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Structural Macroeconomic Model of Slovakia

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Abstract

We estimate a structural econometric model for the Slovak economy that is suitable for both macroeconomic forecasts and simulations. Furthermore, we enrich the model by a fiscal block and make it applicable for a policy analysis. We thus aim to find a trade-off between simplicity and accuracy for forecasting purposes and a detailed structure for a policy analysis. The model is based on error correction equations to incorporate both long-run development of model variables that are consistent with a macroeconomic theory and short-run dynamics of model variables that are estimated from historical data. Next, we present impulse response functions for a set of macroeconomic and fiscal shocks as well as implied fiscal multipliers to evaluate different consolidation scenarios. The most negative outcome results from an increase of capital and labour income taxes that supress not only actual but also potential output in the domestic economy. On the other hand, the most favourable outcome results from an increase of net consumption taxes in a short horizon and a decline of intermediate consumption in a medium horizon.

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1 Introduction

Forecasting of macroeconomic development is a crucial process for a smooth operation of world economies. First, development of production and financial sectors is closely related to actual and future macroeconomic prospects. Second, a reasonable identification of future macroeconomic shocks is necessary for monetary and fiscal authorities to pursue effective countercyclical policies. Finally, development of budgetary plans is based on macroeconomic bases for revenue and expenditure components of a public budget. While an application of expert judgement is an important tool for macroeconomic forecasts that should be included in macroeconomic models, especially in a short horizon, we argue that a model-based approach that incorporates structural relationships in an economy is crucial for consistency and credibility of a forecasting process in a medium horizon. In fact, a forecasting process of many domestic and international institutions is based on a combination of expert judgement and structural macroeconomic models to produce the most accurate macroeconomic forecasts.

There is a number of different model classes that are applied for macroeconomic forecasts and simulations from simple vector autoregressive (VAR) models to complex dynamic stochastic general equilibrium (DSGE) models. Despite a plausible forecasting performance of the VAR models, in general, they do not pass the Lucas critique and could be thus not applicable for a policy analysis. Specifically, since these models are based on a historical projection of macroeconomic variables, they do not capture structural relationships in an economy given by a theory of general equilibrium and rational expectations of macroeconomic agents.[1] On the other hand, the DSGE models are derived from microeconomic foundations of representative agents and their rational expectations and thus pass the Lucas critique for a policy evaluation. However, since these models rely on a set of structural assumptions about rational behaviour of representative agents, they could be too rigid for practical forecasting in small open economies. Therefore, to find a trade-off between a macroeconomic theory, a historical projection and proper impulse response functions, we propose a general equilibrium model based on error correction equations that is plausible for forecasting purposes as well as a policy analysis.

Error correction models (ECM) are based on pairs of structural equations that incorporate both long-run stochastic trends and short-run empirical dynamics of model variables to handle cointegration of macroeconomic time series. This approach thus eliminates non-stationary components in model variables that could result in a spurious identification of model equations in the short runs and also captures a convergence process of model variables that is implied by stochastic trends in the long runs. While the long-run equations are mostly derived from a microeconomic theory, i.e. production and utility functions under a perfect or imperfect competition, the short-run equations are mostly estimated on a historical dataset to obtain the maximal fit of historical data. ECM models thus produce impulse response functions in line with a macroeconomic theory and also capture empirical dynamics of model variables. Furthermore, they meet a demand for structure in contrast to the VAR models and relax too rigid assumptions of the DSGE models. They are thus suitable for both macroeconomic forecasts and simulations. For more information about cointegration of time series variables and introduction to error correction models see Engle and Granger (1987).

Core structure of our model is based on an area wide model (AWM) of the euro area that was proposed by Fagan et al. (2001). The model is adapted for the Slovak economy and extended for comprehensive budgetary restrictions of macroeconomic agents. Furthermore, we enrich the original model by a fiscal block and thus make it suitable for a policy analysis.[2] Structure of the model is based on a theory of a production function and a set of empirical equations that are estimated from historical data with standard econometric methods. Even though there

[1] For more information see Lucas (1976).

[2] Enrichment by a fiscal block is an important extension of the model to produce more accurate macroeconomic forecasts with a respect to fiscal variables and simulate an impact of fiscal policies on the domestic economy for the Stability Programme (SP) and the Draft Budgetary Plan (DBP).

are different versions of error correction models for the Slovak economy that were developed by the National Bank of Slovakia (NBS) or the Council for Budget Responsibility (CBR), we propose an important extension of the original research with a detailed structure of the domestic economy and a focus on macro-fiscal interactions.

First, since the model contains a detailed structure of budgetary restrictions of households and government, we could separately model these budgetary components and thus obtain endogenous estimates of financial flows in the Slovak economy. Second, we provide a sectoral disaggregation of the domestic economy and distinguish between companies, households and government what results in a set of sectoral equations for (i) the domestic labour market, i.e. sectoral employment and wages and (ii) the domestic capital market, i.e. sectoral investment and depreciation, in line with the budgetary restrictions. The model is thus consistent with a construction of national accounts and allows for a correct identification of historical variables as well as a simple tractability of macroeconomic and fiscal shocks.

Finally, we could simulate an impact of a fiscal policy on the domestic economy with a respect to both income and expenditure components of a public budget. While the expenditure components, i.e. public consumption and investment, have a direct impact on a domestic output, the revenue components influence private consumption and investment through budgetary restrictions of companies and households. Furthermore, different instruments of a fiscal policy are affected by a deviation of a fiscal balance and a public debt from their target paths to ensure stabilization of the fiscal variables. The fiscal rules are based on an expenditure side of a public budget, in line with the latest research, see for example Claeys et al. (2016), Feld et al. (2018) or Darvas et al. (2018).[3]

We structure the paper as follows. First, we provide a literature review with a focus on error correction models and fiscal multipliers. Second, we describe a structure of model equations with a detailed view of individual model blocks. Third, we provide an overview of a historical dataset and describe technical aspects of the model. Fourth, we discuss parametrization of the model that consists of econometric estimation of macroeconomic parameters and calibration of fiscal parameters. Finally, we evaluate the model with impulse response functions for a set of macroeconomic and fiscal shocks and provide implied fiscal multipliers for different consolidation strategies on both revenue and expenditure side of a public budget.

[3] For a comparison of alternative fiscal rules see Cordes et al. (2015) and Eyraud et al. (2018).

2 Related literature

An area wide model proposed by Fagan et al. (2001) is one of the most popular methods for macroeconomic forecasts applied by the European Central Bank (ECB). The model is based on error correction equations with an endogenous monetary policy and an exogenous fiscal block. While a supply side of the economy is based on a Cobb-Douglas production function that pins down the potential output by labour and capital production factors, a demand side of the economy defines a national income identity and thus calculates a domestic output by private and public consumption, domestic investment and a trade balance. Wages and prices are pinned down by first order conditions in a long run and empirical equations in a short run.

Furthermore, the area wide model operates with an endogenous financial block that is based on a monetary demand and a term structure of interest rates. Monetary policy is then pinned down by a standard Taylor rule that sets a policy rate with a respect to a deviation of an inflation rate and an output gap from their target values. On the other hand, a fiscal block is rather simplified with a fiscal balance determined by a share of taxes and contributions on gross domestic product and exogenous public consumption. The model is mostly backward looking and thus based on adaptive expectations, with an exception of financial variables that are defined under a model-consistent approach. Specifically, an exchange rate between domestic and external economies is pinned down by an uncovered interest rate parity (UIP) and an effective interest rate is based on future expectations of the policy rate.

Structural econometric models are also a popular tool for macroeconomic forecasts and simulations (i) within the euro area, see models of Ireland by Bergin et al. (2017) and Netherlands by Berben et al. (2018), (ii) outside the euro area, see models of Poland by Budnik et al. (2009) and Norway by Bardsen and Nymoen (2015) and (iii) across the world, see models of Canada by Gervais and Gosselin (2014) and Australia by Balantine et al. (2019).

First econometric model of the Slovak economy was proposed by Livermore (2004). The model is based on a theory of general equilibrium and error correction equations with endogenous monetary and fiscal blocks. The model thus incorporates structural relationships in the domestic economy and active policies of monetary and fiscal authorities. However, since the model includes an active monetary policy and is mostly calibrated from pre-crisis data and related literature, it does not reflect a structure of the Slovak economy in the recent years.

Macroeconomic forecasts and simulations of the NBS are based on a structural econometric model of Reľovský and Široká (2009).[4] The model is based on the original work of Fagan et al. (2001) and adapted for the Slovak economy. Since entering a monetary union of the euro area, a monetary policy is set exogenous to the model and implied by nominal interest rates and exchange rates of the ECB. Finally, we mention a macroeconomic model of the CBR that was proposed by Kľúčik (2015) and extends the original work of Reľovský and Široká (2009) with a fiscal block. This model could be thus applied for macroeconomic forecasts and simulations as well as a quantification of alternative consolidation scenarios.

While a core structure of our model is in line with the model of Reľovský and Široká (2009), we provide important extensions of the original work. First, a sectoral disaggregation of the domestic economy leads to a more detailed estimation of labour and capital markets. Second, a decomposition of budgetary restrictions of companies and households allows for a more detailed definition of private consumption and investment. Finally, an inclusion of a fiscal block allows for (i) a decomposition of a public budget into revenue and expenditure components, (ii) a definition of a fiscal balance and a public debt, (iii) a direct impact of fiscal variables on the domestic economy, (iv) a definition of fiscal rules with a respect to public expenditures and (v) an evaluation of alternative consolidation strategies.

[4] It is important to note that macroeconomic forecasts of the NBS are based on an updated version of the model by Reľovský and Široká (2009).

On the other hand, we extend the model of Kľúčik (2015) with (i) a sectoral disaggregation of the domestic economy to obtain a more detailed structure of public revenues, (ii) a separate set of error correction equations to provide a more detailed definition of public expenditures and (iii) market expectations about a fiscal policy to reflect their impact on a confidence of investors and implied fiscal multipliers.

Next, to evaluate and compare alternative consolidation scenarios, we should be interested in an identification of fiscal multipliers. Literature on fiscal multipliers consists of a number of different models and methods. We could mention a summary of existing literature published by Spilimbergo et al. (2009) and a more recent overview by Gechert and Will (2012). Both dynamic stochastic models (DSGE) and structural econometric models (ECM) produce higher multipliers on an expenditure side than a revenue side of a public budget. For example, we remark dynamic stochastic models by Baksa et al. (2010) or Ambrisko et al. (2012) and error correction models by Dalsgaard et al. (2001) or Henry et al. (2004). Finally, we summarize domestic literature on fiscal multipliers that is based on vector autoregressive models (SVAR), see for example papers by Benčík (2009) or Čolláková et al. (2014), and dynamic stochastic models (DSGE), see for example papers by Múčka (2016) or Zeman (2016). However, since a number of macroeconomic models do not incorporate market expectations about a fiscal policy and could be biased by short data samples and a small number of consolidation episodes, we need to be careful with estimation of fiscal multipliers.[5]

On the other hand, recent works based on the narrative approach analyse particular consolidation episodes and their impact on an economic performance and thus avoid model issues with market expectations and short data samples. These papers argue that the revenue multipliers are empirically higher than the expenditure ones not only in a medium term but also in a short term, see for example Guajardo et al. (2014) and Alesina et al. (2018).[6] The authors assume that while a decline of public expenditures has a positive impact on private investment, in line with a stronger confidence of investors, an increase of taxes and contributions distorts the potential output and thus supresses an economic performance. Furthermore, some papers argue that a fiscal consolidation based on public expenditures could be even expansionary, see for example Giavazzi and Pagano (1990) or Alesina and Perotti (1996). However, the most recent studies suggest that the expansionary contraction is restricted only to particular consolidation scenarios and could be also explained by additional factors.[7]

[5] For more details about the market expectations and their impact on the estimation of fiscal multipliers see Alesina et al. (2018).
[6] For further information and more studies based on the narrative approach see Batini et al. (2014).
[7] For more information see Guajardo et al. (2014).

3 Model specification

We proceed with a specification of a macroeconomic model that consists of a set of behavioural equations and macroeconomic identities and could be decomposed into six model blocks, i.e. a supply side block that pins down the potential output, a demand side block that defines a domestic output, a block of wages and prices that pins down domestic wages and prices, an interest rate block that defines a domestic risk premium, a block of households that captures a disposable income and a block of government that captures a fiscal balance and a public debt. Variables are denoted by letters from the Latin alphabet and parameters by letters from the Greek alphabet. Log() corresponds to a logarithm of variables, sqrt() to a square root of variables, tfp() to a surplus of variables over productivity, diff() to a time differential of rates, dlog() to a time differential of logarithms and dtfp() to a time differential of surpluses over productivity. Furthermore, to capture an asymmetric impact of effective tax rates on domestic prices, we label a time differential with a positive sign by up() and a time differential with a negative sign by down(). Finally, gap() corresponds to a deviation from potential values, dev() corresponds to a deviation from target values and cor() denotes an error correction term. Variables are then labelled by a time index *t*.

3.1 Supply side block

We start with a supply side of the economy that pins down the potential output and corresponding production factors. It is important to note that the supply block is derived from a microeconomic theory of a production function, in contrast to other model blocks that are based on empirical equations and macroeconomic identities. Potential output ($\mathbf{yt_t^*}$) is defined by a Cobb-Douglas production function in line with Fagan et al. (2001) and thus based on a labour production factor ($\mathbf{lt_t^*}$), a capital production factor ($\mathbf{kt_t}$) and a total factor productivity ($\mathbf{at_t}$) as stated in the Eq.1.

$$\mathbf{log(yt_t^*) = log(at_t) + \beta * log(kt_t) + (1-\beta) * log(lt_t^*)} \quad (1)$$

We calibrate the elasticity of labour ($\mathbf{1-\beta}$) from a historical ratio between compensations of employees and gross domestic product and complement with the elasticity of capital ($\boldsymbol{\beta}$). This approach is thus in line with a first order condition with a respect to the labour component, see for example Reľovský and Široká (2009) or Kľúčik (2015).[8] Maximization of profit ($\boldsymbol{\Pi_t}$) under flexible prices ($\mathbf{py_t^*}$) and flexible wages ($\mathbf{wt_t^*}$) then leads to an optimization problem of domestic producers that is given by the Eq.2.

$$\mathbf{Max\ \Pi_t = yt_t^* * py_t^* - lt_t^* * wt_t^* - kt_t * pk_t * (1/4 * lr_t + \delta t_t + \lambda t_t)} \quad (2)$$

The optimization function is based on revenues from domestic production and expenditures on labour and capital production factors. While the labour costs are based on a price of labour ($\mathbf{wt_t^*}$), the capital costs capture a price of capital that consists of a real interest rate ($\mathbf{lr_t}$), a depreciation rate ($\boldsymbol{\delta}\mathbf{t_t}$) and a correction term ($\boldsymbol{\lambda}\mathbf{t_t}$). The real interest rate includes a domestic risk premium and thus incorporates an impact of a fiscal policy on the potential output. We further exogenize the correction term to maintain a historical ratio between domestic investment and a gross domestic product in a steady state.[9] It is important to note that we distinguish between potential output prices ($\mathbf{py_t^*}$) and capital stock prices ($\mathbf{pk_t}$) and thus restrict nominal variables in a short run and real variables in a long run. Solution of the optimization problem results in first order conditions that are further included in the model. Specifically, the first order condition with a respect to the labour component (Eq.3) pins down potential labour costs ($\mathbf{wt_t^*}$) and potential output prices ($\mathbf{py_t^*}$), while the first order condition (Eq.4) with a respect to the capital component corrects an evolution of domestic investment ($\mathbf{it_t}$).

$$\mathbf{lt_t^* * wt_t^* = (1-\beta) * yt_t^* * py_t^*} \quad (3)$$

[8] Compensations of employees are equal to domestic employment that is multiplied by average labour costs of domestic employees.
[9] The correction term captures additional capital costs, for example capital taxes or capital dividends.

$$\mathbf{kt_t * pk_t * (1/4 * lr_t + \delta t_t + \lambda t_t) = \beta * yt_t^* * py_t^*} \tag{4}$$

Domestic labour force ($\mathbf{ls_t}$) is driven by an evolution of productive population ($\mathbf{np_t}$) and domestic employment ($\mathbf{lt_t}$) as stated in the Eq.5. While the first term captures a population projection for the domestic economy, the second term incorporates transition effects between labour demand and supply. Furthermore, we extend the equation with a net labour income ($\mathbf{rn_t}$) and labour taxes and contributions ($\boldsymbol{\tau_t^{tc}}$) to approximate an optimization of households between work and leisure. The equation concludes with an error correction term.

$$\mathbf{dlog(ls_t) = ls_1 * dlog(np_t) + ls_2 * dlog(lt_t) + ls_3 * dlog(ls_{t-1}) + ls_4 * dtfp(rn_t) -} \\ \mathbf{ls_5 * diff(\tau_t^{tc}) - ls_6 * log(ls_{t-1}/ls_{t-1}^*) + \varepsilon_t^{ls}} \tag{5}$$

Demand for labour is implied by domestic employment (ESA) and frictions on the labour market materialize in domestic unemployment (LFS). Next, we decompose domestic employment ($\mathbf{lt_t}$) into private, personal and public components. The private employment ($\mathbf{lf_t}$) is then driven by potential employment ($\mathbf{lt_t^*}$) with a positive impact of a domestic demand ($\mathbf{yt_t}$) and a negative impact of private labour costs ($\mathbf{rf_t}$) as stated in the Eq.6. Furthermore, we extend the equation for a crowding out of public employment ($\mathbf{lg_t}$) to capture a substitutability between private and public labour markets. Finally, the error correction term is based on an inverted production function of a domestic output that is derived from the Eq.1.

$$\mathbf{dlog(lf_t) = lf_1 * dlog(lt_t^*) - lf_2 * dlog(lg_t) + lf_3 * dlog(lf_{t-1}) + lf_4 * dtfp(yt_t) -} \\ \mathbf{lf_5 * dtfp(rf_t) + lf_6 * cor(lt_{t-1}) + \varepsilon_t^{lf}} \tag{6}$$

The personal ($\mathbf{lh_t}$) and public ($\mathbf{lg_t}$) employment are based on identical behavioural equations. Potential employment ($\mathbf{lt_t^*}$) is then based on productive population ($\mathbf{np_t}$) and potential rates of participation ($\boldsymbol{\eta_t^*}$) and unemployment ($\boldsymbol{\mu_t^*}$) as stated in the Eq.7. Furthermore, we extend the equation with labour taxes and contributions ($\boldsymbol{\gamma_t^{tc}}$) to model their impact on the potential labour force and thus on the potential output in the domestic economy.[10]

$$\mathbf{dlog(lt_t^*) = dlog(np_t) + dlog(\eta_t^*) - diff(\gamma_t^{tc}) + dlog(1 - \mu_t^*)} \tag{7}$$

On the other hand, a domestic capital stock ($\mathbf{kt_t}$) is defined by a capital accumulation method and thus based on a depreciation rate ($\boldsymbol{\delta t_t}$) and domestic investment ($\mathbf{it_t}$) as stated in the Eq.8. It is important to note that we include a net capital stock at the beginning of a corresponding period to capture an evolution of a productive capital that is relevant for the potential output. Depreciation rate ($\boldsymbol{\delta t_t}$) of the domestic economy results from a decomposition of the capital market into sectors of companies, households and government.

$$\mathbf{kt_{t+1} = (1 - \delta t_t) * kt_t + it_t} \tag{8}$$

Next, we decompose domestic investment into private, personal and public components. The private investment ($\mathbf{if_t}$) is based on a domestic demand ($\mathbf{yt_t}$) and an operating surplus ($\mathbf{pf_t}$) with a negative impact of interest rate costs ($\mathbf{lr_t}$) and capital income taxes ($\boldsymbol{\tau_t^{ci}}$) as stated in the Eq.9. Furthermore, we extend the equation for a crowding out of public investment ($\mathbf{ig_t}$), to capture a substitutability between private and public capital markets, and incorporate market expectations about a fiscal policy with a respect to components of public employment ($\mathbf{lg_t}$) and labour costs ($\mathbf{rg_t}$), intermediate consumption ($\mathbf{rc_t}$) and public social transfers ($\mathbf{rt_t}$), to reflect their impact on a confidence of investors. Specifically, we assume that an increase of public expenditures has a negative impact on a confidence of investors and thus results in a decline of private investment.[11] This assumption is consistent with a presence of Ricardian households that base their model decisions on future expectations about a fiscal policy.[12] It is important to

[10] While the contemporaneous changes in effective tax rates influence the domestic labour force, the smooth changes in effective tax rates influence the potential labour force.

