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Parameter Drifting in a DSGE Model Estimated on Czech Data*

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Abstract
In this article, we investigate the possible time-varying structure of DSGE models. We follow the study of Andrle et al. (2009), which argues that models designed for monetary policy analysis and forecasting of an economy that is undergoing structural changes must include exogenous processes (technologies) capturing the specific characteristics of individual sectors. We conclude that the presence of structural changes and the convergence process in the data imply drifting of structural parameters in the model without technologies. Incorporating technologies causes the structural parameters to be relatively stable. From the perspective of monetary policy analysis and forecasting, it seems more convenient to assume that the structural parameters are stable and use sectoral technologies owing to their aggregate form.

1. Introduction

The stability of an economy's structural parameters is an important assumption for a majority of current dynamic stochastic general equilibrium (DSGE) models. Thus, the possibility of significant drifting of structural parameters is a challenging issue, as it might make the use of many DSGE-based analyses problematic. In the case of drifting parameters, DSGE models should be calibrated with respect to relatively short periods. This topic has become highly relevant in recent years, as many central banks have developed new core DSGE models for monetary policy purposes.

One of the most important advantages of DSGE models is that they are explicitly derived from microeconomic foundations. The equations are acquired directly from optimization problems of economic agents, implying the description of intra- and inter-temporal behavioral decisions based on agents' preferences, the production structure in various sectors, the pricing decisions of firms, etc. Since these behavioral decisions should be relatively stable in the medium term, the structural parameters of these models should also be stable. Therefore, such frameworks should provide suitable tools for policy analysis and regular forecasting and thus soften the Lucas critique (Lucas, 1976). However, this is an ideal. In addition to optimization-based equ-

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ations, DSGE models are usually supplemented with exogenous processes.[1] These processes, usually called technologies, are motivated to fit a country's long-run stylized facts, which are not usually meant to be addressed by prototype monetary-policy models, e.g., Woodford (2003) or Galí (2008).[2] Their presence in the model is crucial, as these processes are aimed at capturing particular sector-specific (as well as country-specific) behavior.

This stability analysis is especially important for converging countries. More than twenty years after its political and economic transition toward a market economy, the Czech economy remains on a convergence path toward the more developed countries of Western Europe. Moreover, it is still being influenced by many structural changes. Thus, the convergence process may imply gradual long-run shifts in the economy, propagating to possible trends in model parameters. Moreover, some structural changes may imply drifting of structural parameters.[3]

Identification of drifting of structural parameters is an active field of research for advanced economies as well. Canova (2004) estimates a small New-Keynesian model with drifting for the US economy. He finds stable policy rule parameters and varying parameters of the Phillips curve and the Euler equation. Boivin (2006) estimates a Taylor rule with drifting parameters and identifies important but gradual changes in the policy rule parameters for the US economy. Fernández-Villaverde and Rubio-Ramírez (2007) estimate a medium-scale DSGE model with parameter drifting on US data. On the basis of 184 observations, they find changes in the Fed's behavior and also drifting of pricing parameters correlated with changes in inflation. More recently, Fernández-Villaverde et al. (2010) build a DSGE model with stochastic volatility and parameter drifting in the Taylor rule and estimate it non-linearly with Bayesian methods on US data. They find evidence of changes in monetary policy even after controlling for stochastic volatility. Besides DSGE modeling, there is a literature on VAR estimation with time-varying parameters. For example, Sims and Zha (2006) do not find any parameter changes either in the policy rule or in the private sector block of their model. Instead, they identify changing variances of structural disturbances.

In this paper, we investigate the stability of structural parameters of a DSGE model for the Czech economy. Our aim is to find out whether structural parameters are drifting in a framework without supplemented technologies and compare these results with parameter movements in a model that is equipped with technology processes. Furthermore, we investigate whether the filtration of sector-specific technologies reflects time variability of some structural parameters.

[1] See Tovar (2008).

[2] For example, the observed increase in the developed countries' openness in the past 50 years and the terms--of-trade appreciation in converging economies are important issues from the macroeconomic perspective, but they stand outside the scope of prototype monetary DSGE models. Andrle et al. (2009) lucidly discuss the relevance of incorporating trade technologies into the Czech National Bank's core model. On the other hand, long-run issues should be treated by different types of models, such as Brůha and Podpiera (2011), who use a perfect-foresight growth model to explain the observed pace of real exchange rate appreciation in converging economies.

