tau_t = \tau_{t-1} + \underset{(0,119)}{0.443} - \underset{0.124}{0.230} + \underset{(0,344)}{1.475}\tilde{\eta}_t - \underset{(0,527)}{0.959}\tilde{\varepsilon}_t$$

(11) $$c_t = \underset{(0,083)}{0.589}c_{t-1} + \underset{(0,043)}{0.195}c_{t-2} - \underset{(0,322)}{1.318}\tilde{\eta}_t + \underset{(0,466)}{1.991}\tilde{\varepsilon}_t$$

(12) $$\sigma^2_{\tilde{\eta}2} = \underset{(-)}{1} \quad , \quad \sigma^2_{\tilde{\varepsilon}2} = \underset{(0,068)}{0.224}$$

(13) $$\sigma^2_{\tilde{\eta}3} = \underset{(0,040)}{0.085} \quad , \quad \sigma^2_{\tilde{\varepsilon}3} = \underset{(0,011)}{0.053}$$

(14) $$\sigma^2_{\tilde{\eta}4} = \underset{(0,214)}{0.413} \quad , \quad \sigma^2_{\tilde{\varepsilon}4} = \underset{(-)}{0}$$

Given that longer time series were not available for Canada and that the model complexity remains substantial, a 10% significance level is considered appropriate. The estimation for the spillover coefficients k_{12} and k_{21} is statistically significant according to the standard errors. However, the LR test only supports the validity of the former at the 10% level.[7] Here, as in the US case, the chosen variance breaks were verified in an ARIMA(2,1,2) model using the Wald test. It was not possible to confirm stability of the variances or of the MA coefficients in any of the cases. As the Wald test in the ARIMA(2,1,2) model found the third break significant only at the 10% level, its presence was checked again within the simultUC model. The LR test clearly rejected the null hypothesis $\sigma^2_{\tilde{\eta}4} = \sigma^2_{\tilde{\varepsilon}4} = 0$ at the 5% level and, in doing so, confirmed the significance of the fourth regime. As mentioned earlier, it is possible to test the parameters k_{12} and k_{21} for breaks because of the model's overidentification. The LR test was not able to reject the null hypothesis of parameter stability for all three break points. Therefore, it is obvious that only variances and the MA coefficients break, but not the spillover parameters. It should be noted that there is no proportional break in the variances ($\sigma^2_{\tilde{\eta}l} = \sigma^2_{\tilde{\varepsilon}l}$ where $l = 2,3,4.$) and, consequently, no violation of the (sufficient) identification condition. The sum of both AR coefficients amounts to approximately 0.8 for Canada, just as it was the case for the US, which suggests nearly equal cycle persistence.

In the first regime, the simultUC system is influenced equally by both structural shocks ($\tilde{\eta}_t$ and $\tilde{\varepsilon}_t$). It is clear that each component is strongly affected by its own shock. Moreover, each shock's influence is stronger upon its own component, i.e. the structural cycle shock hits the cycle component more than the trend component and vice versa. Thus, it is obvious that the cycle can also have permanent effects, just as trend can act in a transitory fashion. Following the results, the drift break parameter (μ^1) was estimated as -0.230, meaning that the trend flattened out by more than 50% after the break occurred. The slope of the trend before and after the break, as well as the results of additional LR test verification, is similar to the US

[7] With regard to the significance of k_{12} the following can be stated. If one shortens the sample for the test purpose and then subsequently expands it step by step, one gets the following results: p-value declines, while there are only marginal changes in the parameter value.

case. The model estimation without the drift break did not lead to any significant parameter change – except, of course, for the constant ($\mu = 0.229$).

In the second regime, the variance of the structural trend shock remained unchanged, while that of the structural cycle innovation declined by nearly 80%. Thus, the strong negative correlation between the composite shocks can be traced back almost entirely to the spillover of the structural trend innovation from the cycle equation (k_{21}). This, just as in the US case, supports the RBC theory, according to which business cycles are caused by real permanent shocks (supply shocks). In contrast to the US results, the explanation of the Great Moderation in Canada can be seen in the drastic disappearance of genuine cycle volatility. The magnitude of the trend shock remained constant and led to volatility reduction in the entire system. This constellation (that is, a sharp decrease of the cycle volatility accompanied by unaltered trend volatility) points towards the "good policies" hypothesis as a more likely explanation of the Great Moderation phenomenon in Canada. In the third regime, the variability of both structural shocks decreased by over 90% compared to the first regime. As one can see, there was an adjustment of both structural innovation contributions to the negative correlation in the third regime. In the fourth regime, the variance of the structural trend innovation rose fivefold, while the volatility of $\tilde{\varepsilon}_t$ disappeared, just as was the case for the US. Consequently, only $k_{21} = -1.318$ contributes to the negative correlation. The equal increase of trend volatility, combined with the complete insignificance of the structural cycle shocks in both countries, points at the presence of a single source of the slump. Regarding the volatility reduction, the following statement can be made (see Tab. 2 in the appendix). In the first regime, the relation of the standard deviations of the composite shocks η_t and ε_t amounted to 0.74. This suggests a greater volatility of the cycle component, which can be traced back primarily to k_{22}. Furthermore, both shock influences are higher in the cycle equation than in the trend component. As can be seen in Tab. 2, the relation rose from regime to regime, while the volatilities of the composite innovations declined steadily. The reason for this rather "moderate" change in the relation is the transmission coefficient of the structural trend innovation from the cycle equation (k_{21}). In sum, it can be said that the system volatility declined over time and that this reduction should be attributed to both composite shocks. For Canada the volatility of the estimated trend and cycle components was driven for the most part by structural trend innovations.