[11] For more information see Alesina et al. (2018).

[12] Even though we assume a negative impact of public expenditures on private investment, we abstract from a negative impact of public expenditures on private consumption, in line with estimation results of Afonso and Sousa (2009).

note that while a decline of public expenditures has a positive impact on private investment, an increase of taxes and contributions distorts the potential output and thus supresses an economic performance.[13] This assumption is thus in contrast to standard Keynesian postulates and closer to more complex Neo-Keynesian assumptions. Finally, the error correction term is based on a first order condition with a respect to the capital component (Eq.4).

$$\begin{aligned} \mathbf{dlog(if_t)} &= \mathbf{if_1 * dlog(yt_t) - if_2 * dlog(ig_t) + if_3 * dlog(pf_{t-1}) - if_4 * dlog(lg_t) -} \\ &\mathbf{if_4 * dlog(rg_t) - if_5 * dlog(rc_t) - if_6 * dlog(rt_t) - if_7 * diff(\tau_t^{ci}) -} \\ &\mathbf{if_8 * diff(lr_{t-1}) + if_9 * cor(it_{t-1}) + \varepsilon_t^{if}} \end{aligned} \tag{9}$$

The personal investment ($\mathbf{ih_t}$) is then based on a disposable income ($\mathbf{hi_t}$), interest rate costs ($\mathbf{lr_t}$) and capital income taxes ($\boldsymbol{\tau_t^{ci}}$). Again, we extend the equation for a crowding out of public investment ($\mathbf{ig_t}$) and market expectations about a fiscal policy with a respect to components of public employment ($\mathbf{lg_t}$) and labour costs ($\mathbf{rg_t}$), intermediate consumption ($\mathbf{rc_t}$) and public social transfers ($\mathbf{rt_t}$). Finally, the public investment ($\mathbf{ig_t}$) is based on a combination of actual ($\mathbf{yt_t}$) and potential ($\mathbf{yt_t^*}$) output in the domestic economy.

3.2 Demand side block

Demand side of the economy captures a decomposition of gross domestic product into private and public consumption, domestic investment and trade variables. We start with a definition of private consumption ($\mathbf{ct_t^*}$) that is based on a disposable income ($\mathbf{hc_t}$) in a long horizon (Eq.10). We abstract from an impact of domestic assets on private consumption for two reasons. First, since a gross public debt and net foreign assets are mostly owned by foreign investors, we assume that households are not owners of these assets. Second, even though a private capital stock is an important component of a domestic wealth, relevant also for an intertemporal decision of households between consumption and leisure, we do not find any historical evidence of this relationship for the Slovak economy.

$$\mathbf{log(ct_t^*) = ct_1 - ct_2/sqrt(t) + ct_3 * log(hc_t) + \zeta_t^{ct}} \tag{10}$$

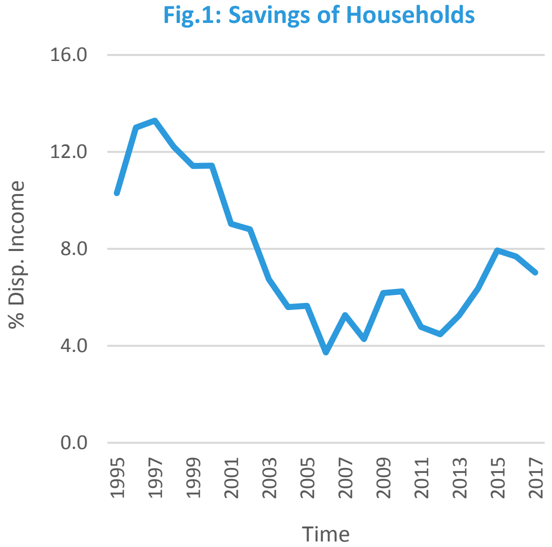
On the other hand, we enrich the equation by constant ($\mathbf{ct_1}$) and trend ($\mathbf{ct_2}$) components to capture a historical decline in a savings rate of households (Fig.1), in line with a convergence process of the Slovak economy. This is driven by a fact that while higher savings contribute to domestic productivity in poor countries, a positive impact of a capital formation is much smaller in rich countries, see for example Aghion et al. (2006). Private consumption ($\mathbf{ct_t}$) is then based on a disposable income ($\mathbf{hc_t}$) and interest rate costs ($\mathbf{sr_t}$) in a short horizon (Eq.11). While the first term reflects a degree of a Non-Ricardian behaviour of households, the latter term is consistent with the Euler equation. We thus incorporate both Ricardian and Non-Ricardian types of households into the model. The equation concludes with an error correction term.

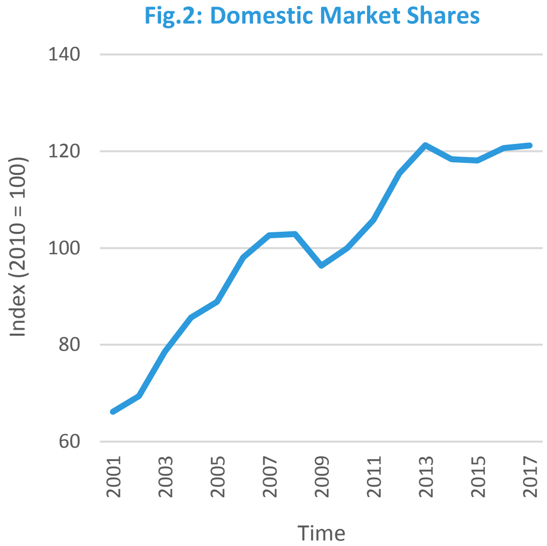
$$\begin{aligned} \mathbf{dlog(ct_t)} &= \mathbf{ct_4 * dlog(hc_t) + ct_5 * dlog(ct_{t-1}) + ct_6 * dlog(hc_{t-1}) -} \\ &\mathbf{ct_7 * diff(sr_{t-1}) - ct_8 * log(ct_{t-1}/ct_{t-1}^*) + \varepsilon_t^{ct}} \end{aligned} \tag{11}$$

Public consumption ($\mathbf{gn_t}$) consists of public compensations ($\mathbf{lwg_t}$), public depreciation ($\boldsymbol{\delta}\mathbf{kg_t}$), intermediate consumption ($\mathbf{ic_t}$), production taxes ($\mathbf{ot_t}$), natural transfers ($\mathbf{nt_t}$) and market production ($\mathbf{mp_t}$) as stated in the Eq.12. Public compensations then consist of employment ($\mathbf{lg_t}$) and labour cost ($\mathbf{wg_t}$) components and public depreciation is further implied by a public capital stock ($\mathbf{kg_t}$) under a public depreciation rate ($\boldsymbol{\delta}\mathbf{g_t}$). Next, intermediate consumption ($\mathbf{ic_t}$) is based on a combination of actual ($\mathbf{yn_t}$) and potential ($\mathbf{yn_t^*}$) output. Finally, natural transfers ($\mathbf{nt_t}$) and market production ($\mathbf{mp_t}$) are implied by a mean-reversion process with a respect to compensations of employees ($\mathbf{lwt_t}$) and a gross value added ($\mathbf{va_t}$) in the domestic economy.

$$\mathbf{gn_t = lwg_t + \delta kg_t + ic_t + ot_t + nt_t - mp_t} \tag{12}$$

[13] For more information see Alesina et al. (2018).





Export of goods and services $(\mathbf{xt_t})$ is driven by an external demand $(\mathbf{dx_t})$ and thus based on weighted imports of our most important trading partners (Eq.13). The imports of our trading partners are based on chain linked volumes in domestic currencies to exclude distortions from an inflation and exchange rate development. The equation is further enriched by a degree of price and real competitiveness and thus by (i) a real exchange rate $(\mathbf{zx_t})$ that is equal to a nominal exchange rate $(\mathbf{er_t})$ plus external prices $(\mathbf{pw_t})$ minus domestic prices $(\mathbf{px_t})$ and (ii) a productivity differential $(\mathbf{da_t})$ between domestic and external factor productivity to approximate a historical development of domestic market shares.[14] Specifically, the domestic export grows faster than the external demand, in line with a structural trend in domestic market shares (Fig.2).

$$\mathbf{dlog(xt_t) = xt_6 * dlog(dx_t) + xt_7 * dlog(zx_t) + xt_8 * dlog(da_t) - xt_9 * log(xt_{t-1}/xt^*_{t-1}) + \varepsilon^{xt}_t} \tag{13}$$

On the other hand, import of goods and services $(\mathbf{mt_t})$ is driven by a domestic demand $(\mathbf{dm_t})$ and thus based on import intensities of private and public consumption, domestic investment and domestic export (Eq.14).[15] It is important to note that we distinguish between the import intensity of private investment, that consists mostly of a technical and transport equipment, and the import intensity of personal and public investment, that consist mostly of buildings and dwellings. The equation is further enriched by the cost items and thus by (i) a real exchange rate $(\mathbf{zm_t})$ that is equal to a nominal exchange rate $(\mathbf{er_t})$ plus external prices $(\mathbf{pw_t})$ minus domestic prices $(\mathbf{pm_t})$ and (ii) an oil price differential $(\mathbf{do_t})$ that is equal to a dollar exchange rate $(\mathbf{us_t})$ plus crude oil prices $(\mathbf{oil_t})$ minus domestic prices $(\mathbf{pm_t})$.

$$\mathbf{dlog(mt_t) = mt_6 * dlog(dm_t) - mt_7 * dlog(zm_t) - mt_8 * dlog(do_t) - mt_9 * log(mt_{t-1}/mt^*_{t-1}) + \varepsilon^{mt}_t} \tag{14}$$

Next, we obtain a net domestic surplus $(\mathbf{ds_t})$ as a difference between a gross value added $(\mathbf{va_t})$, compensations of employees $(\mathbf{lwt_t})$ and depreciation of capital $(\boldsymbol{\delta}\mathbf{kt_t})$. We then extract a private mixed surplus $(\mathbf{ms_t})$ and capital income taxes $(\mathbf{cit_t})$ to obtain a net operating surplus $(\mathbf{os_t})$ as results from the Eq.15. We thus approximate profits of domestic firms that further enter the equation for private investment (Eq.9). Inventories and valuables are set exogenous to the model as a component of a statistical discrepancy.

$$\mathbf{va_t = lwt_t + \boldsymbol{\delta} kt_t + ms_t + cit_t + os_t} \tag{15}$$

[14] It is important to note that the market shares are flat in a steady state.
[15] We calibrate the domestic demand from import intensities of private consumption, public consumption, domestic investment and domestic export that are obtained from national input-output tables in 5-year intervals.

3.3 Wages and prices

Potential labour costs ($\mathbf{wt_t^*}$) are based on a first order condition with a respect to the labour component (Eq.3) and thus on the potential productivity ($\mathbf{lp_t^*}$). On the other hand, we decompose domestic labour costs ($\mathbf{wt_t}$) into private and public components. Private labour costs ($\mathbf{rf_t}$) are then driven by a labour productivity ($\mathbf{lp_t}$) and intersectoral spillovers from public labour costs ($\mathbf{rg_t}$) as stated in the Eq.16. The equation is further extended with contributions of employers to a private sector ($\boldsymbol{\tau}_t^{fc}$) and a public sector ($\boldsymbol{\tau}_t^{gc}$) to divide a direct tax burden between both employers and employees. On the other hand, contributions of employees ($\boldsymbol{\tau}_t^{lc}$) and labour income taxes ($\boldsymbol{\tau}_t^{li}$) are born by households and exposed in actual and potential labour force.[16] Furthermore, we enrich the equation by (i) an unemployment gap ($\boldsymbol{\mu}_t$) to approximate a bargaining power of firms and households and (ii) capital income taxes ($\boldsymbol{\tau}_t^{ci}$) to measure a direct impact of a capital tax burden on a labour cost formation. Next, we determine a price component of domestic labour costs by both consumption ($\mathbf{pc_t}$) and output ($\mathbf{py_t}$) prices to capture a mark-up between employers and employees on the domestic labour market. The equation concludes with an error correction term. Public labour costs ($\mathbf{rg_t}$) are based on an identical behavioural equation.

$$\begin{gathered}\mathbf{dlog(rf_t) = wf_1 * dlog(lp_t) + wf_2 * dlog(rg_{t-1}) + wf_3 * dlog(lp_{t-1}) + wf_4 * dlog(pc_t) -} \\ \mathbf{wf_4 * dlog(py_t) - wf_5 * gap(\boldsymbol{\mu}_t) + wf_6 * diff(\boldsymbol{\tau}_t^{gc}) + wf_7 * diff(\boldsymbol{\tau}_t^{fc}) - wf_8 * diff(\boldsymbol{\tau}_t^{ci}) -} \\ \mathbf{wf_9 * log(wt_{t-1}/wt_{t-1}^*) + \boldsymbol{\varepsilon}_t^{wf}}\end{gathered} \tag{16}$$

Potential output prices ($\mathbf{py_t^*}$) are implied by unit labour costs ($\mathbf{ulc_t}$) under a flexible price setting of domestic producers. Production prices ($\mathbf{pp_t}$) are then driven by a combination of unit labour costs ($\mathbf{ulc_t}$) and inflation expectations ($\mathbf{pl_t}$) as stated in the Eq.17. However, we need to point out that the inflation expectations are obtained as a discounted moving average of a historical inflation rate and are thus not defined in a model consistent manner as in rational expectations models.[17] Furthermore, we enrich the equation by an asymmetric impact of capital income taxes ($\boldsymbol{\tau}_t^{ci}$) to capture a price setting of domestic producers under an imperfect competition. This definition thus implies different impulse response functions for an increase and a decline of capital income taxes. Finally, the error correction term is based on a flexible price indicator (Fig.3) and thus on a ratio between actual ($\mathbf{py_t}$) and potential ($\mathbf{py_t^*}$) output prices.

$$\begin{gathered}\mathbf{dlog(pp_t) = pp_1 * dlog(ulc_t) + pp_2 * dlog(pl_t) + pp_3 * dlog(ulc_{t-1}) + pp_4 * up(\boldsymbol{\tau}_t^{ci}) +} \\ \mathbf{pp_5 * down(\boldsymbol{\tau}_t^{ci}) - pp_6 * \ log(py_{t-1}/py_{t-1}^*) + \boldsymbol{\varepsilon}_t^{pp}}\end{gathered} \tag{17}$$

Next, we decompose consumer prices ($\mathbf{cp_t}$) into core and energy components, in line with their historical shares in a consumption basket (Fig.4).[18] The core component ($\mathbf{pn_t}$) is then driven by production ($\mathbf{pp_t}$) and import ($\mathbf{pm_t}$) prices and a combination of backward-looking and forward-looking expectations as stated in the Eq.18. Furthermore, we enrich the equation by (i) a domestic output gap ($\mathbf{yt_t}$) to capture a degree of economic slack, and (ii) a productivity differential ($\mathbf{bs_t}$) between domestic and external labour productivity to approximate the Balassa-Samuelson effect. The equation is further extended with an asymmetric impact of value added taxes ($\boldsymbol{\tau}_t^{va}$) and net consumption taxes ($\boldsymbol{\tau}_t^{cn}$) to approximate an actual impact of an indirect tax burden on the consumer prices.[19] On the other hand, the energy component ($\mathbf{pe_t}$) is driven by production ($\mathbf{pp_t}$) and crude oil ($\mathbf{oil_t}$) prices and inflation expectations ($\mathbf{pl_t}$).

$$\begin{gathered}\mathbf{dlog(pn_t) = pn_6 * dlog(pp_t) + pn_7 * dlog(pl_t) + pn_8 * dlog(pm_t) + pn_9 * dlog(pn_{t-1}) +} \\ \mathbf{pn_{10} * dlog(bs_t) + pn_{11} * gap(yt_t) + pn_{12} * up(\boldsymbol{\tau}_t^{va}) + pn_{13} * down(\boldsymbol{\tau}_t^{va}) + pn_{14} * up(\boldsymbol{\tau}_t^{cn}) +} \\ \mathbf{pn_{15} * down(\boldsymbol{\tau}_t^{cn}) - pn_{16} * log(pn_{t-1}/pn_{t-1}^*) + \boldsymbol{\varepsilon}_t^{pn}}\end{gathered} \tag{18}$$

---

[16] These assumptions are consistent with estimation results of Kľúčik (2015).

[17] Forward-looking inflation expectations are obtained as a discounted moving average of a monthly consumer inflation rate on a 5-year horizon, with the discount parameter equal to 0.987, in line with Cieslak and Povala (2015).

[18] Decomposition of consumer prices is based on a harmonized index of consumer prices (HICP).

[19] An asymmetric impact of indirect taxes on consumer prices is in line with literature on tax elasticities, see for example Melioris (2015).

Fig.3: Flexible Price Indicator

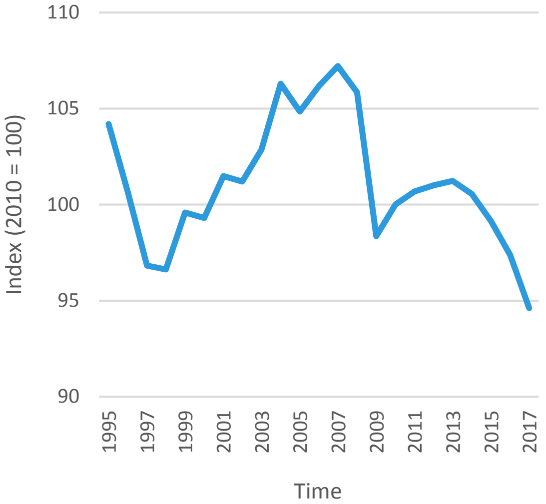
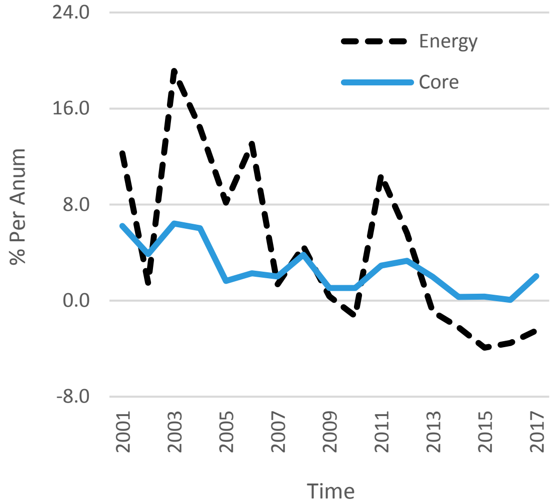


Fig.4: Model Inflation Rates



A deflator of investment ($\mathbf{pi_t}$) is then driven by a combination of production ($\mathbf{pp_t}$) and import ($\mathbf{pm_t}$) prices. We abstract from sectoral deflators for domestic investment, due to a lack of available historical data. On the other hand, a deflator of government ($\mathbf{pg_t}$) is driven by a combination of production ($\mathbf{pp_t}$) and consumption ($\mathbf{pc_t}$) prices. Finally, export ($\mathbf{px_t}$) and import ($\mathbf{pm_t}$) deflators are driven by domestic ($\mathbf{pp_t}$) and external ($\mathbf{pw_t}$) prices.