[3] Examples of such changes include convergence of the nontradable sector to the tradable sector, price deregulation, re-export movements, the introduction of inflation targeting, EU entry, and investment booms associated with specific policy stimuli.

We carry out the analysis in two steps. First, we construct a suitable model and check its properties. For our purposes, we need a sufficiently rich small open economy (SOE) model to fit the main Czech stylized facts. The model is based mainly on the framework of Burriel et al. (2010), which we alter in several sectors (export, government, monetary policy) to make it closer to the Czech data.[4] Then, we incorporate several technology processes into the model, following Andrle et al. (2009). The technologies are designed directly for the stylized facts of the Czech economy.[5] To check the model's performance, we run several tests, which confirm its usefulness for analyses based on the Czech data.[6] Second, we carry out two experiments in order to find out whether structural parameters are drifting in a framework without supplemented technologies and compare these results with parameter movements in a model that is equipped with technology processes. In both cases, we set all the structural parameters as time-varying.[7] We then filter data using the Kalman filter on the first-order approximated model and switch on the technologies in the first experiment and switch off the technologies in the second experiment. When the technologies are switched off, the time-varying parameters related to technologies are strongly moving. Moreover, there are trends in their movements. When we switch on the technologies, the parameters seem to be relatively stable.[8]

Our main conclusion is that the rich model with several technologies is suitable for historical filtrations and medium-term forecasting based on the Czech data. In this model, the structural parameters are stable, since the drifting is mostly captured via movements of technologies. Moreover, we show that the presence of structural changes and the convergence process of the Czech economy imply drifting of some structural parameters in the model with no sector-specific technologies. Thus, the incorporation of technology processes not only allows better specification of the model with respect to the data, but also captures some time-varying characteristics of the economy. The resulting stability of structural parameters allows the central bank to use its core model for a longer calibration period without frequent model changes.

There is one additional advantage of using time-varying model technologies rather than time-varying structural parameters. Structural changes and convergence consequences propagate into the model parameters with different intensity, which is itself changing in time. For the central bank, it is easier to handle drifting of characteristics of the economy via some aggregated (and better motivated) sector processes than via shocks to parameters. These two methods can be substitutable in estima-

[4] For the analysis, we use post-1996 data. Prior to 1996 the data set is incomplete.

[5] Some sectors of the framework are modeled in a parsimonious way, as we do not aim to use the model for regular forecasting. In such case, the model would converge more closely to the CNB's g3 model developed for this objective.

[6] More specifically, we carry out Bayesian estimation of the model parameters and also check the model's properties. These tests cover impulse response analysis, Kalman filtration, the decomposition of endogenous variables into shocks, and the decomposition of forecasts of endogenous variables from the steady--state.

[7] We follow directly the methods proposed in Fernández-Villaverde and Rubio-Ramírez (2007).

[8] Tonner (2011) carries out a further step. He lets the structural parameters drift and subsequently identifies their trajectories via a non-linear particle filtration method on the second-order approximation of the model. Non-linear filtration is necessary in order to overcome the certainty-equivalence property, as in a linear world, agents' decision rules are typically not affected by random changes in parameters.

tions, but the time-varying processes are more interpretable and it is more transparent to impose judgments for filtering and forecasting.

2. The Model

This section explains the motivation for the model choice and provides a brief description of the model. It focuses mainly on the technology processes as these are crucial for the objective of the paper. For full description of the model, we refer to the *Appendix* to this paper, available on the Journal's web site (http://journal.fsv.cuni.cz), and also to Burriel et al. (2010) and Andrle et al. (2009).

2.1 The Structure

Current monetary DSGE models are quite similar to each other. They consist of several sectors approximating the behavior of economic agents, usually supplemented with prescribed policy rules. The final equations are acquired directly from optimization problems and can thus capture the main intra- and inter-temporal substitutions in an economy. Subsequently, the models are often extended to include many features with respect to the data fit and the purposes of the models. Examples of these features include exogenous processes and various wedges. Their number in the models differs significantly, ranging from "standard" DSGE models to central banks' regular forecasting models.[9]

The model is based on two existing models. First, we use the model of Burriel et al. (2010), designed for the Spanish economy, as our starting framework. This model follows the current generation of DSGE models for the inflation targeting regime. It is sufficiently rich and general within its sector structure and contains many widely-used modeling features, such as real and nominal rigidities, technology growth, and local currency pricing. Moreover, it is also described in the literature in great detail.[10] To cope with the Czech data, we alter several sectors (export, government, monetary policy) to make them closer to the Czech data and extend the model to include several features according to Andrle et al. (2009).[11]

The overall structure of the model is described in *Figure 1*. The model contains households, two intermediate goods-producing firms, four final goods-producing firms, monetary and fiscal policy authorities, and an exogenous rest of the world.