The unobserved trend and cycle components for the Canadian IP, filtered in the simultUC model, are presented in Fig. 4. As one can see, the trend's behaviour remained relatively erratic up to the year 1995, and from then on became fairly smooth. The highest variability can be seen in the early and mid-eighties. These facts certainly speak in favour of the chosen break dates. As mentioned previously, the decline in volatility during the mid-nineties is in line with the findings of Stock and Watson (2003), who suggested exactly the same date as a potential break point for Canadian GDP growth rates. This, combined with the filtered components presented in Fig. 4, indicates that the volatility reduction process connected to the Great Moderation in Canada occurred less abrupt than in the USA. The reduction in volatility of Canadian IP was a process, which presumably lasted from about the mid-eighties to the mid-nineties. The main reason for the volatility decrease during the 1990s was the reduction of the structural trend variance. This lagged volatility decline of $\sigma^2_{\tilde{\eta}3}$ coincided with the "rethinking" of monetary policy, which the Bank of Canada undertook in the early 1990s (see section 3.4.1). As Davis and Kahn (2008) have pointed out, this "monetary policy turning point" had already taken place in the USA around 1983. Not only is it in line with the selected break dates for both countries, but it also brings the "good policies" hypothesis to the fore as the most likely explanation of the Great Moderation phenomenon. Compared to both oil crises, the impact of the subprime crisis on the trend was rather insubstantial. Moreover, it should be noted that, in contrast to the filtered trend for the US IP, the Canadian filtered trend exhibits less variability.

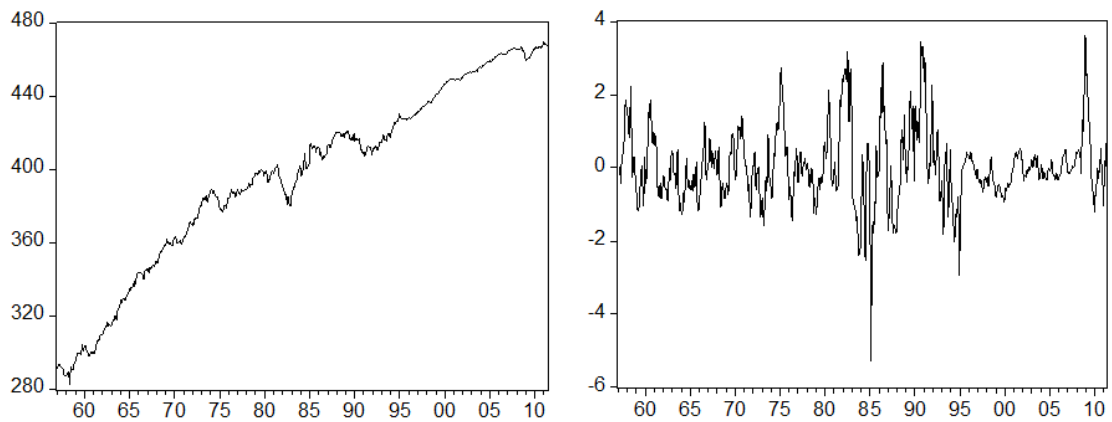

FIG. 4: Filtered IP trend and cycle (Canada)

The 1973 and 1979-80 oil crises are both clearly visible in the filtered cycle, but the latter evidently hit the cycle component more strongly. As already mentioned, the strong fluctuations from the mid-eighties to the mid-nineties can be largely attributed to the short-term effect (transitory) of the trend innovations (k_{21}). This fact indicates that the negative correlation can be seen as a causal effect from trend to cycle. Moreover, the cyclical movements undoubtedly mirror the aforementioned decline in volatility in the mid-nineties. The reduction in the cycle fluctuations between the second and third break reflects the decline of both structural variances. The effect of the subprime crisis was approximately equal to that of each of the oil crises.