3.4 Interest rate block

We distinguish between two types of interest rates in the model to incorporate relationships on financial markets and approximate a term structure of interest rates (Fig.5). First, nominal market rates are set exogenous to the model and correspond to the 3-month Euribor rate ($\mathbf{eu_t}$). This is driven by an absence of an independent monetary policy and is thus in contrast to macroeconomic models with endogenous policy rules. Second, government bond yields are an endogenous part of the model and correspond to 10-year Slovak bonds ($\mathbf{sk_t}$), that further consist of ten-year German bonds ($\mathbf{de_t}$) and a domestic risk premium ($\mathbf{pr_t}$). While the short-term interest rates ($\mathbf{eu_t}$) approximate consumer loans and influence private consumption (Eq.11), the long-term interest rates ($\mathbf{sk_t}$) approximate investment loans and influence private investment (Eq.9). The risk premium is thus an important component of the model that captures an impact of a fiscal policy on the potential output as a capital cost item (Eq.4). We further assume that the risk premium ($\mathbf{pr_t}$) is based on an evolution of a public debt ($\mathbf{dp_t^*}$) and a current account ($\mathbf{ca_t^*}$) as stated in the Eq.19.

$$\mathbf{pr_t} = \boldsymbol{\phi_1} + \boldsymbol{\phi_2} * \mathbf{pr_{t-1}} + \boldsymbol{\phi_3} * \mathbf{dp_t^*} - \boldsymbol{\phi_4} * \mathbf{ca_t^*} \qquad (19)$$

Calibration of the parameters is based on a two-step approach. First, we assume that an impact of a public debt ($\boldsymbol{\phi_3}$) and a current account ($\boldsymbol{\phi_4}$) on the risk premium should be equal before and after the adoption of Euro. We thus compute average values of these variables before and after the adoption of Euro and calibrate the parameters from a system of linear equations. We assume that the adoption of Euro reduces the risk premium by a half percentage point, in line with a higher confidence of investors. This assumption is consistent with a historical development of risk premiums in the Visegrad countries, i.e. a difference between the 10-year Visegrad bonds and the 10-year German bonds. Specifically, we compute a difference between the Visegrad premium and the Slovak premium to approximate a relative confidence of investors to the Slovak economy (Fig.6) and compare its average values before and after the adoption of Euro.[20] Second, we estimate both constant ($\boldsymbol{\phi_1}$) and persistence ($\boldsymbol{\phi_2}$) parameters by the Ordinary Least Squares (OLS) under linear restrictions.

[20] We construct the Visegrad premium as an average risk premium of the Visegrad countries, i.e. Czechia, Hungary, Poland and Slovakia.

Fig.5: Model Interest Rates

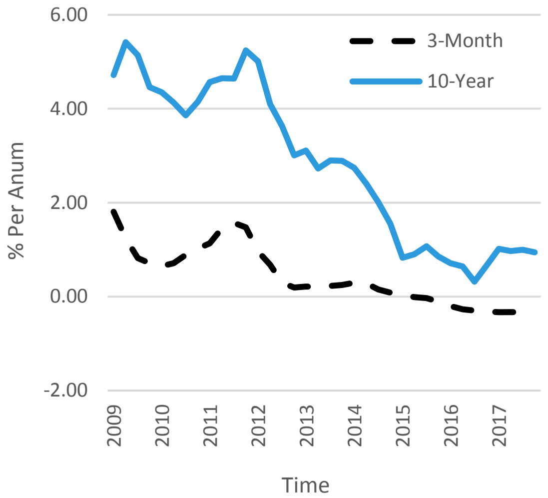
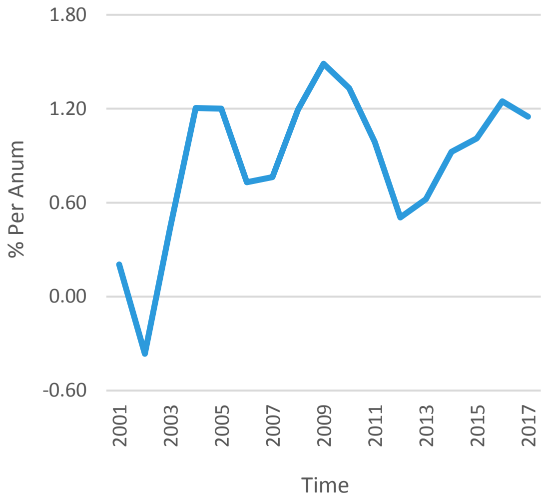


Fig.6: Confidence of Investors



We thus abstract from the nonlinear effects of a fiscal policy on a confidence of investors, due to an absence of a historical evidence. This is driven by a short data sample and a small variance of the fiscal variables. An alternative method to approximate the nonlinear effects is an application of panel estimation of the Visegrad countries, see for example Kľúčik (2015). However, we abstract from this approach for two reasons.

First, a monetary policy shift implied by the adoption of Euro results in a different structure of the domestic premium with a respect to other Visegrad countries. Before the adoption of Euro, the domestic premium was equal to a sum of a term premium, that was based on a domestic monetary policy, and a country premium, that consists of credit and liquidity components. On the other hand, an absence of an independent monetary policy after the adoption of Euro implies a trivial term premium for the domestic economy. For more information about a structure of the domestic premium see Ódor and Povala (2016). Second, an unconventional monetary policy of the European Central Bank (ECB) in the recent years, that is driven mostly by the Quantitative Easing (QE), creates another form of heterogeneity between the Slovak economy and other Visegrad countries that is not captured by estimation methods.

3.5 Block of households

Budgetary restrictions of households define a disposable income ($\mathbf{hn_t}$) under (i) private revenues that come from domestic ($\mathbf{lwt_t}$) and external ($\mathbf{lwe_t}$) compensations, a depreciation of households ($\mathbf{\delta kh_t}$), public social transfers ($\mathbf{st_t}$) and a private mixed surplus ($\mathbf{ms_t}$) and (ii) private expenditures that are spent on taxes ($\mathbf{toh_t}$) and contributions ($\mathbf{coh_t}$) of households, as stated in the Eq.20. We incorporate also net property transfers ($\mathbf{hp_t}$) and net current transfers ($\mathbf{ho_t}$) that are implied by a mean-reversion process with a respect to a gross domestic product.

$$\mathbf{hn_t = lwt_t + lwe_t + \delta kh_t + st_t + ms_t + hp_t + ho_t - toh_t - coh_t} \qquad (20)$$

Public social transfers ($\mathbf{st_t}$) are then based on the potential output ($\mathbf{yn_t^*}$) and domestic employment ($\mathbf{lt_t}$) and labour costs ($\mathbf{wt_t}$) to approximate different types of pension transfers, as stated in the Eq.21. Furthermore, we extend the equation with an unemployment rate ($\mathbf{\mu_t}$) and a participation rate ($\mathbf{\eta_t}$) to approximate different types of labour market transfers. On the other hand, a private mixed surplus ($\mathbf{ms_t}$) is based on the potential output ($\mathbf{yn_t^*}$) and a net domestic surplus ($\mathbf{ds_t}$).

$$\mathbf{dlog(st_t) = st_2 * dlog(yn_t^*) + st_3 * dlog(lt_t) + st_3 * dlog(wt_t) + st_4 * dlog(\eta_t) +}$$
$$\mathbf{st_4 * dlog(\mu_t) + st_8 * cor(st_{t-1}) + \varepsilon_t^{st}} \qquad (21)$$

3.6 Block of government

Budgetary restrictions of government define a fiscal balance ($\mathbf{bp_t}$) under (i) public revenues that are given by direct taxes ($\mathbf{dit_t}$), indirect taxes ($\mathbf{int_t}$), social contributions ($\mathbf{soc_t}$) and public depreciation ($\boldsymbol{\delta}\mathbf{kg_t}$) and (ii) public expenditures that are given by public consumption ($\mathbf{gt_t}$), public investment ($\mathbf{ig_t}$), public social transfers ($\mathbf{st_t}$), interest rate costs ($\mathbf{ir_t}$) and other capital costs ($\mathbf{oc_t}$), as stated in the Eq.22. We incorporate also net property transfers ($\mathbf{gp_t}$), net current transfers ($\mathbf{go_t}$), net external transfers ($\mathbf{ge_t}$) and net capital transfers ($\mathbf{gc_t}$) that are based on external factors and thus set exogenous to the model.

$$\begin{gathered}\mathbf{bp_t = dit_t + int_t + soc_t + \boldsymbol{\delta} kg_t + gp_t + go_t + ge_t + gc_t -} \\ \mathbf{gt_t * pg_t - ig_t * pi_t - st_t - ir_t - oc_t}\end{gathered} \tag{22}$$

The direct taxes ($\mathbf{dit_t}$) consist of labour income taxes ($\mathbf{lit_t}$) that are based on gross wages and salaries, personal income taxes ($\mathbf{pit_t}$) that are based on personal compensations and capital income taxes ($\mathbf{cit_t}$) that are based on a net operating surplus. On the other hand, the indirect taxes ($\mathbf{int_t}$) consist of net consumption taxes ($\mathbf{cnt_t}$) that are based on private consumption and gross domestic product and value added taxes ($\mathbf{vat_t}$) that are based on private consumption, public investment and intermediate consumption.[21] Furthermore, the interest rate costs ($\mathbf{ir_t}$) are based on a previous value of a public debt ($\mathbf{dp_t}$) and an effective interest rate ($\mathbf{ef_t}$) to capture a price of outstanding and new debt portfolios. We need to mention that the interest rate costs ($\mathbf{ir_t}$) include also a domestic risk premium ($\mathbf{pr_t}$) that is further influenced by a fiscal policy and thus produce a fiscal loop for a public debt. Finally, we determine the public debt ($\mathbf{dp_t}$) with an outstanding debt from a previous period and a fiscal balance ($\mathbf{bp_t}$) as stated in the Eq.23. We need to mention that we abstract from an impact of a stock flow adjustment on the public debt and do not distinguish between net and gross public debt.

$$\mathbf{dp_t = dp_{t-1} - bp_t} \tag{23}$$

Endogenous fiscal rules are based on public expenditures, in line with Claeys et al. (2016), Darvas et al. (2018) and Feld et al. (2018). Specifically, we assume that government corrects public expenditures in line with a deviation of a fiscal balance ($\mathbf{bp_t^*}$) and a public debt ($\mathbf{dp_t^*}$) from their target paths. While the fiscal balance is pinned down by the public debt in a steady state, we allow for separate target paths of both fiscal variables in a medium horizon. Finally, we enrich the fiscal rules by a domestic output gap ($\mathbf{yt_t}$), to model a counter-cyclical policy of a fiscal authority. Fiscal reaction functions ($\mathbf{fr_t}$) for different components of a public budget are thus given by the Eq.24. It is important to note, that we need to calibrate the fiscal rules due to a short data sample and a lack of historical evidence.

$$\mathbf{dev(fr_t) = \Lambda_1 * dev(bp_t^*) - \Lambda_2 * dev(dp_t^*) - \Lambda_3 * gap(yt_t)} \tag{24}$$

Default fiscal strategy is then based on public compensations, public investment, intermediate consumption and public social transfers. We prefer expenditure over revenue components of a public budget, due to a simple practical implementation and plausible stabilization properties of the model. Furthermore, the expenditure components produce more convenient fiscal multipliers with a respect to the revenue components. Finally, a fiscal policy based on the expenditure components is more consistent with a policy focus on expenditure ceilings proposed by Šuchta et al. (2018). An alternative approach to a fiscal policy could be based on a combination of revenue and expenditure components of a public budget, as proposed by Kľúčik (2015). For a comparison of different consolidation strategies in the European Union see Cournede et al. (2013) and Beetsma et al. (2018).

[21] Consumption taxes consist of excise taxes, that are based on private consumption, and product taxes, that are based on gross domestic product, in line with their historical shares. It is important to note that only relevant parts of private consumption, public investment and intermediate consumption form a macroeconomic basis for value added taxes. Furthermore, we abstract from a fiscal drag in a construction of a macroeconomic basis for labour taxes and contributions.

Next, we decompose a fiscal balance into structural and cyclical components, with the latter one derived from a domestic output gap.[22] It is important to note that the structural balance is implied by the model and does not influence a fiscal policy of a public sector. However, a practical implementation of a fiscal policy should be based on a structural balance that is consistent with official fiscal rules of the European Commission. Consolidation strategy should be further driven by a budgetary plan to maintain macroeconomic forecasts consistent with the fiscal projections. We thus need to construct a consolidation mix in line with the budgetary plan that stabilizes the structural balance. However, this is problematic for three main reasons. First, a construction of a fiscal block in the model is not identical to a decomposition applied by the budgetary plan. Second, revisions of national accounts create inconsistences between an actual state of the economy and the budgetary plan. Third, formation of the budgetary plan on an annual basis is not consistent with more frequent macroeconomic forecasts.

To overcome issues with the budgetary plan and provide macroeconomic forecasts that are consistent with the fiscal projections, we implement a two-step forecasting process that is based on a proportional consolidation. In the first step, we turn off the fiscal rules and forecast model variables with no fiscal restrictions to obtain a baseline forecast of the domestic economy. In the second step, we target a structural balance from the budgetary plan under a proportional consolidation that is distributed between public revenues (50%) and public expenditures (50%), in line with historical shares of the budgetary components. Even though we prefer fiscal rules that are based on public expenditures for an evaluation of a model performance, we tend to apply a neutral consolidation mix for macroeconomic forecasts, due to a lack of relevant information about a future fiscal policy.

Furthermore, the consolidation mix that is applied for macroeconomic forecasts is different from the fiscal rules that are proposed in the model, since (i) we need to target a structural public balance in contrast to a total public balance and a gross public debt and (ii) we need to obtain a target value of the structural balance in each simulation period that is not consistent with a reaction function of the fiscal rules. On the other hand, this approach does not stabilize the model in a steady state, due to an unconstrained public debt, and is thus not applicable for an evaluation of a model performance.

[22] An alternative approach is based on a decomposition of public revenues and expenditures by multivariate filters.

4 Methodology and data

We propose a structural econometric model of the Slovak economy that is built on Fagan et al. (2001) and adapted for the domestic conditions. Furthermore, we construct a sectoral decomposition of labour and capital markets and comprehensive budgetary restrictions of macroeconomic agents. Finally, the model is enriched by a fiscal block and is thus suitable for a policy analysis. Since the Slovak Republic is characterized as a small open economy without an independent monetary policy, we build a single country model and exogenize external variables, i.e. a total external demand $(\mathbf{dx_t})$, an effective external price $(\mathbf{pw_t})$, a crude oil price $(\mathbf{oil_t})$, 3-month Euribor rates $(\mathbf{eu_t})$, 10-year German bonds $(\mathbf{de_t})$, an effective exchange rate $(\mathbf{er_t})$ and a dollar exchange rate $(\mathbf{us_t})$, in line with forecasts of international institutions. Furthermore, we define a stochastic path for a total factor productivity $(\mathbf{at_t})$, the potential unemployment rate $(\boldsymbol{\mu}_t^*)$ and the potential participation rate $(\boldsymbol{\eta}_t^*)$ to exogenize potential variables and close the model. Other model variables are treated as endogenous.

The model consists of 22 error correction equations and a number of macroeconomic identities and could be decomposed into six model blocks: a supply side block, a demand side block, a block of wages and prices, an interest rate block, a block of households and a block of government. The error correction equations are further restricted by homogeneity conditions and estimated by the Ordinary Least Squares (OLS) on a time period from the first quarter of 1995 to the last quarter of 2017. Quarterly data are seasonally adjusted and benchmarked to annual values.[23] The model is solved by a trust region algorithm that is derived from the Newton method. Estimation of model parameters is implemented in the R software and solution of model equations is implemented in the Matlab software. The model is based on quarterly data and designed for macroeconomic projections on a medium horizon.

Estimation of the potential output $(\mathbf{yt}_t^*)$ from historical data is based on a Cobb-Douglas production function. First, we identify the capital component $(\mathbf{kt_t})$ with the Perpetual inventories method (PIM) that includes information about domestic investment, domestic depreciation and net capital assets in reproductive prices.[24] This method allows us to decompose a nominal capital stock into real and price components under existence of a time variant depreciation rate and different price deflators for outstanding and new capital assets. This decomposition results in (i) a higher inflation rate of domestic capital with a respect to domestic investment, in line with a changing composition of the domestic investment from buildings and dwellings to a technical equipment and (ii) a higher depreciation rate with a respect to Reľovský and Široká (2009) or Kľúčik (2015) that results from a difference between net and gross capital stock.

Second, we estimate the labour component $(\mathbf{lt}_t^*)$ from a dataset of productive population $(\mathbf{np_t})$, potential participation $(\boldsymbol{\eta}_t^*)$ and potential unemployment $(\boldsymbol{\mu}_t^*)$. We incorporate national population from 15 to 64 years and eliminate structural breaks in the time series that are driven by a low frequency of a population census. The participation rate $(\boldsymbol{\eta}_t)$ is then decomposed into potential and cyclical components by the Hodrick-Prescott filter. On the other hand, a decomposition of the unemployment rate $(\boldsymbol{\mu}_t)$ is based on the Kalman filter that incorporates the Phillips curve to exploit a functional relationship between an inflation rate and an unemployment gap. We thus obtain a non-accelerating inflation rate of unemployment (NAIRU), a popular approximation for the natural rate of unemployment, in line with Habrman and Rybák (2016).

Finally, to decompose a domestic output $(\mathbf{yt_t})$ into potential and cyclical components, we combine benefits of a production function approach, to obtain information about labour $(\mathbf{lt}_t^*)$ and capital $(\mathbf{kt_t})$ production factors, with a multivariate filter approach, to exploit information from a real economy. We thus construct a model of unobserved components with the potential output $(\mathbf{yt}_t^*)$ defined by a production function and thus implied by a stochastic process for

[23] Data are seasonally adjusted by the X13-Arima-Seats method and benchmarked to annual values by the Denton-Cholette method. Sectoral data are then aggregated by the Multivariate Denton method.
[24] We prefer a net capital stock over a gross capital stock, due to a changing composition of domestic investment.

a total factor productivity ($\mathbf{at_t}$) and a domestic output gap pinned down by a number of behavioural equations.[25] Specifically, we exploit relationships between the output gap and an inflation rate (Phillips curve), an unemployment gap (Okun's law) and a trade balance (Current account). The model is estimated by the Kalman filter with the Bayesian interface. We thus propose one of the most robust and complex view of potential output that is estimated from both potential and cyclical side of an economy. See for example Havik et al. (2014) for a production function approach applied by the ECB or Blagrave et al. (2015) for a multivariate filter approach applied by the IMF. Finally, we mention the paper by Darvas and Simon (2015), that extends multivariate filters for a current account and thus incorporates open economy considerations into estimation of potential output. We assume that this extension of standard equations applied by multivariate filters, i.e. the Phillips curve and the Okun's law, is crucial for a reasonable identification of potential output in small open economies.

Next, we construct an indicator of an external demand ($\mathbf{dx_t}$) as weighted imports of our most important trading partners. The import shares are based on individual exports of Slovakia to particular countries and these data are obtained from the Eurostat. Similar aggregation method is applied for an effective external price ($\mathbf{pw_t}$) and an effective exchange rate ($\mathbf{er_t}$). We need to mention that a construction of the external variables is based on economies of the Euro Area and the Visegrad Group.[26] We prefer this specification over a single economy of the Euro Area, due to a significant contribution of the Visegrad Group to both domestic export and import.[27] Historical time series of a crude oil price ($\mathbf{oil_t}$), a dollar exchange rate ($\mathbf{us_t}$) and a nominal market rate ($\mathbf{eu_t}$) are received from the Bloomberg. Yields on government bonds are obtained from a term structure of interest rates that is provided by the Bundesbank of Germany ($\mathbf{de_t}$) and the National bank of Slovakia ($\mathbf{sk_t}$). Data on gross domestic product and domestic labour market are obtained from the ESA national accounts with a baseline year 2010. Sectoral decomposition of the domestic economy is based on the ESA sectoral accounts of companies, households and government. Taxes and contributions are also constructed under the ESA methodology. Domestic data are obtained from the Statistical Office and the Institute for Financial Policy.

[25] It is important to note that we estimate the potential factor productivity for a Cobb-Douglas production function and abstract from an actual factor productivity obtained as the Solow residual. Labour and capital components are set exogenous to this model.

[26] Total external demand is based on individual imports of Germany, Czechia, France, Poland, Austria, Hungary, Italy and Spain. External prices and exchange rates are constructed for Euro area, Czechia, Poland and Hungary.

[27] Approximately 35% and 65% of domestic exports and 40% and 60% of domestic imports are based on the Visegrad Group and the Euro Area.

5 Model parametrization

Parametrisation of the model is based on a combination of calibration and estimation and we distinguish between four basic groups of model parameters. First, equilibrium parameters that pin down a convergence process of the model and are calibrated in line with related literature and structural assumptions about the domestic economy. Second, structural parameters that capture macroeconomic ratios and are based on a historical development of model variables. Third, behavioural parameters that define empirical properties of the model and are mostly estimated with econometric methods, and finally, fiscal parameters that capture a structure and a magnitude of a fiscal policy and its impact on the domestic economy. These parameters are calibrated in line with impulse response functions. The estimation process then consists of one-by-one estimation of individual empirical equations. Specifically, the error correction equations are restricted by homogeneity conditions and calibration of individual parameters and estimated by the Ordinary Least Squares (OLS).