The economy is populated by a continuum of households. Each household consumes a consumption bundle, makes investment decisions, supplies differentiated labor, rents capital, and trades domestic and foreign government bonds. Because of the monopolistic competition associated with differentiated labor, there is a bundler who packs these labor types into a single composite good and sells it to domestic intermediate firms.[12] The wage-setting is a Calvo-type with indexation. Moreover,

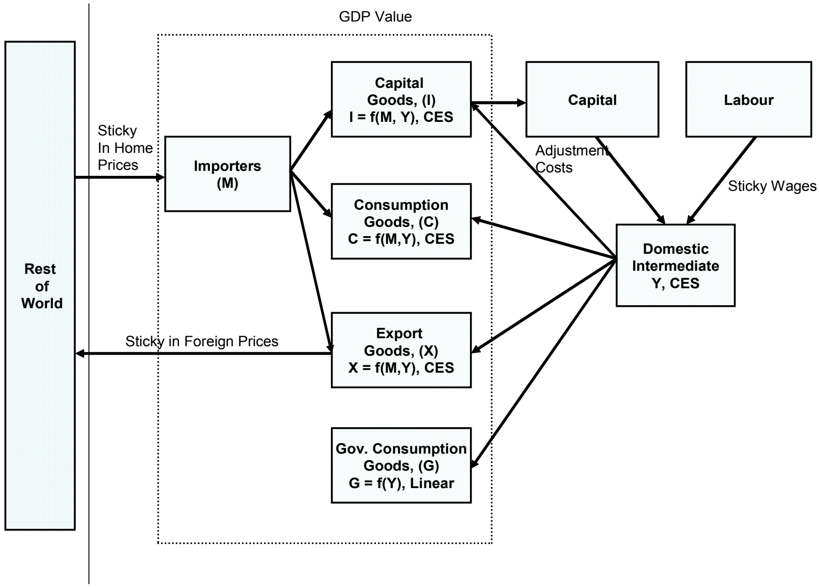
[9] Adding various features into a DSGE model should not be ad hoc. As Andrle et al. (2009) note for the case of regulated (administered) prices: "In a structural model regulated prices require structural interpretation." We believe that this might hold in general.

[10] See also Fernández-Villaverde and Rubio-Ramírez (2007).

[11] Andrle et al. (2009) describe the Czech National Bank's new core model. They summarize the main stylized facts of the Czech economy and discuss ways of (structurally) incorporating them into the monetary DSGE framework.

[12] The same assumption is used for all monopolistic sectors in the model in order to simplify the aggregation. See Erceg et al. (2000).

Figure 1 The Structure of the Model



households own all firms in the model and thus receive the dividends (or finance them internally).

The production structure with intermediate and final goods-producing firms allows the GDP accounts to be captured. Domestic and import intermediate sectors are assumed to be monopolistically competitive with Calvo price-setting with indexation. The domestic intermediate goods-producing firms combine labor and capital rented from households and produce differentiated intermediate goods via the Cobb-Douglas production function. The intermediate importers differentiate the single foreign good costlessly. The (packed) domestic and import intermediate goods are purchased by the final goods-producing firms (except the government goods sector), who utilize them as inputs for final goods production. The final government goods are produced from domestic inputs only. The monopolistically competitive export-producing firms set prices according to Calvo setting in order to capture the gradual exchange rate pass-through via local currency pricing.

The central bank operates under the inflation targeting regime. It reacts to the deviation of four-period-ahead year-on-year inflation from the target and to the specification of the output gap. Fiscal policy in the model is Ricardian. Besides our focus on monetary policy, there are possible ambiguities and uncertainties in analyzing fiscal policy effects.[13] The model is closed with a debt-elastic premium according to Schmitt-Grohé and Uribe (2003).

2.2 Technologies

As noted earlier, DSGE models are usually supplemented with exogenous processes to get them closer to the data. Typical examples include sector-specific technol-

[13] See for example Barro (1974), Botman et al. (2007), or Perotti (2007).

ogies, which capture important features of an economy. In this respect, these processes can be regarded as time-varying parameters. To capture some aspects of the Czech economy, we decided to incorporate three exogenous processes into the model (Andrle et al., 2009).