4 USA VS CANADA

The major objective of this paper was to analyse the impact of the subprime crisis on the outputs of the US and Canada using Weber's (2011) simultUC model. The main emphasis was placed on the examination of the influencing factors that have been driving the trend and cycle components in the past few decades and especially during the subprime crisis. Furthermore, the separation into several regimes made it possible to study the way in which the effects and causality of individual components change over time.
The implemented structural framework allowed for identification and estimation of the trend and cycle causal structure. The application of the simultUC model to the US and Canada's IP reveals one similarity, that is, the entire disappearance of the structural cycle shock volatility. Moreover the two countries show different shock coefficient relations in the first regime. Although in Canada each component is dominated by the respective "specific shock", US trend and cycle are driven more strongly by structural cycle innovations. At the same time, however, it was possible to confirm strong negative correlation across all regimes.

Aside from the subprime crisis, another event manifested itself in both time series: the Great Moderation. In the US data, it showed itself in a sharp decline of both structural volatilities, while in Canada only the volatility of the structural cycle shock decreased. The strong reduction of structural cycle volatilities in both countries suggests that the "good policies" hypothesis is likely to be a plausible explanation of the Great Moderation phenomenon. However, for the USA, the "good luck" hypothesis can also be considered a potential explanation, since the decline of its structural trend variance was quite sharp. All in all, the IP differences together with the estimated volatilities indicate that the Great Moderation process in Canada lasted longer than in the USA, that is, until the mid-1990s. Generally, both components exhibit higher volatility in the USA than in Canada.

With regard to the shocks during the subprime crisis, the following can be pointed out. Against the previous period, there was a fivefold increase in the variance of the structural trend innovation from the middle of the year 2008 onwards, and this result holds true for both countries. Expressed in absolute terms, the variance of the structural trend shock rose considerably more strongly in the USA than in Canada. As a result, the United States exhibits higher volatility of the composite shocks, and thus also of its two components. The filtered components from the simultUC model illustrate this point (see Fig. 2 and 4). The fact that the subprime crisis had its origins in the USA obviously plays a part here. In general, almost all real economic variables – GDP, unemployment, IP, etc. – reacted significantly more strongly to the crisis in the USA than in Canada. Structural problems in the USA, especially those in banking, finance, real estate and fiscal sectors and not least in the labour market, can be put forward as the main reason for this. Moreover, the high level of private sector debt, combined with the low savings rate, will have also played a substantial role. In contrast to the United States, the Canadian economy was in a relatively solid condition when the crisis struck. As Cross (2011) has argued, consumption (due to much lower private sector debt and a flexible labour market), and the quick actions of the Canadian central bank, together with government economic stimulus programmes, not to mention the stable banking sector,[8] were particularly able to alleviate the crisis. Nonetheless, the Canadian economy was strongly hit by the global crisis, with the result that exports and investments in particular decreased sharply. As can be seen from the Canadian filtered trend component, the upward trend was distorted by the subprime crisis and it has not (yet) completely returned to the old path that would have been reached absent the crisis. This indicates a permanent effect and, thus, the existence of durable structural causes.

For both countries it was possible to confirm the existence of strong negative correlation between the components during the subprime crisis. Moreover, in either case this can be seen as a causal effect from trend to cycle, and not vice versa. The subprime crisis is conspicuous in the IP time series, which is directly related to the strong impact it had on real variables. The "dot-com" bubble and the subsequent recession can be cited here as a counter-example, as they scarcely show up in the IP data. That bubble had very little real background and therefore played only a minor role in this investigation. Transitory effects (such as fiscal policy) appear to have had little influence on the IP components during the subprime crisis and are thus hardly perceptible in the underlying data and the model. It remains to be seen if the latest

[8] In the Global Competitiveness Report 2008-2009 published by the World Economic Forum the Canadian banking system was praised as the soundest and, thus, the most stable in the world.

high-volatility-regime keeps its character or if volatility reverts after the subprime turbulence. The recent more steady growth rates in both countries may support the latter supposition. Future research on this decisive question appears highly promising.

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APPENDIX

Regime	Correlation	Relation of STD
1 (1947m1 - 1960m12)	-0.934	0.98
2 (1961m1 - 1984m1)	-0.920	1.09
3 (1984m2 - 2008m5)	-0.935	1.47
4 (2008m6 - 2011m3)	-1	1.84

TAB. 1: Correlation coefficients and the relations of standard deviations of the composite shocks (USA)

Regime	Correlation	Relation of STD
1 (1957m1 - 1985m1)	-0.917	0.74
2 (1985m2 - 1994m12)	-0.949	0.77
3 (1995m1 - 2008m5)	-0.922	0.80
4 (2008m6 - 2011m5)	-1	1.12

TAB. 2: Correlation coefficients and the relations of standard deviations of the composite shocks (CA)