5.1 Steady state calibration

Steady state of the model is implied by a set of equilibrium parameters that includes output, population and price dynamics, depreciation, unemployment and participation rates and interest and exchange rates. Specifically, we set an equilibrium value for an output growth to 2.5% and for a population growth to 0.0%, in line with our assumptions on a long horizon.[28] Furthermore, we assume that domestic inflation converges to an inflation target of the ECB under a law of one price and thus set an equilibrium value for an inflation rate to 2.0%. However, it is important to note that a convergence process of the domestic economy implies higher domestic prices with a respect to the external ones in a medium horizon. This assumption is in line with a price convergence under the Balassa-Samuelson effect.[29]

Next, we set a steady state for a depreciation rate (Fig.7) equal to 4.0%, for an unemployment rate (Fig.8) equal to 5.0% and for a participation rate (Fig.9) equal to 75.0%, in line with structural trends in historical time series. We further assume that a real interest rate in the euro area is equal to 1.0% on a short horizon, i.e. for the market rates, and 1.5% on a long horizon, i.e. for the government bonds. This assumption is consistent with an estimation of the natural rate of interest over the last 15 years, for more information see Holston et al. (2016). On the other hand, a real exchange rate is set as constant in a steady state (Fig.10), in line with a constant value of a nominal exchange rate and a law of one price.

Furthermore, we calibrate a set of structural parameters from a historical dataset and thus fix a share of capital on production ($\boldsymbol{\beta}$) equal to 56.0%, in line with a historical ratio between compensations of employees and gross domestic product (Fig.11), and fix a share of investment on output ($\boldsymbol{\alpha}$) equal to 24.0%, in line with a historical ratio between domestic investment and gross domestic product (Fig.12).[30] We then calibrate an equilibrium growth of a domestic productivity ($\mathbf{at_t}$) from the production function (Eq.1) and calibrate an equilibrium value of the correction term ($\boldsymbol{\lambda}\mathbf{t_t}$) from the first order condition (Eq.4). Equilibrium value of a public debt with a respect to a domestic output ($\mathbf{dp_t^*}$) is set to 40.0%, in line with a target level of a debt brake proposed by the CBR.[31] It is important to note that a stricter debt rule with a respect to the Maastricht criteria is needed, due to an impact of population ageing on the domestic economy. Equilibrium value of a public balance with a respect to a domestic output ($\mathbf{bp_t^*}$) is then implied by the fiscal identity (Eq.23).

[28] These assumptions are consistent with Kľúčik (2015).

[29] Absence of a domestic currency after the adoption of Euro leads to a zero convergence by a nominal exchange rate what results in a convergence process by a domestic inflation rate. Domestic prices should be thus higher than the external ones throughout the convergence process.

[30] We calibrate the elasticity of labour ($\mathbf{1-\boldsymbol{\beta}}$) from a historical ratio between compensations of employees and gross domestic product and complement with the elasticity of capital ($\boldsymbol{\beta}$), see the definition of the production function (Eq.1).

[31] See for example a macroeconomic model by Múčka (2016). The target value of the debt brake should be reached at the end of 2028.

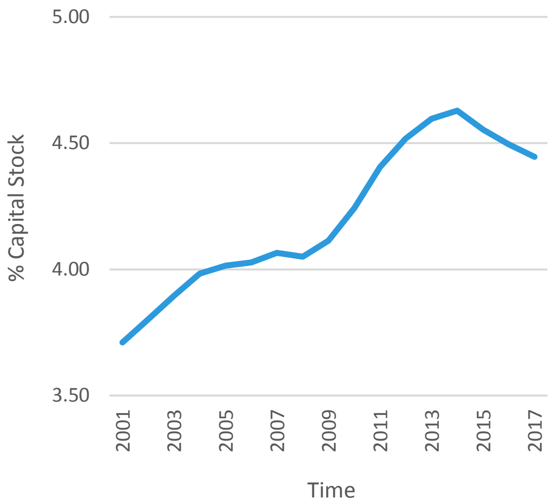


Fig.7: Depreciation of Capital

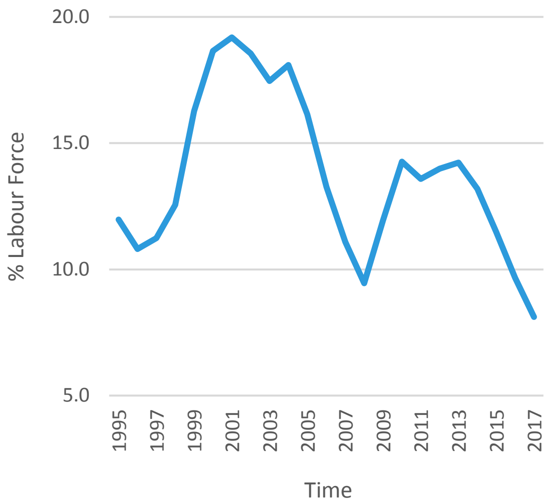


Fig.8: Domestic Unemployment

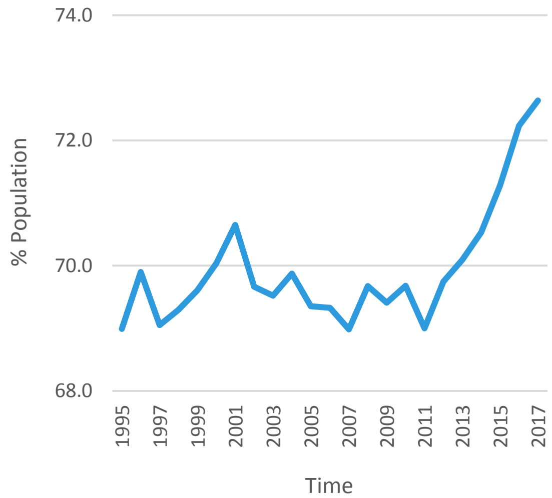


Fig.9: Domestic Participation

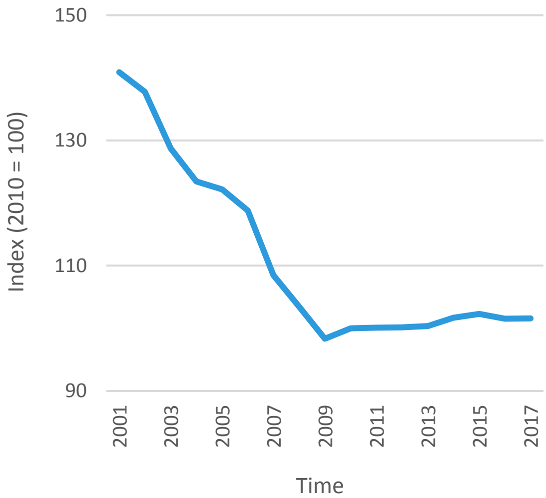


Fig.10: Effective Exchange Rate

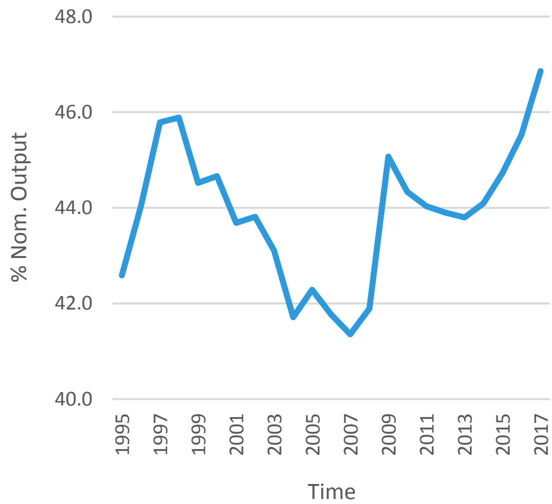


Fig.11: Elasticity of Labour

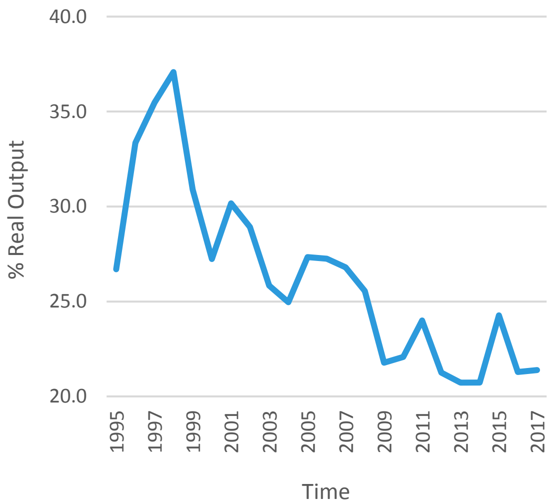


Fig.12: Share of Investment

5.2 Econometric estimation

We start with estimation of private consumption (Eq.D2) that implies a significant impact of both actual ($\mathbf{ct_4}$) and previous ($\mathbf{ct_6}$) disposable income. We further estimate a high degree of consumption persistence ($\mathbf{ct_5}$) and a significant impact of interest rate costs ($\mathbf{ct_7}$) on the private consumption (Eq.D2). Next, we estimate the equation for private investment (Eq.S1) that is driven by a domestic demand ($\mathbf{if_1}$) and an operating surplus ($\mathbf{if_3}$) and the equation for personal investment (Eq.S2) that is based on an actual ($\mathbf{ih_1}$) and previous ($\mathbf{ih_3}$) disposable income.[32] On the other hand, we calibrate an empirical impact of interest rate costs on both private ($\mathbf{if_8}$) and personal ($\mathbf{ih_8}$) investment, in line with a macroeconomic model of Reľovský and Široká (2009). We further expect a stronger impact of interest rate costs on the sector of companies (Eq.S1) than on the sector of households (Eq.S2), due to a higher flexibility of corporate loans with a respect to mortgage loans. Finally, we calibrate a crowding out of public investment ($\mathbf{if_2}, \mathbf{ih_2}$) and market expectations about a fiscal policy with a respect to components of public compensations ($\mathbf{if_4}, \mathbf{ih_4}$), intermediate consumption ($\mathbf{if_5}, \mathbf{ih_5}$) and public social transfers ($\mathbf{if_6}, \mathbf{ih_6}$) from an impulse response analysis.[33]

Next, we calibrate the parameter for an external demand ($\mathbf{xt_6}$) in the export equation (Eq.D4) and the parameter for a domestic demand ($\mathbf{mt_6}$) in the import equation (Eq.D6) to maintain the homogeneity conditions. We further estimate a significant impact of a real exchange rate ($\mathbf{xt_7}$) on the domestic export (Eq.D4) and calibrate an empirical impact of a real exchange rate ($\mathbf{mt_7}$) on the domestic import (Eq.D6) from estimation results of Kľúčik (2015). We need to mention that a sum of exchange rate components in the export and import equations is less than one and thus violates the Marshall-Lerner conditions. However, since only a part of an export deflator (Eq.C6) is driven by domestic prices and only a part of an import deflator (Eq.C8) is driven by external prices, in contrast to the original assumptions, the Marshall-Lerner conditions do not need to hold to obtain plausible simulation results. Furthermore, we overestimate an empirical impact of a productivity differential ($\mathbf{xt_8}$) on the domestic export (Eq.D4), since a positive evolution of domestic market shares leads to a counterintuitive response of model variables to a domestic productivity shock. We thus need to calibrate the model to obtain plausible simulation results. Finally, we assume that a direct impact of an oil price differential ($\mathbf{mt_8}$) on the domestic import (Eq.D6) is equal to zero.

We continue with estimation of private (Eq.S5) and personal (Eq.S6) employment that are based on a domestic demand ($\mathbf{lf_4}, \mathbf{lh_4}$) and domestic labour costs ($\mathbf{lf_5}, \mathbf{lh_5}$) and a combination of potential ($\mathbf{lf_1}, \mathbf{lh_1}$) and persistence ($\mathbf{lf_3}, \mathbf{lh_3}$) components. We estimate a stronger impact of the demand factor on the private employment (Eq.S5) and a stronger impact of the labour cost factor on the personal employment (Eq.S6). On the other hand, we calibrate a crowding out of public employment ($\mathbf{lf_2}, \mathbf{lh_2}$) from an impulse response analysis of macroeconomic and fiscal shocks to the domestic economy.[34]

Estimation of domestic labour force (Eq.S4) then implies a significant impact of productive population ($\mathbf{ls_1}$) and domestic employment ($\mathbf{ls_2}$). Furthermore, we estimate a high degree of labour persistence ($\mathbf{ls_3}$) and calibrate the spillovers from a net labour income ($\mathbf{ls_4}$), in line with a historical evidence from the domestic labour market.[35] Next, we calibrate the spillovers from labour taxes and contributions with a respect to their historical shares on a disposable income of households. Labour income taxes ($\mathbf{ls_7}$) and contributions of employees ($\mathbf{ls_9}$) have

[32] The approximation of a domestic demand with a gross domestic product provides a better fit of historical data than the approximation with a gross value added for both domestic investment and domestic employment.

[33] A one percent increase of a public investment to output ratio in a steady state leads to a decline of a private investment to output ratio by 0.26%. On the other hand, a one percent increase of a public expenditures to output ratio in a steady state leads to a decline of a private investment to output ratio by 0.52%. These numbers are consistent with estimation results of Cavallo and Daude (2011) and Furceri and Sousa (2011).

[34] A one percent increase of a public employment rate in a steady state leads to a decline of a private employment rate by 0.68% and a decline of an unemployment rate by 0.32%. These numbers provide a compromise between estimation results of Lamo et al. (2014) and Behar and Mok (2013).

[35] In the first step, we estimate a coefficient between a domestic labour force and a previous labour income to obtain a significant estimate of a labour to income elasticity. In the second step, we take the estimate from the previous step and calibrate a coefficient between a domestic labour force and an actual labour income to exclude lags from the equation.

thus a stronger impact on the domestic labour force with a respect to personal income taxes ($\mathbf{ls_8}$) and contributions in self-employment ($\mathbf{ls_{10}}$). Furthermore, the calibration aims to find a compromise between estimation results of Fiorito and Zanella (2008) that are based on microeconomic and macroeconomic Frisch elasticities and estimation results of Siebertová et al. (2014) that are based on a microeconomic simulation model. We further distinguish between contributions of employers that are paid to public ($\mathbf{ls_{11}}$) and private ($\mathbf{ls_{12}}$) sectors. The first ones have a limited impact on the domestic labour force (Eq.S4), in line with a share of contributions paid by employers and a form of income reduction of employees.[36] On the other hand, the latter ones have a zero impact on the domestic labour force (Eq.S4), under an assumption that while the public contributions result in a reduction of a disposable income, the private contributions result in an increase of savings of households.

We continue with estimation of private (Eq.W1) and public (Eq.W2) labour costs that are based on an actual ($\mathbf{wf_1}, \mathbf{wg_1}$) and previous ($\mathbf{wf_3}, \mathbf{wg_3}$) labour productivity and a mark-up between employers and employees ($\mathbf{wf_4}, \mathbf{wg_4}$) on the domestic labour market.[37] Furthermore, we estimate a significant impact of an unemployment gap ($\mathbf{wf_5}$) on the private labour costs (Eq.W1) and assume a zero impact of labour market rigidities ($\mathbf{wg_5}$) on the public labour costs (Eq.W2). On the other hand, we calibrate the spillovers from labour taxes and contributions from estimation results of Kľúčik (2015). We thus assume that contributions of employers to public ($\mathbf{wf_6}, \mathbf{wg_6}$) and private ($\mathbf{wf_7}, \mathbf{wg_7}$) sectors are paid by both employers and employees on the domestic labour market. On the other hand, we assume that labour income taxes and contributions of employees are born by households and thus do not affect the domestic labour costs. These assumptions are further consistent with findings of Symons and Robertson (1990) that a fiscal neutral shift from a direct taxation of employees to a direct taxation of employers leads to an increase of domestic labour costs and thus rejects the Invariance of Incidence Proposition (IIP). Finally, we calibrate a degree of intersectoral spillovers to private ($\mathbf{wf_2}$) and public ($\mathbf{wg_2}$) labour costs from an impulse response analysis of macroeconomic and fiscal shocks to the domestic economy.[38]

We continue with estimation of production prices (Eq.P5) that are based on an actual ($\mathbf{pp_1}$) and previous ($\mathbf{pp_3}$) unit labour costs and inflation expectations ($\mathbf{pp_2}$) of domestic producers. We need to mention that we approximate the production prices (Eq.P5) with a deflator of production for the purpose of model estimation. Estimation of consumer prices (Eq.P2) then implies a significant impact of production ($\mathbf{pn_6}$) and import ($\mathbf{pn_8}$) components and more backward-looking ($\mathbf{pn_9}$) than forward-looking ($\mathbf{pn_7}$) behaviour of domestic consumers. We further find a historical evidence of the Balassa-Samuelson effect ($\mathbf{pn_{10}}$) and estimate a significant impact of a domestic output gap ($\mathbf{pn_{11}}$) on the consumer prices (Eq.P2). Estimation of energy prices (Eq.P4) then implies a significant impact of production ($\mathbf{pe_5}$) and crude oil ($\mathbf{pe_7}$) components and inflation expectations ($\mathbf{pe_6}$) of domestic consumers. Furthermore, a deflator of investment (Eq.C2) is based on a combination of production ($\mathbf{pi_4}$) and import ($\mathbf{pi_5}$) prices in the economy and a deflator of government (Eq.C4) is based on a combination of production ($\mathbf{pg_5}$) and consumption ($\mathbf{pg_6}$) prices in the economy. Finally, both export (Eq.C6) and import (Eq.C8) deflators are based on a combination of domestic ($\mathbf{px_4}, \mathbf{pm_5}$) and external ($\mathbf{px_5}, \mathbf{pm_6}$) components.

Next, we calibrate a direct impact of capital income taxes on private labour costs (Eq.W1), production prices (Eq.P5) and private (Eq.S1) and personal (Eq.S2) investment from literature on tax elasticities. The spillovers to production prices are set in line with Baker et al. (2020) but in an asymmetric manner for an increase ($\mathbf{pp_4}$) and a decline ($\mathbf{pp_5}$) in the effective tax rate. On the other hand, a distribution of capital income taxes between a net domestic surplus,

[36] A reduction in the premium component implied by the contributions of employers should have a smaller behavioural impact on an intertemporal decision of households than a reduction in the wage component implied by the contributions of employees.
[37] The specification with a labour productivity of the domestic economy, e.g. a domestic output over domestic employment, provides a better fit of historical data than the specification with a labour productivity of the private sector, e.g. a domestic output over private and personal employment.
[38] The calibration of intersectoral spillovers between private and public labour costs is consistent with Afonso and Gomes (2008).

that further manifest in private ($\mathbf{if_7}$) and personal ($\mathbf{ih_7}$) investment, and compensations of employees, that further manifest in private labour costs ($\mathbf{wf_8}$), is set in line with Dwenger et al. (2011) and Fuest et al. (2015). Furthermore, we assume that capital income taxes are born only by firms (Eq.S1) and not by households (Eq.S2). We continue with spillovers from value added taxes that affect core (Eq.P2) and energy (Eq.P4) prices in an asymmetric manner for an increase ($\mathbf{pn_{12}, pe_8}$) and a decline ($\mathbf{pn_{13}, pe_9}$) in the effective tax rate. Finally, we need to distribute spillovers from net consumption taxes between core (Eq.P2) and energy (Eq.P4) prices with a respect to relative magnitudes of food and energy taxes and relative shares of core and energy components in the consumption basket. Again, we distinguish between an increase ($\mathbf{pn_{14}, pe_{10}}$) and a decline ($\mathbf{pn_{15}, pe_{11}}$) in the effective tax rate.

We continue with estimation of public social transfers (Eq.G2) that are based on the potential output ($\mathbf{st_2}$) and compensations of employees ($\mathbf{st_3}$). On the other hand, we need to calibrate the spillovers from labour market rigidities ($\mathbf{st_4}$) to identify different types of labour market transfers in the domestic economy.[39] Estimation of a private mixed surplus (Eq.H1) is then based on the potential output ($\mathbf{ms_1}$) and a net domestic surplus ($\mathbf{ms_2}$).