First, we incorporated export-specific technology growth $\dot{a}^X$ to capture the Harrod-Balassa-Samuelson effect, which implies real exchange rate appreciation in consumer prices in the steady state and explains the relative effectiveness of the tradable sector w.r.t. the non-tradable sector in the domestic economy. Growth in this technology increases productivity in the tradable goods production sector relative to the non-tradable goods production sector, but the less productive workers in the non-tradable sector will demand an increase in wages so that the wage gap between the tradable and non-tradable sectors in the domestic economy does not arise. This, of course, leads to inflation because the wage growth in the non-tradable sector is not supported by a corresponding increase in productivity. On the other hand, the exchange rate appreciates because the tradable sectors are able to produce more goods at lower cost, so the balance of payments moves into surplus, which implies a strengthening of the exchange rate. The response of the monetary authority is ambiguous and depends on whether the effect of the exchange rate or higher wages prevails at the monetary policy horizon. In our case, the effect of the stronger exchange rate prevails and the monetary authority sets lower rates.

We need five assumptions to find a relation between export-specific technology and real exchange rate appreciation in consumer prices. The first one is the law of one price in the steady state

$$1 = EXR = EX \frac{\tilde{P}^{M*}}{P^X}$$

where EXR is the real exchange rate, EX is the nominal exchange rate, $\tilde{P}^{M*}$ is the import price in the rest of the world in the foreign currency, and P^X is the export price in the domestic currency. The second and the third assumptions are steady-state constant terms of trade in the home country and in the rest of the world

$$\Pi^X = \Pi^M, \tilde{\Pi}^{X*} = \tilde{\Pi}^{M*}$$

where Π^X $(= -0.4\% p.a.)$ is export price inflation, Π^M $(= -0.4\% p.a.)$ is import price inflation in domestic currency, $\tilde{\Pi}^{X*}$ $(= 2\% p.a.)$ is export price inflation in the rest of the world in the foreign currency, and $\tilde{\Pi}^{M*}$ $(= 2\% p.a.)$ is import price inflation in the rest of the world in the foreign currency. Assuming the Baumol-Bowen[14] effect in the domestic country and in the rest of the world in the steady state, we get

$$\Pi^C = \dot{a}^X + \Pi^M, \ \tilde{\Pi}^{C*} = \dot{a}^{X*} + \tilde{\Pi}^{M*}$$

where Π^C $(= 2\% p.a.)$ is consumer price inflation in the domestic economy, $\dot{a}^X$ $(= 2.4\% p.a.)$ is export-specific technology growth, $\tilde{\Pi}^{C*}$ $(= 2\% p.a.)$ is consumer

[14] The Baumol–Bowen effect describes the fact that the prices of non-traded goods are higher than the prices of traded goods due to technology improvements in transition economies.

price inflation in the rest of the world in the foreign currency, and $\dot{a}^{X*}$ $(=0\%p.a.)$ is export-specific technology growth in the rest of the world. When expressing the real exchange rate in growth $E\dot{X}R$, we get the real exchange rate in growth in consumption prices $E\dot{X}R^{PC}$

$$0 = E\dot{X}R = \tilde{\Pi}^{M*} + E\dot{X} - \Pi^{X} = \tilde{\Pi}^{C*} - \dot{a}^{X*} + E\dot{X} - \left(\Pi^{C} - \dot{a}^{X}\right)$$

$$0 = E\dot{X}R = \tilde{\Pi}^{C*} + E\dot{X} - \Pi^{C} + \dot{a}^{X} - \dot{a}^{X*}$$

$$0 = E\dot{X}R = E\dot{X}R^{PC} + \dot{a}^{X} - \dot{a}^{X*}$$

$$E\dot{X}R^{PC} = \dot{a}^{X*} - \dot{a}^{X} = E\dot{X} = -2.4$$

Second, we aim to capture some aspects of the high openness of the Czech economy, especially the fact that exports are very import intensive. Thus, we assume trade openness technology $\dot{a}^{O}$, which helps us to work with re-export effects in a model-consistent way. A positive trade openness technology shock increases the growth rates of exports, imports, and foreign demand equally. The aim of this technology is primarily to remove the effect of re-exports from the observed time series. Other model variables are not affected by this shock.