Finally, we discuss a parametrization of a domestic risk premium (Eq.F1). We need to mention that our calibration of an empirical impact of a public debt on the domestic premium (0.05) is consistent with assumptions of the European Commission (0.03) and the International Monetary Fund (0.04) as stated in Alcidi and Gros (2019). On the other hand, our calibration of an empirical impact of a current account on the domestic premium (0.05) is smaller than the estimation of the Council for Budget Responsibility (0.10) as stated in Kľúčik (2015).

5.3 Convergence properties

While a parametrization of the model consists of a one-by-one estimation of each empirical equation, a solution of the model is based on a general equilibrium theory. Specifically, we put the model equations together and solve the system in an iterative manner for each time period to obtain macroeconomic forecasts and simulations.[40] It is important to note that the model is characterized as backward looking and we are thus able to obtain the iterative solution without solving of rational expectations.[41] Model convergence is ensured by error correction terms that correct macroeconomic variables and fiscal policy rules that correct fiscal variables. We further need to ensure homogeneity conditions, i.e. an equality between steady-state dynamics of an explained variable and a weighted sum of steady-state dynamics of explanatory variables. The homogeneity conditions thus imply linear restrictions on the model equations.

Existence and speed of model convergence into a steady state is implied by a definition of persistence parameters, error correction terms and fiscal policy rules. We need to mention that even though a detailed structure of the model slows down the convergence process, we are able to achieve equilibrium values of model variables in a long horizon, i.e. for gross domestic product (Fig.13), domestic employment (Fig.14), domestic prices (Fig.15), domestic wages (Fig.16), public sector debt (Fig.17) and public sector balance (Fig.18). The model variables thus converge to their potential counterparts in a steady state, closing model gaps and meeting target values of a fiscal policy.

Next, we analyse a sensitivity of model convergence to a calibration of error correction terms and fiscal policy rules. We find out that a variation of the error correction terms for private ($\mathbf{if_9}$) and personal ($\mathbf{ih_9}$) investment leads only to mild differences in terms of model convergence (Fig.C1). Furthermore, even though a variation of the error correction terms for private ($\mathbf{wf_9}$) and public ($\mathbf{wg_{11}}$) labour costs has a significant impact on convergence properties of domestic prices and wages, we observe only a marginal effect of this calibration

[39] We calibrate the parameter as a share of unemployment and social benefits on the public social transfers.

[40] The model is solved by a trust region algorithm, solving n equations about n variables. We need to mention that a detailed structure of the model does not complicate the solution algorithm.

[41] This approach would be not applicable if some components of the model are defined in a model-consistent manner under rational expectations.

on a pace of model convergence (Fig.C2). On the other hand, a calibration of the reaction function to a fiscal balance (Λ_1) and a public debt (Λ_2) is crucial for a process of model convergence, since a decline of the balance parameter (Fig.C3) and an increase of the debt parameter (Fig.C4) could slow down the convergence process and even destabilize the model. Finally, a variation of the reaction function to an output gap (Λ_3) leads only to mild differences in terms of model convergence (Fig.C5).

An equilibrium share of domestic investment on a gross domestic product is equal to 24%, as implied by the calibration of the model (Fig.12). Furthermore, a process of convergence implies that private consumption (Fig.19) explains 48% and public consumption (Fig.20) explains 16% of a gross domestic product in a steady state. On the other hand, an export to output ratio (Fig.21) is equal to 122% and an import to output ratio (Fig.22) is equal to 110% in a steady state, in line with structural trends in historical time series. A trade to output ratio is thus equal to 12% in a steady state. Finally, we need to discuss convergence properties of a domestic risk premium. It results from a definition of the risk premium (Eq.F1) that an unconstrained public debt and current account would imply an unconstrained value of the risk premium. On the other hand, equilibrium values of the public debt and the current account imply an equilibrium value of the risk premium that is equal to a half percentage point.

Fig.13: Domestic Output

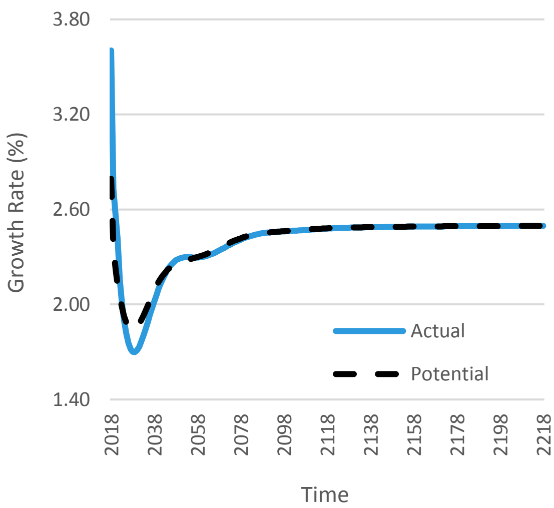


Fig.14: Total Employment

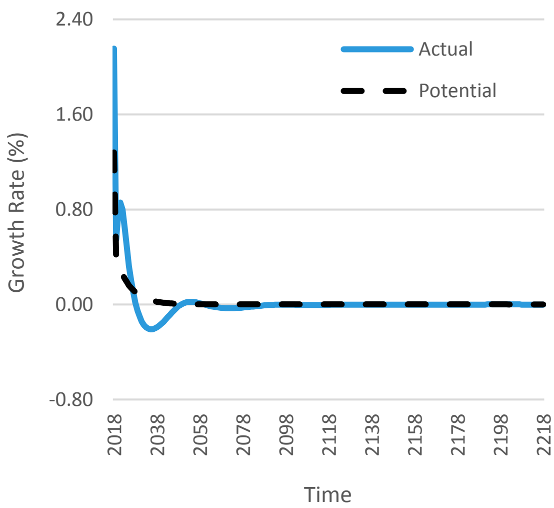


Fig.15: Output Prices

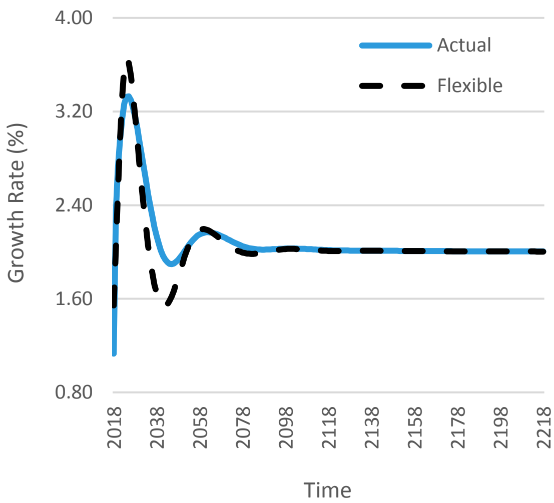
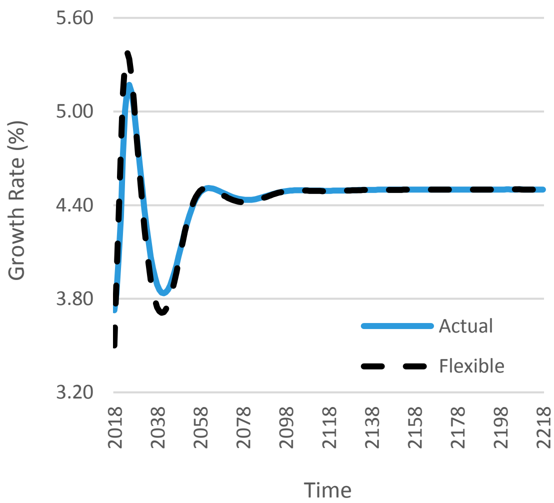


Fig.16: Labour Costs



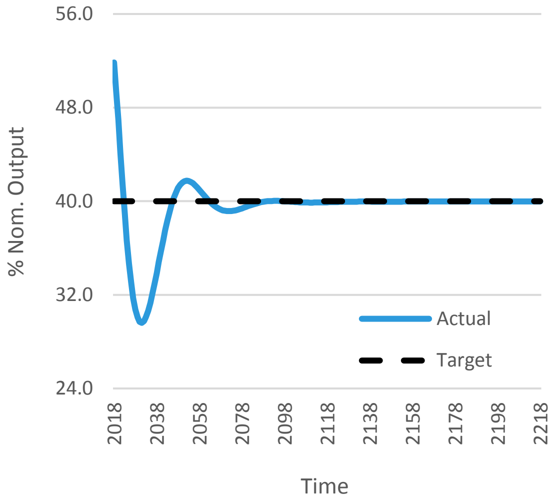


Fig.17: Public Debt

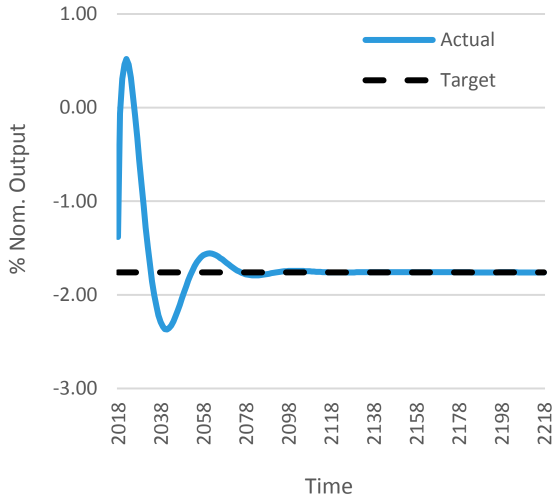


Fig.18: Public Balance

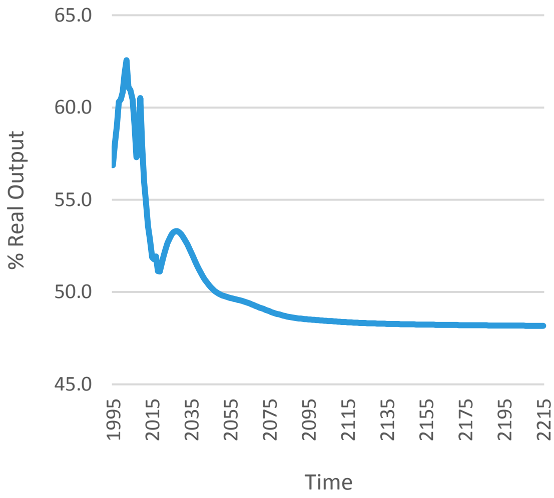


Fig.19: Private Consumption

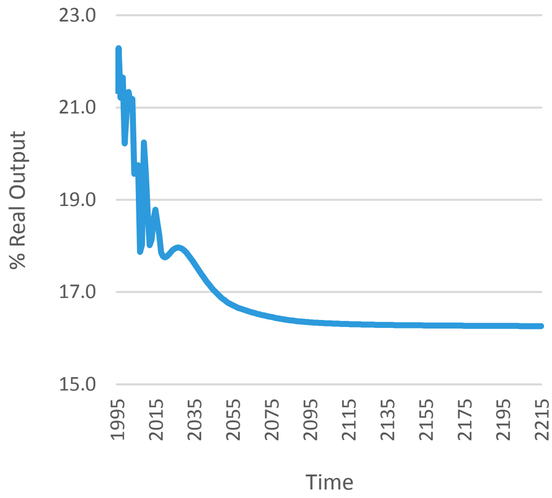


Fig.20: Public Consumption

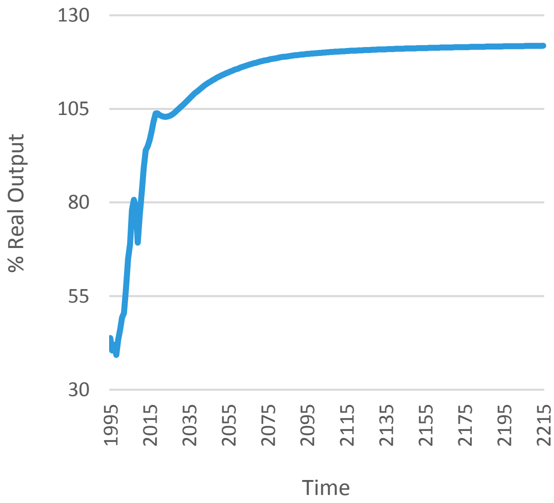


Fig.21: Domestic Export

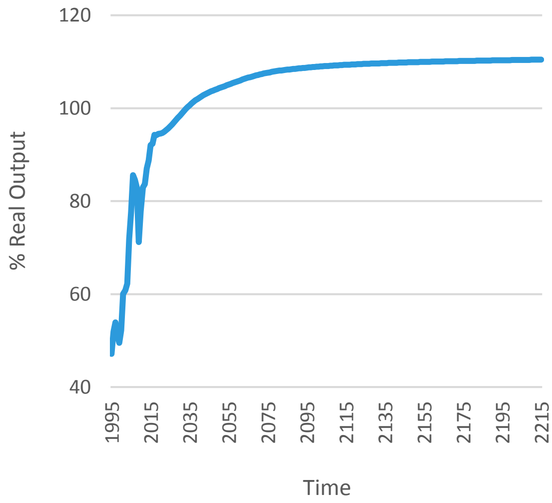


Fig.22: Domestic Import

6 Model evaluation

Evaluation of a model performance is based on impulse response functions and implied fiscal multipliers. We compute impulse response functions for the most important macroeconomic and fiscal shocks in the Slovak economy, i.e. shocks to a domestic productivity, an external demand, interest rates and crude oil prices and shocks to domestic taxes, social contributions and public expenditures. The shock to a domestic productivity and an external demand corresponds to an increase of a growth rate by 0.25 p.p. in the first quarter, the shock to crude oil prices and public expenditures corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter and the shock to interest rates, domestic taxes and social contributions corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. All shocks are set as permanent in the model. Impulse response functions are then presented as percentage deviations from baseline growth rates.[42] Implied fiscal multipliers are based on a method of Uhlig (2010) to evaluate both short-term and medium-term impact of alternative consolidation scenarios on the domestic economy.

It is important to note that we let the fiscal rules switched on and thus follow an endogenous response of a fiscal policy in both the impulse response analysis and the estimation of fiscal multipliers. Our results should be thus viewed as an empirical rather than an undisturbed impact of macroeconomic and fiscal shocks on the domestic economy. On the other hand, we model a relatively mild response of a fiscal policy to limit its impact on the impulse response functions and the implied fiscal multipliers. This is in contrast to models of Fagan and Morgan (2005) without active fiscal rules. However, we argue that this approach could destabilize fiscal variables in a medium horizon. On the other hand, Klyuev and Snudden (2011) discuss an activation of fiscal rules for both an impulse response analysis and an estimation of fiscal multipliers. Kľúčik (2015) proposes a combination of these methods and turns off fiscal rules for two years after the shock and turns them on afterwards.

6.1 Macroeconomic shocks

We start with a demand side of the model and evaluate an impact of a positive shock to an external demand (Fig.M1) on the domestic economy. A positive trade balance materializes in a positive output gap and puts an upward pressure on domestic wages and prices. Rising domestic output helps to create new jobs on the labour market what results in a decline of an unemployment rate and an increase of a participation rate. Compensations of employees then put an upward pressure on private consumption and a stronger domestic demand leads to an increase of private investment. Finally, a positive demand shock leads to an improvement of a public deficit and a public debt.

We continue with a supply side of the model and evaluate an impact of a positive shock to a domestic productivity (Fig.M2) on the domestic economy. The higher productivity puts an upward pressure on both actual and potential output in line with a production function and market share spillovers. Furthermore, the potential output surpasses the actual one what implies a negative output gap. The higher productivity will also cause workers and companies to produce more efficiently and thus leads to an increase of domestic wages and a decline of domestic employment. Lower labour costs have a dampening effect on domestic prices right after the shock that is further multiplied by a negative output gap. Afterwards, a labour productivity puts an upward pressure on domestic prices, in line with the Balassa-Samuelson effect.[43] Domestic market shares boost an export performance and thus result in a positive trade balance. Later on, an exogenous character of external prices implies an appreciation of a real exchange rate with a negative impact on a domestic trade balance.

[42] The baseline scenario is set under an absence of macroeconomic and fiscal shocks.
[43] For an evaluation of a productivity shock in small open economies see for example Ambrisko (2015).

A positive shock to crude oil prices (Fig.M4) materializes in consumer and import prices with negative implications for private consumption and investment. The decline of a domestic demand then puts a downward pressure on a domestic output gap. Furthermore, an increase of import prices overcomes a decline of real imports what results in a negative trade balance in nominal terms, in contrast to a positive trade balance in real terms. Next, a positive shock to interest rates (Fig.M3) leads to a decline of private consumption and investment and thus limits domestic output and employment.[44] Lower domestic wages and prices then materialize in a depreciation of a real exchange rate and thus result in a positive trade balance. Higher interest rate costs have also a negative impact on the fiscal variables.

Next, we analyse a sensitivity of impulse response functions to a calibration of core model parameters, i.e. a productivity differential ($\mathbf{xt_8}$) in the export equation (Eq.D4), an oil price differential ($\mathbf{mt_8}$) in the import equation (Eq.D6) and spillovers from a public debt ($\boldsymbol{\phi_3}$) and a current account ($\boldsymbol{\phi_4}$) in the premium equation (Eq.F1). We find out that a variation of the premium parameters leads only to mild differences after both macroeconomic and fiscal shocks to the economy. On the other hand, a stronger impact of a productivity differential on the domestic export implies a stronger trade surplus and a positive output gap after the shock to a domestic productivity (Fig.S1) and a positive impact of an oil price differential on the domestic import implies a milder trade deficit and a positive output gap after the shock to crude oil prices (Fig.S2). Calibration of these parameters is thus crucial to obtain plausible impulse response functions to domestic and external shocks.[45]

6.2 Fiscal policy shocks

An increase of capital income taxes (Fig.R2) puts a downward pressure on an operating surplus and thus on private investment. On the other hand, production prices increase and private wages decline to compensate the impact of capital income taxes on the profits of firms. A domestic output declines through both actual and potential components and puts a downward pressure on domestic employment two quarters after the shock. The decline of a disposable income then materializes in private consumption. Finally, the decline of a domestic demand results in a positive trade balance despite an appreciation of a real exchange rate.

On the other hand, an increase of labour income taxes (Fig.R1) puts a downward pressure on both actual and potential labour force and employment. Significant decline in the domestic labour force then results in a wedge between labour demand and supply and puts an upward pressure on domestic labour costs one year after the shock. Furthermore, we observe a decline in both actual and potential output with further implications for private consumption and investment. A negative output gap puts a downward pressure on domestic prices in a short horizon. However, the output gap almost closes two years after the shock, due to a decline in the potential labour force. Spillovers from contributions of employees (Fig.R3) are identical to labour income taxes and thus result in a negative impact on both actual and potential components of a domestic labour force. On the other hand, spillovers from contributions of employers (Fig.R4) materialize in domestic wages and prices and result in a milder decline of domestic output and employment with a respect to contributions of employees.

An increase of value added taxes (Fig.R5) materializes in consumer prices and domestic wages and supresses private consumption. The decline in private consumption then puts a downward pressure on domestic output and employment with further implications for private investment. An increase of net consumption taxes (Fig.R6) has similar implications for the domestic economy but with a different magnitude, in line with a persistence of core and energy components of the consumer prices.

[44] The interest rate shock corresponds to a positive shock to both short-term and long-term interest rates.
[45] We increase an impact of a productivity differential on the domestic export from 1.00 to 2.50 and increase an impact of an oil price differential on the domestic import from 0.00 to 0.01.

We continue with a positive shock to public employment (Fig.E1) that puts an upward pressure on private consumption and thus boosts the domestic output. On the other hand, negative market expectations about a fiscal policy result in a decline of private investment. A positive shock to public labour costs (Fig.E2) has a similar impact on the domestic economy but leads to a stronger increase of a disposable income and a significant decline of an operating surplus. This is driven by the spillovers to private labour costs that materialize also in higher domestic prices. A positive shock to public investment (Fig.E3) puts an upward pressure on both actual and potential output. Stronger domestic demand helps to create new jobs on the labour market and results in an increase of domestic wages and prices. Furthermore, we observe an increase of private consumption and a crowding out of private investment. Finally, a positive shock to intermediate consumption (Fig.E5) materializes in consumption of government and a positive shock to public social transfers (Fig.E4) boosts consumption of households. However, these shocks have a negative impact on a confidence of investors and thus limit the potential output in the domestic economy.

6.3 Implied fiscal multipliers

Evaluation of alternative consolidation scenarios is based on implied fiscal multipliers in line with Uhlig (2010). We thus calculate an actual fiscal multiplier for a particular consolidation scenario as a ratio between a differential of a domestic output in constant prices and public revenues or expenditures in a percentage of gross domestic product. Specifically, the numerator is equal to a logarithm of a domestic output in constant prices ($\mathbf{yt_t^s}$) relative to a baseline value ($\mathbf{yt_t^b}$) under an absence of a fiscal consolidation. The denominator is then equal to a ratio between nominal public revenues or expenditures and gross domestic product ($\mathbf{bt_t^s}$) relative to a baseline value ($\mathbf{bt_t^b}$).[46] Next, we compute a cumulative fiscal multiplier in an actual period p as a ratio between a sum of numerators and denominators in previous periods t as stated in the Eq.25. We need to mention that we present the fiscal multipliers for a fiscal restriction to evaluate an impact of alternative consolidation scenarios on the domestic economy. It is important to note that some fiscal multipliers would be different for a fiscal expansion, in line with an asymmetric impact of effective tax rates on domestic prices.

$$\sum_{t=1}^{p}(\mathbf{yt_t^s}-\mathbf{yt_t^b})\,/\sum_{t=1}^{p}(\mathbf{bt_t^s}-\mathbf{bt_t^b}) \qquad (25)$$

On a revenue side of a public budget, the most unfavourable consolidation scenarios in terms of implied fiscal multipliers are based on an increase of labour and capital income taxes. The direct taxes have a negative impact not only on actual but also on potential output in the domestic economy. The highest fiscal multiplier in a short horizon is implied by an increase of capital income taxes (Fig.24) that supress private investment, reduce private labour costs and boost production prices. On the other hand, the highest fiscal multiplier in a medium horizon is implied by an increase of labour income taxes (Fig.23) that put a downward pressure on the potential labour force and thus supress the potential output in the domestic economy.[47] Contributions of employees (Fig.25) produce the same fiscal multipliers as labour income taxes, in contrast to milder cumulative multipliers that are implied by contributions of employers (Fig.26). Finally, value added taxes (Fig.27) produce higher cumulative multipliers than net consumption taxes (Fig.28), in line with a more persistent character of core consumer prices with a respect to energy consumer prices. However, since the indirect taxes influence mostly cyclical and not potential variables in the model, they have a limited impact on the potential output in the domestic economy. The most favourable consolidation scenario on a revenue side of a public budget is then based on an increase of net consumption taxes.

[46] An alternative approach to fiscal multipliers is based on a fiscal balance in contrast to public revenues or expenditures.

[47] The short-term multiplier corresponds to a cumulative fiscal multiplier one year after the shock and the medium-term multiplier corresponds to a cumulative fiscal multiplier four years after the shock.

Fig.23: Labour Income Taxes

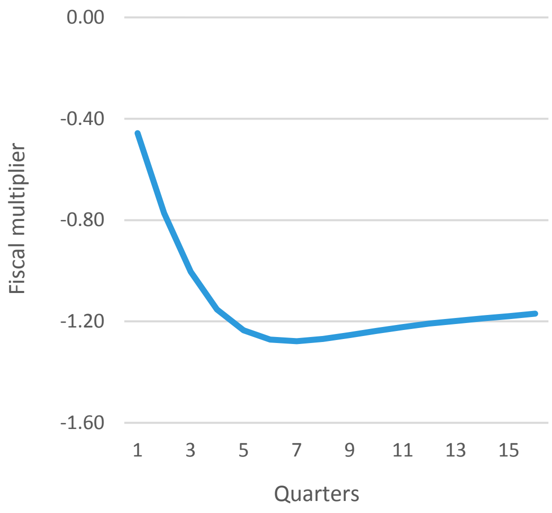


Fig.24: Capital Income Taxes

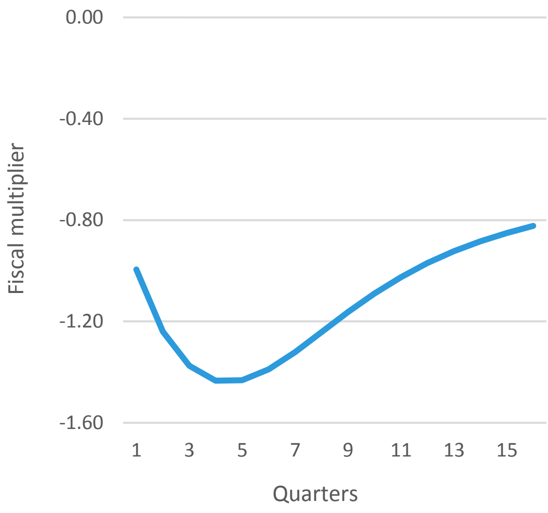


Fig.25: Employees Contributions

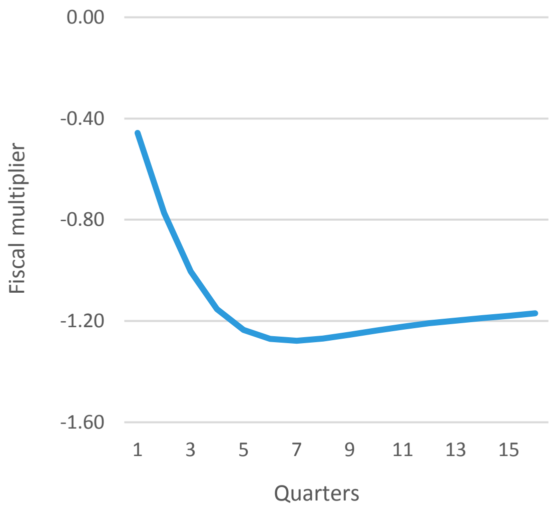


Fig.26: Employers Contributions

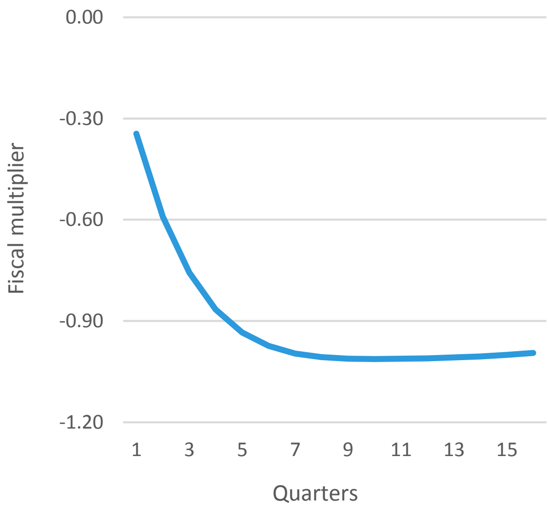


Fig.27: Value Added Taxes

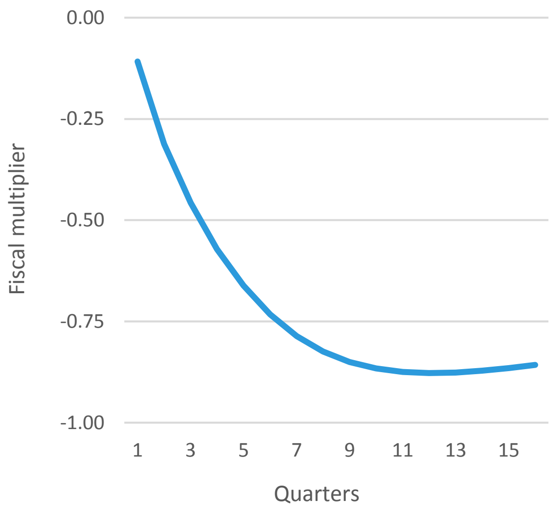
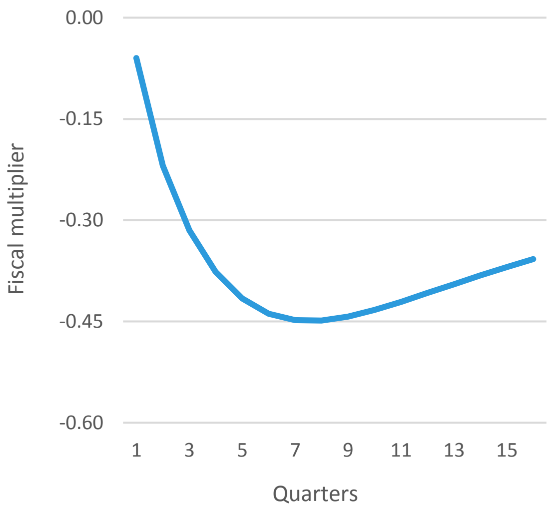


Fig.28: Net Consumption Taxes



On an expenditure side of a public budget, the most unfavourable consolidation scenario in a term of implied fiscal multipliers is based on a decline of government investment (Fig.29). Intermediate consumption (Fig.31) implies a similar fiscal multiplier as government investment in a short horizon but provides much better results in a medium horizon, in line with its positive impact on a confidence of investors. Finally, public compensations (Fig.30) produce a higher cumulative multiplier than public social transfers (Fig.32) in a short horizon, due to sectoral spillovers to private labour costs, but a milder cumulative multiplier in a medium horizon, due to a crowding out of private and personal employment.[48] The most favourable consolidation scenario on an expenditure side of a public budget is then based on a decline of intermediate consumption. Even though the consolidation based on public expenditures could produce higher fiscal multipliers in a short horizon, the consolidation based on public revenues distorts potential variables and thus results in more negative implications in a medium horizon.

Fig.29: Government Investment

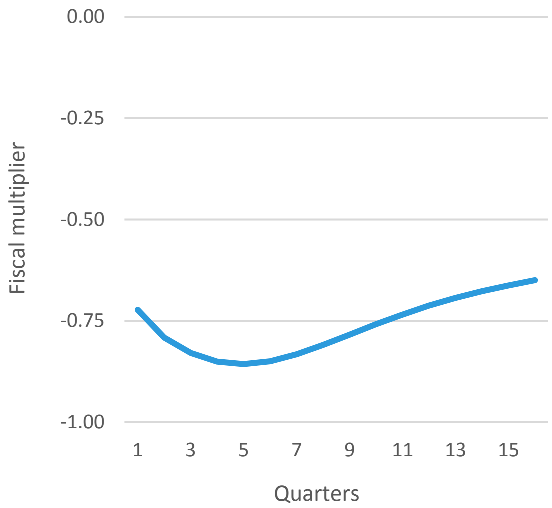


Fig.30: Public Compensations

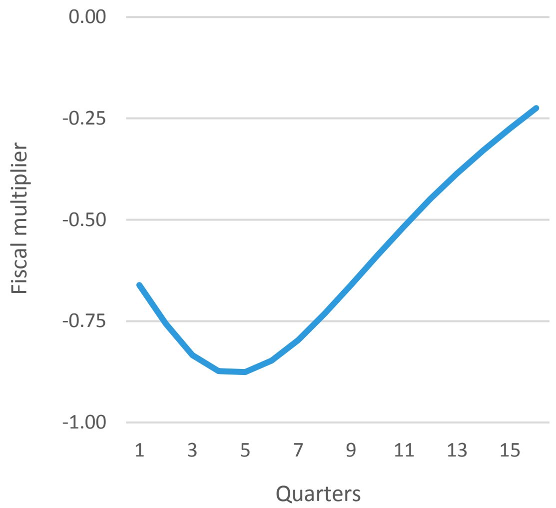


Fig.31: Intermediate Consumption

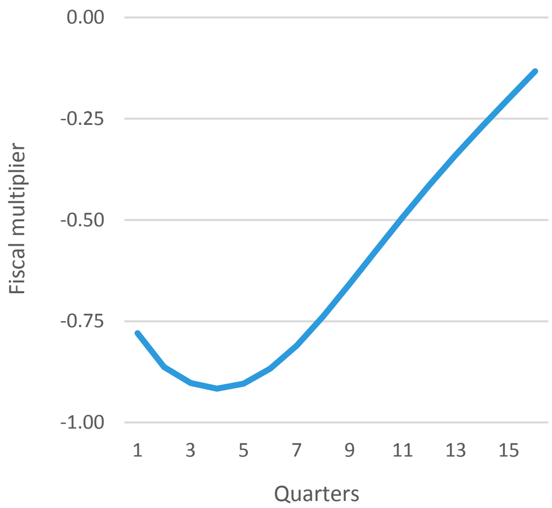
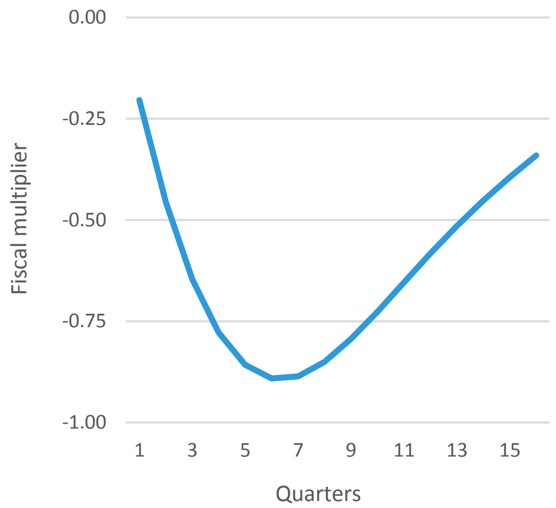


Fig.32: Public Social Transfers



[48] A negative shock to public compensations corresponds to a negative shock to public employment and labour costs.

Next, we compare our simulation results with other evaluation studies of the Slovak economy. Fiscal multipliers for labour income taxes and social contributions are within an estimation range of Múčka (2016) and Zeman (2016). Furthermore, we estimate a similar cumulative multiplier for capital income taxes on a short horizon (Tab.1) but a milder cumulative multiplier on a medium horizon (Tab.2). Fiscal multipliers for value added taxes and net consumption taxes are on a bottom of the estimation range of Múčka (2016) and Zeman (2016). Finally, we estimate higher cumulative multipliers for public expenditures on a short horizon (Tab.1) and milder cumulative multipliers on a medium horizon (Tab.2).

Tab.1: Short-term fiscal multipliers

	Múčka (2016)	Zeman (2016)	Priesol (2020)
Labour Income Taxes	1.47	0.18	1.15
Capital Income Taxes	1.49	NaN	1.43
Employees Contributions	1.47	0.18	1.15
Employers Contributions	1.47	0.34	0.86
Value Added Taxes	1.17	0.52	0.57
Net Consumption Taxes	1.17	0.52	0.38
Government Investment	0.37	0.65	0.85
Public Compensations	0.66	0.63	0.87
Intermediate Consumption	0.48	0.63	0.92
Public Social Transfers	0.60	0.69	0.78

Tab.2: Medium-term fiscal multipliers

	Múčka (2016)	Zeman (2016)	Priesol (2020)
Labour Income Taxes	1.95	0.10	1.17
Capital Income Taxes	1.94	NaN	0.82
Employees Contributions	1.95	0.10	1.17
Employers Contributions	1.95	1.13	1.00
Value Added Taxes	1.36	0.82	0.86
Net Consumption Taxes	1.36	0.82	0.36
Government Investment	0.81	0.68	0.65
Public Compensations	0.55	0.59	0.22
Intermediate Consumption	0.40	0.59	0.13
Public Social Transfers	0.58	0.52	0.34

Furthermore, we compare our simulation results with a set of fiscal multipliers of Kľúčik and Múčka (2015) that are based on two evaluation methods, i.e. a structural econometric model (ECM) and a dynamic stochastic model (DSGE) of the Slovak economy (Tab.3). Fiscal multipliers for direct taxes and social contributions are in a middle and fiscal multipliers for indirect tax are on a bottom of the estimation range of Kľúčik and Múčka (2015). On the other hand, fiscal multipliers for public compensations are in a middle and fiscal multipliers for government investment and intermediate consumption are on a bottom of the estimation range of Kľúčik and Múčka (2015).

Tab.3: Fiscal multipliers of Kľúčik and Múčka (2015)

	ECM model	DSGE model
Labour Income Taxes	0.70	1.60
Capital Income Taxes	0.70	1.90
Employees Contributions	0.70	1.60
Employers Contributions	0.20	1.60
Value Added Taxes	0.50	1.70
Net Consumption Taxes	0.30	1.70
Government Investment	2.00	0.90
Public Compensations	1.75	0.50
Intermediate Consumption	1.40	0.90

7 Concluding remarks

We proposed a structural econometric model of the Slovak economy that is suitable for both macroeconomic forecasts and simulations. Our model is built on Fagan et al. (2001) but extends the original model with comprehensive budgetary restrictions of macroeconomic agents. Furthermore, we enriched the model by a fiscal block and proposed simple fiscal rules in line with Claeys et al. (2016). Finally, we need to mention that the model produces macroeconomic forecasts and simulations with fiscal implications for the Stability Programme (SP) and the Draft Budgetary Plan (DBP) and is thus an important part of a policy analysis.

Estimation of model parameters is based on standard econometric methods with linear restrictions. On the other hand, calibration of model parameters is based on impulse response functions and related literature. Model solution is then implied by a theory of general equilibrium. Evaluation of a model performance is based on convergence properties of the model and impulse response functions. Even though a detailed structure of the model slows down the convergence process, we are able to achieve steady-state values of model variables in a long horizon. On the other hand, both macroeconomic and fiscal shocks produce impulse response functions consistent with related literature.

Finally, we evaluate alternative consolidation scenarios with implied fiscal multipliers. Even though a decline of public expenditures could produce higher cumulative multipliers in a short horizon, market expectations about a fiscal policy have a significant impact on a confidence of investors and result in a Neo-Keynesian reaction of model variables in a medium horizon. On the other hand, an increase of taxes and contributions puts a downward pressure on potential variables and thus supresses an economic performance in both short and medium horizons. The most negative outcome results from an increase of capital income taxes in a short horizon and an increase of labour income taxes in a medium horizon. On the other hand, the most favourable outcome results from an increase of net consumption taxes in a short horizon and a decline of intermediate consumption in a medium horizon.