Real export growth $\dot{X}$ $(=9\%p.a.)$ and real import growth $\dot{M}$ $(=9\%p.a.)$ are equal to domestic value added growth $\dot{Y}^{d}$ $(=4.5\%p.a.)$ plus the growth of export--specific and openness technologies. Thus, the steady-state link is

$$\dot{X} = \dot{Y}^{d} + \dot{a}^{X} + \dot{a}^{O} = \dot{M}$$

The links to exports and imports in the model are given via stationarization of the variables

$$x_t = \frac{X_t}{Y_t^d a_t^O a_t^X}, m_t = \frac{M_t}{Y_t^d a_t^O a_t^X}$$

where x_t and m_t are stationarized model exports and imports, and X_t, M_t Y_t^d, a^O, and a^X, are the levels of observed real exports, observed real imports, domestic value added, trade openness technology, and export-specific technology, respectively.

Third, since Czech headline CPI inflation is still influenced by regulated prices, we incorporate regulated price technology $\dot{a}^{R}$ into the model. This technology is merely a proxy for the regulated price goods sector. A positive shock to this technology directly increases consumer price inflation. The consumer basket is composed of both non-regulated goods and goods whose prices are heavily regulated (rents and energy prices being good examples for the Czech Republic). The monetary authority must respond by raising interest rates so that inflation will hit the inflation target. Government consumption will increase, because the income from the increased regulated prices is income of the government. Since the only input into the production of government consumption goods is domestic intermediate goods, domestic intermediate goods are replaced by imports in other production sectors, but not enough to maintain real consumption, investment, and exports at their equilibrium growth levels (crowding-out effect). The balance of payments deficit increases, which implies exchange rate depreciation. We should add that regulated prices are approximated by an exogenous process in this model, i.e., there is no link to the observed regulated prices.

In the steady state, final consumption goods price inflation Π^C ($=2\% p.a.$) is equal to domestic intermediate goods price inflation Π ($=2\% p.a.$) minus regulated price technology growth $\dot{a}^R$ ($=0\% p.a.$). Real consumption $\dot{C}$ ($=4.5\% p.a.$) is equal to domestic value added growth $\dot{Y}^d$ ($=4.5\% p.a.$) in the steady state.

$$\Pi^C = \Pi - \dot{a}^R, \dot{C} = \dot{Y}^d + \dot{a}^R$$

The effects on consumer price inflation and real consumption are again defined via stationarization

$$p_t^C = \frac{P_t^C a_t^R}{P_t}, c_t = \frac{C_t}{Y_t^d a_t^R}$$

where p_t^C and c_t are stationarized model consumer prices and stationarized real consumption, and P_t^C, a_t^R, P_t, and C_t are the levels of observed consumer prices, regulated price technology, intermediate goods prices, and observed real consumption, respectively.

Note that $\dot{a}_t^X$, $\dot{a}_t^O$, and $\dot{a}_t^R$ are expressed as simple AR processes.

3. Model Estimation

In this section, we present and discuss the results of the Bayesian estimation on quarterly Czech and euro area data. Posterior distributions are constructed using the Metropolis-Hastings algorithm of the Dynare Toolbox.[15]

3.1 Data

The quarterly Czech data sample covers 59 observations from 1996Q1 to 2010Q3. We use 16 time series as observables. The seasonally adjusted national accounts data come from the Czech Statistical Office (CZSO). We use the real volumes of consumption, investment, government spending, exports, and imports, and deflators for investment, exports, and imports.[16] Headline CPI inflation also comes from the CZSO. For the labor market data, we use the average nominal wage in the business sector (CZSO) and the time series of the number of people employed in the economy (Labor Force Survey) as the observables for labor demand.[17] The exchange rate is CZK/EUR. The domestic interest rate is 3M PRIBOR. The foreign observables include 3M EURIBOR, the effective euro area PPI from the Consensus Forecast (CF), and foreign demand, acquired from effective euro area GDP (CF).[18] Foreign demand is acquired by multiplying foreign GDP by a factor of four (Andrle et al., 2009).

[15] One million draws are used for the estimation.

[16] We use CPI inflation instead of the consumption deflator. The government deflator is not necessary because of the simple fiscal policy treatment in the model.

[17] Both time series are seasonally adjusted to obtain their trend-cyclical components.

[18] The weights used in the calculation of the effective variables are the shares of the individual euro area economies in the foreign trade turnover of the Czech Republic. See the Inflation Reports of the CNB.

We allow for measurement errors in the model to deal with the high data uncertainty associated with frequent data revisions, methodology changes, and high volatility of the quarter-on-quarter growth rates of several time series. The measurement errors are incorporated on levels via measurement equations where we let the observables differ from the measurements.