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List of model variables

Supply side block

yt_t^* – Gross potential product (Real, Endogenous)

yn_t^* – Gross potential product (Nominal, Endogenous)

at_t – Total factor productivity (Real, Exogenous)

kt_t – Domestic capital stock (Real, Endogenous)

kn_t – Domestic capital stock (Nominal, Endogenous)

λt_t – Capital correction term (Rate, Exogenous)

it_t – Domestic investment (Real, Endogenous)

in_t – Domestic investment (Nominal, Endogenous)

δt_t – Domestic depreciation (Rate, Endogenous)

δkt_t – Domestic depreciation (Nominal, Endogenous)

if_t – Private investment (Real, Endogenous)

kf_t – Private capital stock (Real, Endogenous)

δf_t – Private depreciation (Rate, Exogenous)

δkf_t – Private depreciation (Nominal, Endogenous)

ih_t – Personal investment (Real, Endogenous)

kh_t – Personal capital stock (Real, Endogenous)

δh_t – Personal depreciation (Rate, Exogenous)

δkh_t – Personal depreciation (Nominal, Endogenous)

ig_t – Public investment (Real, Endogenous)

kg_t – Public capital stock (Real, Endogenous)

δg_t – Public depreciation (Rate, Exogenous)

δkg_t – Public depreciation (Nominal, Endogenous)

np_t – Domestic population (Persons, Exogenous)

ls_t^* – Potential labour force (Persons, Endogenous)

η_t^* – Potential participation (Rate, Exogenous)

γ_t^{tc} – Taxes and contributions (Rate, Endogenous)

lt_t^* – Potential employment (Persons, Endogenous)

μ_t^* – Potential unemployment (Rate, Exogenous)

ls_t – Domestic labour force (Persons, Endogenous)

η_t – Domestic participation (Rate, Endogenous)

τ_t^{tc} – Taxes and contributions (Rate, Endogenous)

lt_t – Domestic employment (Persons, Endogenous)

μ_t – Domestic unemployment (Rate, Endogenous)

le_t – External employment (Persons, Endogenous)

σ_t – External employment (Rate, Exogenous)

lf_t – Private employment (Persons, Endogenous)

lh_t – Personal employment (Persons, Endogenous)

lg_t – Public employment (Persons, Endogenous)

Demand side block

$\mathrm{yt_t}$ – Gross domestic product (Real, Endogenous)

$\mathrm{yn_t}$ – Gross domestic product (Nominal, Endogenous)

$\mathrm{va_t}$ – Gross value added (Nominal, Endogenous)

$\mathrm{dt_t}$ – Statistical discrepancy (Real, Exogenous)

$\mathrm{dn_t}$ – Statistical discrepancy (Nominal, Endogenous)

$\mathrm{ds_t}$ – Net domestic surplus (Nominal, Endogenous)

$\mathrm{os_t}$ – Net operating surplus (Nominal, Endogenous)

$\mathrm{sf_t}$ – Surplus of companies (Nominal, Endogenous)

$\mathrm{pf_t}$ – Surplus of companies (Real, Endogenous)

$\mathrm{sh_t}$ – Surplus of households (Nominal, Endogenous)

$\mathrm{ph_t}$ – Surplus of households (Real, Endogenous)

$\mathrm{ct_t^*}$ – Potential consumption (Real, Endogenous)

$\mathrm{cn_t}$ – Private consumption (Nominal, Endogenous)

$\mathrm{ct_t}$ – Private consumption (Real, Endogenous)

$\mathrm{gn_t}$ – Public consumption (Nominal, Endogenous)

$\mathrm{gt_t}$ – Public consumption (Real, Endogenous)

$\mathrm{xt_t^*}$ – Total potential export (Real, Endogenous)

$\mathrm{xn_t}$ – Total domestic export (Nominal, Endogenous)

$\mathrm{xt_t}$ – Total domestic export (Real, Endogenous)

$\mathrm{dx_t}$ – Total external demand (Real, Exogenous)

$\mathrm{zx_t}$ – Export exchange rate (Real, Endogenous)

da_t – Productivity differential (Real, Endogenous)

ψ_t – World factor productivity (Real, Exogenous)

mt_t^* – Total potential import (Real, Endogenous)

mn_t – Total domestic import (Nominal, Endogenous)

mt_t – Total domestic import (Real, Endogenous)

dm_t – Total domestic demand (Real, Endogenous)

zm_t – Import exchange rate (Real, Endogenous)

do_t – Oil price differential (Real, Endogenous)

us_t – Dollar exchange rate (Nominal, Exogenous)

oil_t – World crude oil price (Index, Exogenous)

ca_t – Total current account (Nominal, Endogenous)

ca_t^* – Total current account (Rate, Endogenous)

er_t – Effective exchange rate (Nominal, Exogenous)

pw_t – Effective external price (Index, Exogenous)

Wages and prices

lp_t^*– Potential productivity (Real, Endogenous)

wt_t^*– Potential labour costs (Nominal, Endogenous)

rt_t^*– Potential labour costs (Real, Endogenous)

lp_t – Domestic productivity (Real, Endogenous)

wt_t – Domestic labour costs (Nominal, Endogenous)

rt_t – Domestic labour costs (Real, Endogenous)

lwt_t – Gross domestic wages (Nominal, Endogenous)

we_t – External labour costs (Nominal, Endogenous)

κ_t – External labour costs (Rate, Exogenous)

lwe_t – Gross external wages (Nominal, Endogenous)

wn_t – Total labour income (Nominal, Endogenous)

rn_t – Total labour income (Real, Endogenous)

lwn_t – Net domestic wages (Nominal, Endogenous)

wf_t – Private labour costs (Nominal, Endogenous)

rf_t – Private labour costs (Real, Endogenous)

lwf_t – Gross private wages (Nominal, Endogenous)

wg_t – Public labour costs (Nominal, Endogenous)

rg_t – Public labour costs (Real, Endogenous)

lwg_t – Gross public wages (Nominal, Endogenous)

cp_t – Total consumer prices (Index, Endogenous)

pn_t^* – Core potential prices (Index, Endogenous)

pn_t – Core consumer prices (Index, Endogenous)

bs_t – Productivity differential (Real, Endogenous)

φ_t – World labour productivity (Real, Exogenous)

pe_t^* – Energy potential prices (Index, Endogenous)

pe_t – Energy consumer prices (Index, Endogenous)

py_t^* – Potential output prices (Index, Endogenous)

ulc_t – Unit labour costs (Nominal, Endogenous)

py_t – Domestic output prices (Index, Endogenous)

pp_t – Total production prices (Index, Endogenous)

pi_t^* – Potential capital prices (Index, Endogenous)

pi_t – Domestic capital prices (Index, Endogenous)

pk_t – Capital stock prices (Index, Endogenous)

pg_t^* – Potential public prices (Index, Endogenous)

pg_t – Domestic public prices (Index, Endogenous)

pc_t – Private sector prices (Index, Endogenous)

px_t^* – Potential export prices (Index, Endogenous)

px_t – Domestic export prices (Index, Endogenous)

pm_t^* – Potential import prices (Index, Endogenous)

pm_t – Domestic import prices (Index, Endogenous)

Interest rate block

sr_t – Short-term interest rate (Real, Endogenous)

eu_t – 3-month Euribor rate (Nominal, Exogenous)

πs_t – Short-term inflation rate (Rate, Endogenous)

ps_t – Short-term domestic price (Index, Endogenous)

lr_t – Long-term interest rate (Real, Endogenous)

sk_t – 10-year Slovak bonds (Nominal, Endogenous)

πl_t – Long-term inflation rate (Rate, Endogenous)

pl_t – Long-term domestic price (Index, Endogenous)

de_t – 10-year German bonds (Nominal, Exogenous)

pr_t – Domestic risk premium (Nominal, Endogenous)

Block of households

hn_t – Disposable income (Nominal, Endogenous)

ms_t – Private mixed surplus (Nominal, Endogenous)

ω_t – Private mixed surplus (Rate, Exogenous)

hc_t – Consumption income (Real, Endogenous)

toh_t – Total income taxes (Nominal, Endogenous)

hi_t – Investment income (Real, Endogenous)

coh_t – Total contributions (Nominal, Endogenous)

hr_t – Private revenues (Nominal, Endogenous)

pa_t – Pension adjustment (Nominal, Endogenous)

ς_t – Pension adjustment (Rate, Exogenous)

he_t – Private expenditures (Nominal, Endogenous)

ni_t – Non-profit institutions (Nominal, Endogenous)

ρ_t – Non-profit institutions (Rate, Exogenous)

hs_t – Savings of households (Rate, Endogenous)

gsc_t – Public contributions (Nominal, Endogenous)

τ_t^{gc} – Public contributions (Rate, Exogenous)

γ_t^{gc} – Public contributions (Rate, Endogenous)

hp_t – Property transfers (Nominal, Endogenous)

ν_t – Property transfers (Rate, Exogenous)

fsc_t – Private contributions (Nominal, Endogenous)

τ_t^{fc} – Private contributions (Rate, Exogenous)

γ_t^{fc} – Private contributions (Rate, Endogenous)

ho_t – Current transfers (Nominal, Endogenous)

υ_t – Current transfers (Rate, Exogenous)

esc_t – External contributions (Nominal, Endogenous)

τ_t^{ec} – External contributions (Rate, Exogenous)

γ_t^{ec} – External contributions (Rate, Endogenous)

Block of government

rp_t – Public revenues (Nominal, Endogenous)

ep_t – Public expenditures (Nominal, Endogenous)

gp_t – Net property transfers (Nominal, Exogenous)

go_t – Net current transfers (Nominal, Exogenous)

ge_t – Net external transfers (Nominal, Exogenous)

gc_t – Net capital transfers (Nominal, Exogenous)

bp_t – Total public balance (Nominal, Endogenous)

bp_t^* – Total public balance (Rate, Endogenous)

dp_t – Gross public debt (Nominal, Endogenous)

dp_t^* – Gross public debt (Rate, Endogenous)

int_t – Total indirect taxes (Nominal, Endogenous)

vat_t – Value added taxes (Nominal, Endogenous)

τ_t^{va} – Value added taxes (Rate, Exogenous)

γ_t^{va} – Value added taxes (Rate, Endogenous)

cnt_t – Consumption taxes (Nominal, Endogenous)

τ_t^{cn} – Consumption taxes (Rate, Exogenous)

γ_t^{cn} – Consumption taxes (Rate, Endogenous)

ynt_t – Production taxes (Nominal, Exogenous)

dit_t – Total direct taxes (Nominal, Endogenous)

lit_t – Labour income taxes (Nominal, Endogenous)

τ_t^{li} – Labour income taxes (Rate, Exogenous)

γ_t^{li} – Labour income taxes (Rate, Endogenous)

pit_t – Personal income taxes (Nominal, Endogenous)

τ_t^{pi} – Personal income taxes (Rate, Exogenous)

γ_t^{pi} – Personal income taxes (Rate, Endogenous)

cit_t – Capital income taxes (Nominal, Endogenous)

τ_t^{ci} – Capital income taxes (Rate, Exogenous)

γ_t^{ci} – Capital income taxes (Rate, Endogenous)

hit_t – Taxes of households (Nominal, Endogenous)

τ_t^{hi} – Taxes of households (Rate, Exogenous)

γ_t^{hi} – Taxes of households (Rate, Endogenous)

git_t – Taxes of government (Nominal, Exogenous)

soc_t – Social contributions (Nominal, Endogenous)

lsc_t – Labour contributions (Nominal, Endogenous)

τ_t^{lc} – Labour contributions (Rate, Exogenous)

γ_t^{lc} – Labour contributions (Rate, Endogenous)

psc_t – Personal contributions (Nominal, Endogenous)

τ_t^{pc} – Personal contributions (Rate, Exogenous)

γ_t^{pc} – Personal contributions (Rate, Endogenous)

hsc_t – Other contributions (Nominal, Endogenous)

τ_t^{hc} – Other contributions (Rate, Exogenous)

γ_t^{hc} – Other contributions (Rate, Endogenous)

nt_t – Natural transfers (Nominal, Endogenous)

θ_t – Natural transfers (Rate, Exogenous)

ic_t – Intermediate costs (Nominal, Endogenous)

rc_t – Intermediate costs (Real, Endogenous)

mp_t – Market production (Nominal, Endogenous)

χ_t – Market production (Rate, Exogenous)

st_t – Social transfers (Nominal, Endogenous)

rt_t – Social transfers (Real, Endogenous)

ot_t – Other public taxes (Nominal, Endogenous)

ξ_t – Other public taxes (Rate, Exogenous)

ir_t – Interest rate costs (Nominal, Endogenous)

ef_t – Effective interest rate (Rate, Endogenous)

oc_t – Other capital costs (Nominal, Exogenous)

List of model equations

Supply side block

$$\log(yt_t^*) = \log(at_t) + \beta * \log(kt_t) + (1-\beta) * \log(lt_t^*)$$

$$\log(yn_t^*) = \log(yt_t^*) + \log(py_t)$$

$$kt_t = kf_t + kh_t + kg_t$$

$$\log(kn_t) = \log(kt_t) + \log(pk_t)$$

$$it_t = if_t + ih_t + ig_t$$

$$cor(it_t) = \beta * yn_t/kn_t - \delta t_t - 1/4 * lr_t - \lambda t_t$$

$$\log(in_t) = \log(it_t) + \log(pi_t)$$

$$\delta t_t * kt_t = \delta f_t * kf_t + \delta h_t * kh_t + \delta g_t * kg_t$$

$$\delta kt_t = \delta t_t * kt_t * pk_t$$

$$dlog(if_t) = if_1 * dlog(yt_t) - if_2 * dlog(ig_t) + if_3 * dlog(pf_{t-1}) - if_4 * dlog(lg_t) - if_4 * dlog(rg_t) - if_5 * dlog(rc_t) - if_6 * dlog(rt_t) - if_7 * diff(\tau_t^{ci}) - if_8 * diff(lr_{t-1}) + if_9 * cor(it_{t-1}) + \varepsilon_t^{if}$$

$$kf_{t+1} = (1-\delta f_t) * kf_t + if_t$$

$$\delta kf_t = \delta f_t * kf_t * pk_t$$

$$dlog(ih_t) = ih_1 * dlog(hi_t) - ih_2 * dlog(ig_t) + ih_3 * dlog(hi_{t-1}) - ih_4 * dlog(lg_t) - ih_4 * dlog(rg_t) - ih_5 * dlog(rc_t) - ih_6 * dlog(rt_t) - ih_7 * diff(\tau_t^{ci}) - ih_8 * diff(lr_{t-1}) + ih_9 * cor(it_{t-1}) + \varepsilon_t^{ih}$$

$$kh_{t+1} = (1-\delta h_t) * kh_t + ih_t$$

$$\delta kh_t = \delta h_t * kh_t * pk_t$$

$$dlog(ig_t) = ig_1 * dlog(yt_t^*) + ig_2 * dlog(yt_t) - ig_3 * gap(yt_{t-1}) + ig_4 * dev(bp_{t-1}^*) - ig_5 * dev(dp_{t-1}^*) + ig_6 * cor(it_{t-1}) + \varepsilon_t^{ig}$$

$$kg_{t+1} = (1-\delta g_t) * kg_t + ig_t$$

$$\delta kg_t = \delta g_t * kg_t * pk_t$$

$$\mathrm{dlog}(ls_t^*) = \mathrm{dlog}(np_t) + \mathrm{dlog}(\eta_t^*) - \mathrm{diff}(\gamma_t^{tc})$$

$$\mathrm{gap}(\eta_t) = \eta_t - \eta_t^*$$

$$\mathrm{diff}(\gamma_t^{tc}) = ls_7 * \mathrm{diff}(\gamma_t^{li}) + ls_8 * \mathrm{diff}(\gamma_t^{pi}) + ls_9 * \mathrm{diff}(\gamma_t^{lc}) + ls_{10} * \mathrm{diff}(\gamma_t^{pc}) + ls_{11} * \mathrm{diff}(\gamma_t^{gc}) + ls_{12} * \mathrm{diff}(\gamma_t^{fc})$$

$$\mathrm{dlog}(lt_t^*) = \mathrm{dlog}(ls_t^*) + \mathrm{dlog}(1 - \mu_t^*)$$

$$\mathrm{gap}(\mu_t) = \mu_t - \mu_t^*$$

$$\mathrm{dlog}(ls_t) = ls_1 * \mathrm{dlog}(np_t) + ls_2 * \mathrm{dlog}(lt_t) + ls_3 * \mathrm{dlog}(ls_{t-1}) + ls_4 * \mathrm{dtfp}(rn_t) - ls_5 * \mathrm{diff}(\tau_t^{tc}) - ls_6 * \log(ls_{t-1}/ls_{t-1}^*) + \varepsilon_t^{ls}$$

$$\log(\eta_t) = \log(ls_t/np_t)$$

$$\mathrm{diff}(\tau_t^{tc}) = ls_7 * \mathrm{diff}(\tau_t^{li}) + ls_8 * \mathrm{diff}(\tau_t^{pi}) + ls_9 * \mathrm{diff}(\tau_t^{lc}) + ls_{10} * \mathrm{diff}(\tau_t^{pc}) + ls_{11} * \mathrm{diff}(\tau_t^{gc}) + ls_{12} * \mathrm{diff}(\tau_t^{fc})$$

$$lt_t = lf_t + lh_t + lg_t$$

$$\mathrm{cor}(lt_t) = \log(yt_t) - \log(at_t) - \beta * \log(kt_t) - (1 - \beta) * \log(lt_t)$$

$$\log(\mu_t) = \log(1 - lt_t/ls_t)$$

$$\log(le_t) = \log(\sigma_t) + \log(np_t)$$

$$\mathrm{dlog}(lf_t) = lf_1 * \mathrm{dlog}(lt_t^*) - lf_2 * \mathrm{dlog}(lg_t) + lf_3 * \mathrm{dlog}(lf_{t-1}) + lf_4 * \mathrm{dtfp}(yt_t) - lf_5 * \mathrm{dtfp}(rf_t) + lf_6 * \mathrm{cor}(lt_{t-1}) + \varepsilon_t^{lf}$$

$$\mathrm{dlog}(lh_t) = lh_1 * \mathrm{dlog}(lt_t^*) - lh_2 * \mathrm{dlog}(lg_t) + lh_3 * \mathrm{dlog}(lh_{t-1}) + lh_4 * \mathrm{dtfp}(yt_t) - lh_5 * \mathrm{dtfp}(rt_t) + lh_6 * \mathrm{cor}(lt_{t-1}) + \varepsilon_t^{lh}$$

$$\mathrm{dlog}(lg_t) = lg_1 * \mathrm{dlog}(lt_t^*) + lg_2 * \mathrm{dlog}(lg_{t-1}) + lg_3 * \mathrm{dtfp}(yt_t) - lg_4 * \mathrm{dtfp}(rg_t) + lg_5 * \mathrm{cor}(lt_{t-1}) + \varepsilon_t^{lg}$$

Demand side block

$$yt_t = ct_t + gt_t + it_t + xt_t - mt_t + dt_t$$

$$gap(yt_t) = yt_t/yt_t^* - 1$$

$$yn_t = cn_t + gn_t + in_t + xn_t - mn_t + dn_t$$

$$tfp(yt_t) = \log(yt_t) - \log(at_t)/(1 - \beta)$$

$$va_t = yn_t - vat_t - cnt_t - ynt_t$$

$$\log(dn_t) = \log(dt_t) + \log(py_t)$$

$$ds_t = va_t - lwt_t - \delta kt_t$$

$$os_t = ds_t - ms_t - cit_t$$

$$sf_t = \delta kf_t + os_t$$

$$\log(pf_t) = \log(sf_t) - \log(pi_t)$$

$$sh_t = \delta kh_t + ms_t$$

$$\log(ph_t) = \log(sh_t) - \log(pi_t)$$

$$\log(ct_t^*) = ct_1 - ct_2/sqrt(t) + ct_3 * \log(hc_t) + \zeta_t^{ct}$$

$$\log(cn_t) = \log(ct_t) + \log(pc_t)$$

$$dlog(ct_t) = ct_4 * dlog(hc_t) + ct_5 * dlog(ct_{t-1}) + ct_6 * dlog(hc_{t-1}) - ct_7 * diff(sr_{t-1}) - ct_8 * \log(ct_{t-1}/ct_{t-1}^*) + \varepsilon_t^{ct}$$

$$gn_t = lwg_t + \delta kg_t + ic_t + ot_t + nt_t - mp_t$$

$$\log(gt_t) = \log(gn_t) - \log(pg_t)$$

$$\log(xt_t^*) = xt_1 - xt_2/sqrt(t) + xt_3 * \log(dx_t) + xt_4 * \log(zx_t) + xt_5 * \log(da_t) + \zeta_t^{xt}$$

$$\log(xn_t) = \log(xt_t) + \log(px_t)$$

$$dlog(xt_t) = xt_6 * dlog(dx_t) + xt_7 * dlog(zx_t) + xt_8 * dlog(da_t) - xt_9 * \log(xt_{t-1}/xt_{t-1}^*) + \varepsilon_t^{xt}$$

$$\log(zx_t) = \log(pw_t) + \log(er_t) - \log(px_t)$$

$$\log(da_t) = \log(at_t) - \log(\psi_t)$$

$$\log(mt_t^*) = mt_1 - mt_2/sqrt(t) + mt_3 * \log(dm_t) - mt_4 * \log(zm_t) - mt_5 * \log(do_t) + \zeta_t^{mt}$$

$$\log(mn_t) = \log(mt_t) + \log(pm_t)$$

$$dlog(mt_t) = mt_6 * dlog(dm_t) - mt_7 * dlog(zm_t) - mt_8 * dlog(do_t) - mt_9 * \log(mt_{t-1}/mt_{t-1}^*) + \varepsilon_t^{mt}$$

$$dm_t = 0.15 * gt_t + 0.25 * ig_t + 0.35 * ct_t + 0.25 * ih_t + 0.55 * if_t + 0.65 * xt_t$$

$$\log(zm_t) = \log(pw_t) + \log(er_t) - \log(pm_t)$$

$$\log(do_t) = \log(oil_t) + \log(us_t) - \log(pm_t)$$

$$ca_t = xt_t * px_t - mt_t * pm_t$$

$$ca_t^* = (ca_t + ca_{t-1} + ca_{t-2} + ca_{t-3})/(yn_t + yn_{t-1} + yn_{t-2} + yn_{t-3})$$