3.2 Priors

First of all, we set the steady-state growth rates. The overall growth in the model is slightly above 4.5% a year, which is approximately consistent with the previous GDP growth of the Czech economy. The steady-state population growth is set to zero.[19] We set the steady-state nominal appreciation rate to 2.4% a year. This value corresponds approximately to the period until 2009.[20]

The steady-state CPI inflation rate corresponds to the 2% inflation target set in annual terms. The foreign inflation steady state is calibrated according to the 2% inflation target of the ECB. Foreign demand growth for domestic exports is set at a pace of 9% a year, so long-run EU GDP growth is set to 2.25%.[21] The steady-state foreign nominal interest rate is calibrated to 4% annually.

3.3 Posteriors

In this subsection, we present point estimates of the model parameters. Our objective here is to underline and discuss those parameters which have relatively clear counterparts in the real economy.

The point estimate of the habit formation parameter h is approximately 0.93. This value corresponds to the high level of consumption smoothing in the Czech economy, supported by a relatively low decrease of consumption during the mid-2008–2009 crisis due to the social security system and government transfers. The debt-elastic premium parameter ρ_{b_W} affects, among other things, the important link between domestic and foreign interest rates.[22] The posterior value is 0.0016, implying a tight link between domestic and foreign interest rates. The elasticities of substitution differ between 5.0 for the domestic intermediate sector (ε) and 9.5 for the export goods-producing sector (ε_x). These values correspond to a range of average markups between 25% and 12%. It is difficult to check the resulting markups with micro data because there are no corresponding official series for the Czech economy.[23] The wage markup (η) is 16%.

[19] In the model, the overall steady-state growth is generated via neutral technology only. Thus, population growth and investment-specific technology do not contribute to the determination of the long-run growth.

[20] Adding the latest data would decrease the appreciation rate, as there was a considerable depreciation. In this respect, we interpret this period as a temporary shock and do not change the assumption about the steady-state appreciation rate.

[21] Note that the measurement equation is on levels whereas the balanced growth path (which defines the model steady state) is on growth rates.

[22] A high value of this parameter weakens the relationship, i.e., large changes in foreign interest rates will not cause significant responses in domestic rates. Conversely, too low values imply a very strong domestic interest rate reaction to foreign interest rate changes.

[23] The only available series are for prices in the food branch (agricultural prices, food production prices, and consumer prices of food), but these tables show only final prices without any detailed specifications of firms' costs.

The posterior values of the Calvo price-setting parameters (θ_p, θ_x, θ_M) are 0.51 for domestic intermediate prices, 0.08 for export prices, and 0.76 for import prices, with corresponding indexation parameters of 0.68, 0.27, and 0.62 (χ, χ_x, χ_M). These estimates imply an approximate contract duration of two quarters for the domestic intermediate sector, higher price flexibility in the export sector with a duration slightly above one quarter, and relatively sticky prices in the import sector (four quarters). The Calvo parameter for wages θ_w is 0.46 and the indexation has a posterior value of 0.86 (χ_w).[24]

The inflation parameter (γ_Π) in the monetary policy rule has a posterior of just over 1.16, whereas the output parameter (γ_y) is more than five times lower, with a value of 0.23. The posterior of the lagged interest rate parameter (γ_R) equals 0.83 and thus corresponds to the smooth profile of interest rates.

The parameter ρ_G defines the ratio of government expenditures to GDP as part of the ratio of domestic consumption to GDP. Overall, the components of GDP are thus estimated in the steady state as 60% for private consumption, 30% for government consumption, and about 10% for investment.

The estimates of the openness characteristics of the Czech economy show relatively high import intensities for the GDP components, most significantly for the investment sector, with more than 90% import intensity. The share of domestic consumption goods (n_c) in the total consumption basket (home bias in consumption) is approximately 37%. The share for the investment sector (n_i) is 7% and that for the export sector (n_x) is 43%.[25]

The estimated standard deviations show the importance of intertemporal preference shocks ξ_t^d and technology shocks ξ_t^A and ξ_t^μ. In the model specification with no direct shocks to habit formation, the preference shocks capture a considerable part of the behavior associated with households' utility. The high standard deviation of the investment-specific technology shock (ξ_t^μ) suggests high volatility of the quarter--on-quarter growth rate of observed investment.

We use the estimated model for the analyses presented in the next section. In order to estimate the time-varying parameters, the Bayesian point estimates are set as initial conditions (starting points) for the drifting of structural parameters.

3.4 Model Moments

To evaluate the model properties we carried out various tests. These tests cover impulse response analysis, Kalman filtration, the decomposition of endogenous variables into shocks, and the decomposition of forecasts of endogenous variables

[24] These results might have been influenced by the presence of indexation parameters in the price- and wage-setting equations. In the model, prices and wages change due to reoptimizing and indexation. Thus, it might sometimes be difficult to interpret these two parameters together.

[25] In Rojíček (2008), the import intensity of exports is estimated at 45% for 2000 and 50% for 2005.

from the steady-state. In the *Appendix* available on the web site of this journal (http://journal.fsv.cuni.cz) we present a comparison of the model moments with the data. From *Table 1*, we can see that the means of the main variables roughly coincide. The exception is the mean of nominal interest rates, which is higher, most significantly due to higher values during 1996–1999.

The comparison of the second moments shows that the model fits the volatility of the foreign time series well. However, the volatility of the domestic time series is lower than the model volatility. The results of the cross correlation analysis in *Table 2* show that the model and data properties broadly coincide among the main variables.

4. Time-Varying Parameter Estimation

In this section, we try find out whether the structural parameters are drifting.[26] In the first subsection, we compare the parameter drifting in a framework without supplemented sector-specific technologies with parameter movements in the model that is equipped with technology processes. In the second subsection, we compare the filtration of sector-specific technologies with the data. Moreover, we are interested in the mutual invertibility of these two possible views of time-varying parameters. Particularly, we investigate whether the filtration of sector-specific technologies can substitute the time variability of any of the structural parameters.

4.1 Filtering Study

This subsection compares the results of two Kalman filtrations of the model. The first filtration is carried out on the model version without supplemented technologies where structural parameters are allowed to drift. The second filtration is on the model version where structural parameters are again allowed to drift but the model is equipped with technology processes. In both cases, the structural parameters are drifting according to the process

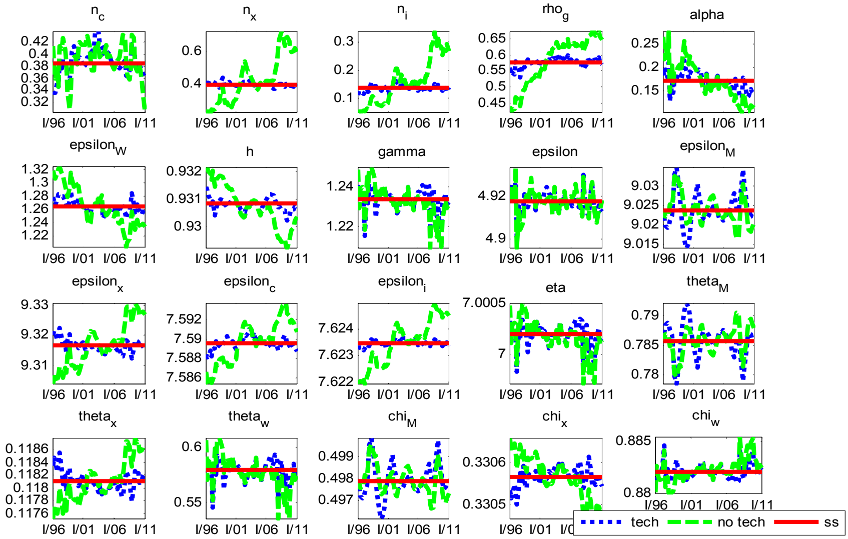
$$par_t = \rho_{par} par_{t-1} + \left(1 - \rho_{par}\right) par_{ss} + \xi_t^{par}$$

where the steady-state values (initial conditions) are taken from the Bayesian estimation. For both experiments, we use the same observables.

The comparison of the two filtrations is shown in *Figure 2*. In the case with no technology processes, several parameters are drifting or have trends during the 1996–2010 period. In this respect, the most important parameters are the domestic shares of GDP components (home bias parameters). The home bias parameters capture the changing import intensities and production structure of the economy, and their changing values correspond to the transition nature of the Czech economy. The estimation suggests an increasing share of imported consumption goods, an increasing domestic share of exports goods, and an increase in the domestic share of investment during the 2008–2009 crisis. Because of structural changes such as changes in productivity between the tradable and nontradable sectors, deregulation, and re-export movements, the model filtration uses time-varying parameters to get close to the data. The drifting or trends of the majority of the other parameters are less significant and can be considered roughly stable over time. When we switch the technologies on, the parameters capturing domestic shares are closer to their steady-state values.

[26] using the IRIS Toolbox (Beneš, 2006)

Figure 2 Filtered Technologies and Time-Varying Parameters



We carry out the augmented Dickey-Fuller[27] test for a unit root in parameter movements (the null hypothesis). The results for both filtrations are presented in *Table 3* in the *Appendix*. In the model with technologies, the null hypothesis is rejected up to the 95% level. In the model without technologies, the hypothesis of the existence of a unit root cannot be rejected for the time-varying parameters related to technologies.

Thus, the presence of structural changes and production structure changes is captured either by the time-varying parameters or by sector-specific technologies. In the second case, the movements of the incorporated technologies imply greater stability of the structural parameters in the model.

4.2 Observed Data Study

The filtered technologies provide an important check of the model's settings and ability to analyze the data. *Figure 3* shows the evolution of the technologies, based on Kalman filtration, and compares them with the corresponding data.[28]

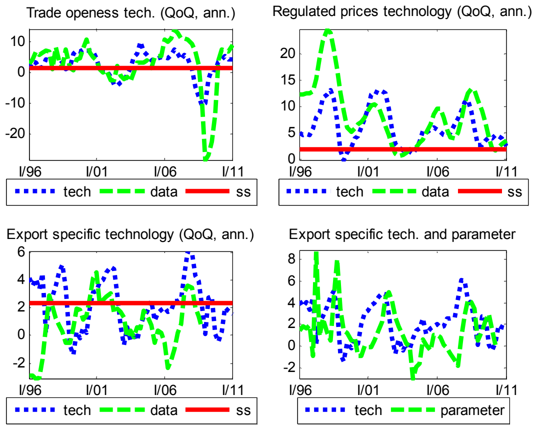
The filtration of trade openness technology is in line with the foreign demand data and shows a significant decrease of re-exports in the Czech economy during the mid-2008–2009 crisis. The second panel compares the regulated price technology with the observed regulated prices. Although there is no regulated price measurement equation in the model, the technology follows the trajectory of the observed data. In the third panel, the cyclical component of export-specific technology is in line with the cyclical component of the price in the nontradable sector relative to the price in the tradable sector.[29]

[27] Using the econometrics toolbox (LeSage, 1999).

[28] The comparison shows the correlations of the cyclical components only. Some time series are rescaled so that they can be displayed in a single figure.

[29] Note that there is no observable for the relative price of nontradables and tradables in the model.

Figure 3 Filtered Technologies and Data



Moreover, the last panel shows a comparison of the export-specific technology filtration and the time-varying parameter of the import intensity of exports. To avoid interactions we switch on the export-specific technology and switch off the time-varying import intensity parameters in the first experiment and do the opposite in the second experiment. We conclude that the technology capturing the Harrod-Balassa-Samuelson effect is, at least in its cyclical component, a reflection of the time-varying import intensity parameters.

5. Summary

In this article, we analyze the possible drifting of structural parameters in a relatively comprehensive DSGE model estimated on Czech data. The model contains several sector-specific technologies to make it closer to the Czech data. Particularly, export-specific technology captures the Harrod-Balassa-Samuelson effect, openness technology deals with re-exports, and regulated price technology is a proxy for the regulated price goods sector. The model is estimated using the Bayesian technique on quarterly Czech and Eurozone data. The technique for assessing the drifting of structural parameters contains two analyses. First, we compare the parameters drifting in a framework without supplemented sector-specific technologies with parameter movements in the model that is equipped with technology processes. Second, we compare the filtration of sector-specific technologies with the data.

Our main conclusion is that the rich model with several technologies is suitable for historical filtrations and medium-term forecasting based on the Czech data. In this model, the structural parameters are more stable, since the drifting is mostly captured via movements of technologies. Thus, the incorporation of technology processes not only allows better specification of the model with respect to the (Czech) data, but also captures some time-varying characteristics of the economy.

Using the model with technologies has at least two implications for the central bank. First, the resulting stability of structural parameters allows the central bank to use its core model for a longer calibration period without frequent model changes. Second, since structural changes and convergence consequences propagate into the model parameters with different intensity, which is itself changing in time, the central bank should choose some method to deal with these features. Particularly, it is easier to handle drifting of characteristics of the economy via some aggregated (and better motivated) sector processes than via shocks to parameters. These two methods can be substitutable in estimations, but the time-varying processes are more interpretable and it is more transparent to impose judgments for filtering and forecasting.

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