Wages and prices

$$\log(lp_t^*) = \log(yt_t^*) - \log(lt_t^*)$$

$$\log(wt_t^*) = \log(rt_t^*) + \log(py_t)$$

$$\log(rt_t^*) = \log(lp_t^*) + \log(1 - \beta)$$

$$\log(lp_t) = \log(yt_t) - \log(lt_t)$$

$$lf_t * wt_t + lg_t * wt_t = lf_t * wf_t + lg_t * wg_t$$

$$\log(rt_t) = \log(wt_t) - \log(py_t)$$

$$lwt_t = lt_t * wt_t$$

$$tfp(rt_t) = \log(rt_t) - \log(at_t)/(1 - \beta)$$

$$\log(we_t) = \log(\kappa_t) + \log(wt_t)$$

$$lwe_t = le_t * we_t$$

$$lt_t * wn_t = lt_t * wt_t - lit_t - pit_t - lsc_t - psc_t - gsc_t - fsc_t$$

$$\log(rn_t) = \log(wn_t) - \log(pc_t)$$

$$lwn_t = lt_t * wn_t$$

$$tfp(rn_t) = \log(rn_t) - \log(at_t)/(1 - \beta)$$

$$\text{dlog}(rf_t) = wf_1 * \text{dlog}(lp_t) + wf_2 * \text{dlog}(rg_{t-1}) + wf_3 * \text{dlog}(lp_{t-1}) + wf_4 * \text{dlog}(pc_t) - wf_4 * \text{dlog}(py_t) - wf_5 * gap(\mu_t) + wf_6 * \text{diff}(\tau_t^{gc}) + wf_7 * \text{diff}(\tau_t^{fc}) - wf_8 * \text{diff}(\tau_t^{ci}) - wf_9 * \log(wt_{t-1}/wt_{t-1}^*) + \varepsilon_t^{wf}$$

$$\log(wf_t) = \log(rf_t) + \log(py_t)$$

$$lwf_t = lf_t * wf_t$$

$$tfp(rf_t) = \log(rf_t) - \log(at_t)/(1 - \beta)$$

$$\text{dlog}(rg_t) = wg_1 * \text{dlog}(lp_t) + wg_2 * \text{dlog}(rf_{t-1}) + wg_3 * \text{dlog}(lp_{t-1}) + wg_4 * \text{dlog}(pc_t) - wg_4 * \text{dlog}(py_t) - wg_5 * gap(\mu_t) + wg_6 * \text{diff}(\tau_t^{gc}) + wg_7 * \text{diff}(\tau_t^{fc}) - wg_8 * gap(yt_{t-1}) + wg_9 * dev(bp_{t-1}^*) - wg_{10} * dev(dp_{t-1}^*) - wg_{11} * \log(wt_{t-1}/wt_{t-1}^*) + \varepsilon_t^{wg}$$

$$\log(wg_t) = \log(rg_t) + \log(py_t)$$

$$lwg_t = lg_t * wg_t$$

$$tfp(rg_t) = \log(rg_t) - \log(at_t)/(1 - \beta)$$

$$cp_t = 0.85 * pn_t + 0.15 * pe_t$$

$$\log(pn_t^*) = pn_1 - pn_2/sqrt(t) + pn_3 * \log(py_t) + pn_4 * \log(pm_t) + pn_5 * \log(bs_t) + \zeta_t^{pn}$$

$$dlog(pn_t) = pn_6 * dlog(pp_t) + pn_7 * dlog(pl_t) + pn_8 * dlog(pm_t) + pn_9 * dlog(pn_{t-1}) + pn_{10} * dlog(bs_t) + pn_{11} * gap(yt_t) + pn_{12} * up(\tau_t^{va}) + pn_{13} * down(\tau_t^{va}) + pn_{14} * up(\tau_t^{cn}) + pn_{15} * down(\tau_t^{cn}) - pn_{16} * \log(pn_{t-1}/pn_{t-1}^*) + \varepsilon_t^{pn}$$

$$\log(bs_t) = \log(lp_t) - \log(\varphi_t)$$

$$\log(pe_t^*) = pe_1 - pe_2/sqrt(t) + pe_3 * \log(py_t) + pe_4 * \log(oil_t) + pe_4 * \log(us_t) + \zeta_t^{pe}$$

$$dlog(pe_t) = pe_5 * dlog(pp_t) + pe_6 * dlog(pl_t) + pe_7 * dlog(oil_t) + pe_7 * dlog(us_t) + pe_8 * up(\tau_t^{va}) + pe_9 * down(\tau_t^{va}) + pe_{10} * up(\tau_t^{cn}) + pe_{11} * down(\tau_t^{cn}) - pe_{12} * \log(pe_{t-1}/pe_{t-1}^*) + \varepsilon_t^{pe}$$

$$\log(py_t^*) = \log(ulc_t) - \log(1 - \beta)$$

$$\log(ulc_t) = \log(lt_t) + \log(wt_t) - \log(yt_t)$$

$$\log(py_t) = \log(yn_t) - \log(yt_t)$$

$$dlog(pp_t) = pp_1 * dlog(ulc_t) + pp_2 * dlog(pl_t) + pp_3 * dlog(ulc_{t-1}) + pp_4 * up\left(\tau_t^{ci}\right) + pp_5 * down\left(\tau_t^{ci}\right) - pp_6 * \log(py_{t-1}/py_{t-1}^*) + \varepsilon_t^{pp}$$

$$\log(pi_t^*) = pi_1 + pi_2 * \log(py_t) + pi_3 * \log(pm_t) + \zeta_t^{pi}$$

$$dlog(pi_t) = pi_4 * dlog(pp_t) + pi_5 * dlog(pm_t) - pi_6 * \log(pi_{t-1}/pi_{t-1}^*) + \varepsilon_t^{pi}$$

$$dlog(pk_t) = dlog(pp_t) + \varepsilon_t^{pk}$$

$$\log(pg_t^*) = pg_1 - pg_2/sqrt(t) + pg_3 * \log(py_t) + pg_4 * \log(pc_t) + \zeta_t^{pg}$$

$$dlog(pg_t) = pg_5 * dlog(pp_t) + pg_6 * dlog(pc_t) - pg_7 * \log(pg_{t-1}/pg_{t-1}^*) + \varepsilon_t^{pg}$$

$$\mathrm{dlog}(\mathrm{pc}_t) = \mathrm{dlog}(\mathrm{cp}_t) + \varepsilon_t^{pc}$$

$$\log(\mathrm{px}_t^*) = \mathrm{px}_1 + \mathrm{px}_2 * \log(\mathrm{py}_t) + \mathrm{px}_3 * \log(\mathrm{pw}_t) + \mathrm{px}_3 * \log(\mathrm{er}_t) + \zeta_t^{px}$$

$$\mathrm{dlog}(\mathrm{px}_t) = \mathrm{px}_4 * \mathrm{dlog}(\mathrm{pp}_t) + \mathrm{px}_5 * \mathrm{dlog}(\mathrm{pw}_t) + \mathrm{px}_5 * \mathrm{dlog}(\mathrm{er}_t) - \mathrm{px}_6 * \log(\mathrm{px}_{t-1}/\mathrm{px}_{t-1}^*) + \varepsilon_t^{px}$$

$$\log(\mathrm{pm}_t^*) = \mathrm{pm}_1 + \mathrm{pm}_2 * \log(\mathrm{py}_t) + \mathrm{pm}_3 * \log(\mathrm{pw}_t) + \mathrm{pm}_3 * \log(\mathrm{er}_t) +$$
$$\mathrm{pm}_4 * \log(\mathrm{oil}_t) + \mathrm{pm}_4 * \log(\mathrm{us}_t) + \zeta_t^{pm}$$

$$\mathrm{dlog}(\mathrm{pm}_t) = \mathrm{pm}_5 * \mathrm{dlog}(\mathrm{pp}_t) + \mathrm{pm}_6 * \mathrm{dlog}(\mathrm{pw}_t) + \mathrm{pm}_6 * \mathrm{dlog}(\mathrm{er}_t) + \mathrm{pm}_7 * \mathrm{dlog}(\mathrm{oil}_t) +$$
$$\mathrm{pm}_7 * \mathrm{dlog}(\mathrm{us}_t) - \mathrm{pm}_8 * \log(\mathrm{pm}_{t-1}/\mathrm{pm}_{t-1}^*) + \varepsilon_t^{pm}$$

Interest rate block

$$(1 + sr_t) = (1 + eu_t)/(1 + \pi s_t)$$

$$\pi s_t = ps_t/ps_{t-1} - 1$$

$$dlog(ps_t) = 0.75 * dlog(ps_{t-1}) + 0.25 * dlog(pp_t)$$

$$(1 + lr_t) = (1 + sk_t)/(1 + \pi l_t)$$

$$\pi l_t = pl_t/pl_{t-1} - 1$$

$$dlog(pl_t) = 0.95 * dlog(pl_{t-1}) + 0.05 * dlog(pp_t)$$

$$sk_t = de_t + pr_t$$

$$pr_t = \phi_1 + \phi_2 * pr_{t-1} + \phi_3 * dp_t^* - \phi_4 * ca_t^* + \varepsilon_t^{pr}$$

Block of households

$$hn_t = lwt_t + lwe_t + \delta kh_t + st_t + ms_t + hp_t + ho_t - toh_t - coh_t$$

$$cor(ms_t) = \log(\omega_t) + \log(yn_t^*) - \log(ms_t)$$

$$d\log(ms_t) = ms_1 * d\log(yn_t^*) + ms_2 * d\log(ds_t) + ms_3 * cor(ms_{t-1}) + \varepsilon_t^{ms}$$

$$\log(hc_t) = \log(hn_t) - \log(pc_t)$$

$$toh_t = lit_t + pit_t + hit_t$$

$$\log(hi_t) = \log(hn_t) - \log(pi_t)$$

$$coh_t = lsc_t + psc_t + gsc_t + fsc_t + hsc_t + esc_t$$

$$hr_t = hn_t + pa_t$$

$$\log(pa_t) = \log(\varsigma_t) + \log(lt_t) + \log(wt_t)$$

$$he_t = cn_t - ni_t$$

$$\log(ni_t) = \log(\rho_t) + \log(cn_t)$$

$$\log(hs_t) = \log(1 - he_t/hr_t)$$

$$gsc_t = lf_t * wf_t * \frac{\tau_t^{gc}}{1 + \tau_t^{gc} + \tau_t^{fc}} + lg_t * wg_t * \frac{\tau_t^{gc}}{1 + \tau_t^{gc} + \tau_t^{fc}}$$

$$\gamma_t^{gc} = 0.75 * \gamma_{t-1}^{gc} + 0.25 * \tau_t^{gc}$$

$$\log(hp_t) = \log(\nu_t) + \log(yn_t)$$

$$fsc_t = lf_t * wf_t * \frac{\tau_t^{fc}}{1 + \tau_t^{gc} + \tau_t^{fc}} + lg_t * wg_t * \frac{\tau_t^{fc}}{1 + \tau_t^{gc} + \tau_t^{fc}}$$

$$\gamma_t^{fc} = 0.75 * \gamma_{t-1}^{fc} + 0.25 * \tau_t^{fc}$$

$$\log(ho_t) = \log(\upsilon_t) + \log(yn_t)$$

$$esc_t = le_t * we_t * \tau_t^{ec}$$

$$\gamma_t^{ec} = 0.75 * \gamma_{t-1}^{ec} + 0.25 * \tau_t^{ec}$$

Block of government

$$rp_t = dit_t + int_t + soc_t + \delta kg_t + gp_t + go_t + ge_t + gc_t$$

$$ep_t = gt_t * pg_t + ig_t * pi_t + st_t + ir_t + oc_t$$

$$bp_t = rp_t - ep_t$$

$$bp_t^* = (bp_t + bp_{t-1} + bp_{t-2} + bp_{t-3})/(yn_t + yn_{t-1} + yn_{t-2} + yn_{t-3})$$

$$dp_t = dp_{t-1} - bp_t$$

$$dp_t^* = dp_t/(yn_t + yn_{t-1} + yn_{t-2} + yn_{t-3})$$

$$int_t = vat_t + cnt_t + ynt_t$$

$$vat_t = 0.76 * cn_t * \frac{\tau_t^{va}}{1 + \tau_t^{va}} + 0.82 * ic_t * \frac{\tau_t^{va}}{1 + \tau_t^{va}} + 0.93 * ig_t * \frac{\tau_t^{va}}{1 + \tau_t^{va}}$$

$$\gamma_t^{va} = 0.75 * \gamma_{t-1}^{va} + 0.25 * \tau_t^{va}$$

$$cnt_t = 0.88 * cn_t * \frac{\tau_t^{cn}}{1 + \tau_t^{va}} + 0.12 * yn_t * \frac{\tau_t^{cn}}{1 + \tau_t^{va}}$$

$$\gamma_t^{cn} = 0.75 * \gamma_{t-1}^{cn} + 0.25 * \tau_t^{cn}$$

$$dit_t = lit_t + pit_t + cit_t + hit_t + git_t$$

$$lit_t = lf_t * wf_t * \frac{\tau_t^{li}}{1 + \tau_t^{gc} + \tau_t^{fc}} + lg_t * wg_t * \frac{\tau_t^{li}}{1 + \tau_t^{gc} + \tau_t^{fc}}$$

$$\gamma_t^{li} = 0.75 * \gamma_{t-1}^{li} + 0.25 * \tau_t^{li}$$

$$pit_t = lh_t * wt_t * \tau_t^{pi}$$

$$\gamma_t^{pi} = 0.75 * \gamma_{t-1}^{pi} + 0.25 * \tau_t^{pi}$$

$$cit_t = os_t * \frac{\tau_t^{ci}}{1 - \tau_t^{ci}}$$

$$\gamma_t^{ci} = 0.75 * \gamma_{t-1}^{ci} + 0.25 * \tau_t^{ci}$$

$$hit_t = hn_t * \tau_t^{hi}$$

$$\gamma_t^{hi} = 0.75 * \gamma_{t-1}^{hi} + 0.25 * \tau_t^{hi}$$

$$soc_t = lsc_t + psc_t + gsc_t + hsc_t$$

$$lsc_t = lf_t * wf_t * \frac{\tau_t^{lc}}{1 + \tau_t^{gc} + \tau_t^{fc}} + lg_t * wg_t * \frac{\tau_t^{lc}}{1 + \tau_t^{gc} + \tau_t^{fc}}$$

$$\gamma_t^{lc} = 0.75 * \gamma_{t-1}^{lc} + 0.25 * \tau_t^{lc}$$

$$psc_t = lh_t * wt_t * \tau_t^{pc}$$

$$\gamma_t^{pc} = 0.75 * \gamma_{t-1}^{pc} + 0.25 * \tau_t^{pc}$$

$$hsc_t = hn_t * \tau_t^{hc}$$

$$\gamma_t^{hc} = 0.75 * \gamma_{t-1}^{hc} + 0.25 * \tau_t^{hc}$$

$$\log(nt_t) = \log(\theta_t) + \log(lt_t) + \log(wt_t)$$

$$cor(ic_t) = \log(ic_1) + \log(yn_t^*) - \log(ic_t)$$

$$dlog(ic_t) = ic_2 * dlog(yn_t^*) + ic_3 * dlog(yn_t) - ic_4 * gap(yt_{t-1}) + ic_5 * dev(bp_{t-1}^*) - ic_6 * dev(dp_{t-1}^*) + ic_7 * cor(ic_{t-1}) + \varepsilon_t^{ic}$$

$$\log(rc_t) = \log(ic_t) - \log(py_t)$$

$$\log(mp_t) = \log(\chi_t) + \log(va_t)$$

$$cor(st_t) = \log(st_1) + \log(yn_t^*) - \log(st_t)$$

$$dlog(st_t) = st_2 * dlog(yn_t^*) + st_3 * dlog(lt_t) + st_3 * dlog(wt_t) + st_4 * dlog(\eta_t) + st_4 * dlog(\mu_t) - st_5 * gap(yt_{t-1}) + st_6 * dev(bp_{t-1}^*) - st_7 * dev(dp_{t-1}^*) + st_8 * cor(st_{t-1}) + \varepsilon_t^{st}$$

$$\log(rt_t) = \log(st_t) - \log(py_t)$$

$$\log(ot_t) = \log(\xi_t) + \log(gn_t)$$

$$ir_t = 1/4 * ef_t * dp_{t-1}$$

$$ef_t = 0.95 * ef_{t-1} + 0.05 * sk_t$$

Convergence properties

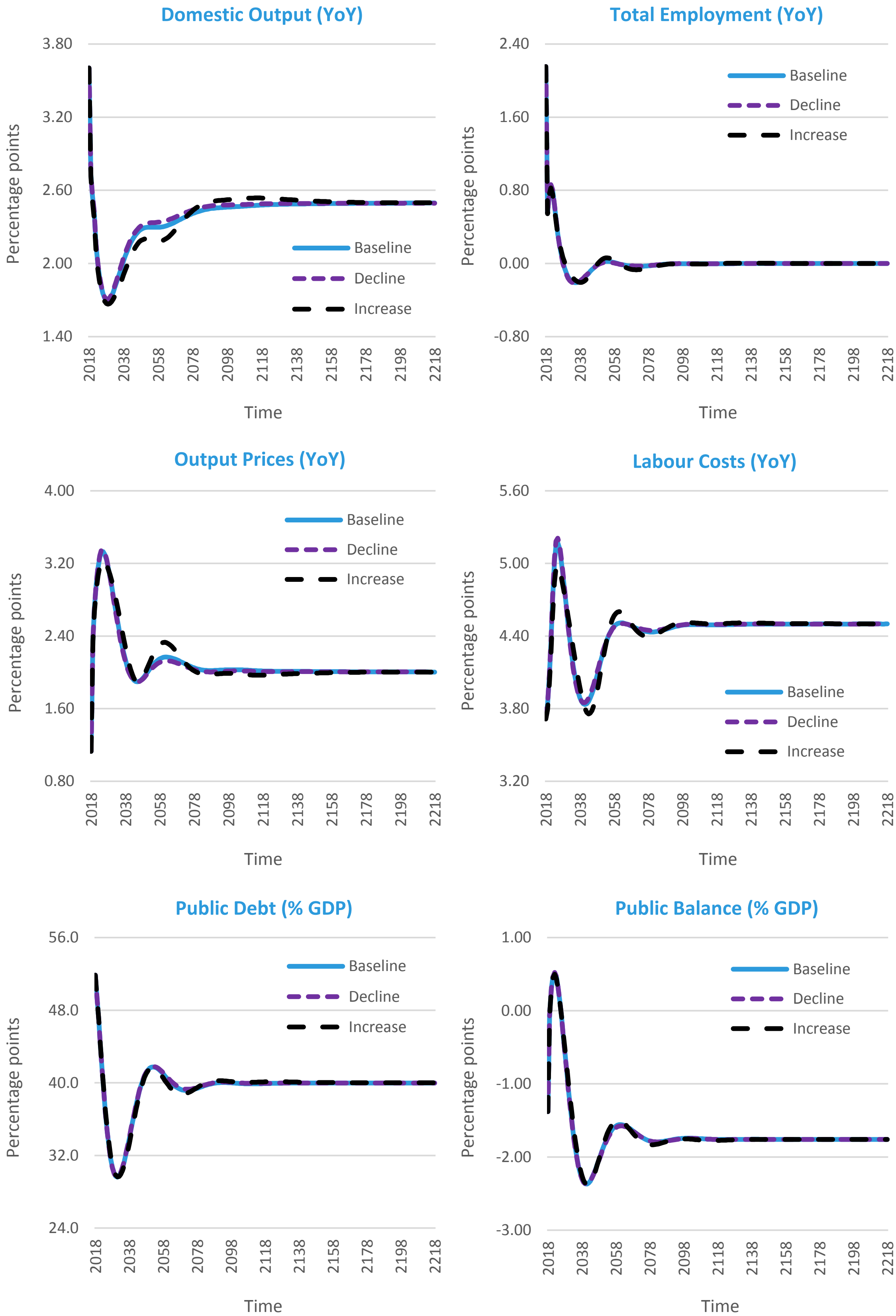


Fig.C1: Convergence properties of model variables under a baseline scenario with a calibration of $\mathrm{if}_9 = 0.10$ and $\mathrm{ih}_9 = 0.05$, a decline scenario with a calibration of $\mathrm{if}_9 = 0.02$ and $\mathrm{ih}_9 = 0.01$ and an increase scenario with a calibration of $\mathrm{if}_9 = 0.50$ and $\mathrm{ih}_9 = 0.25$.

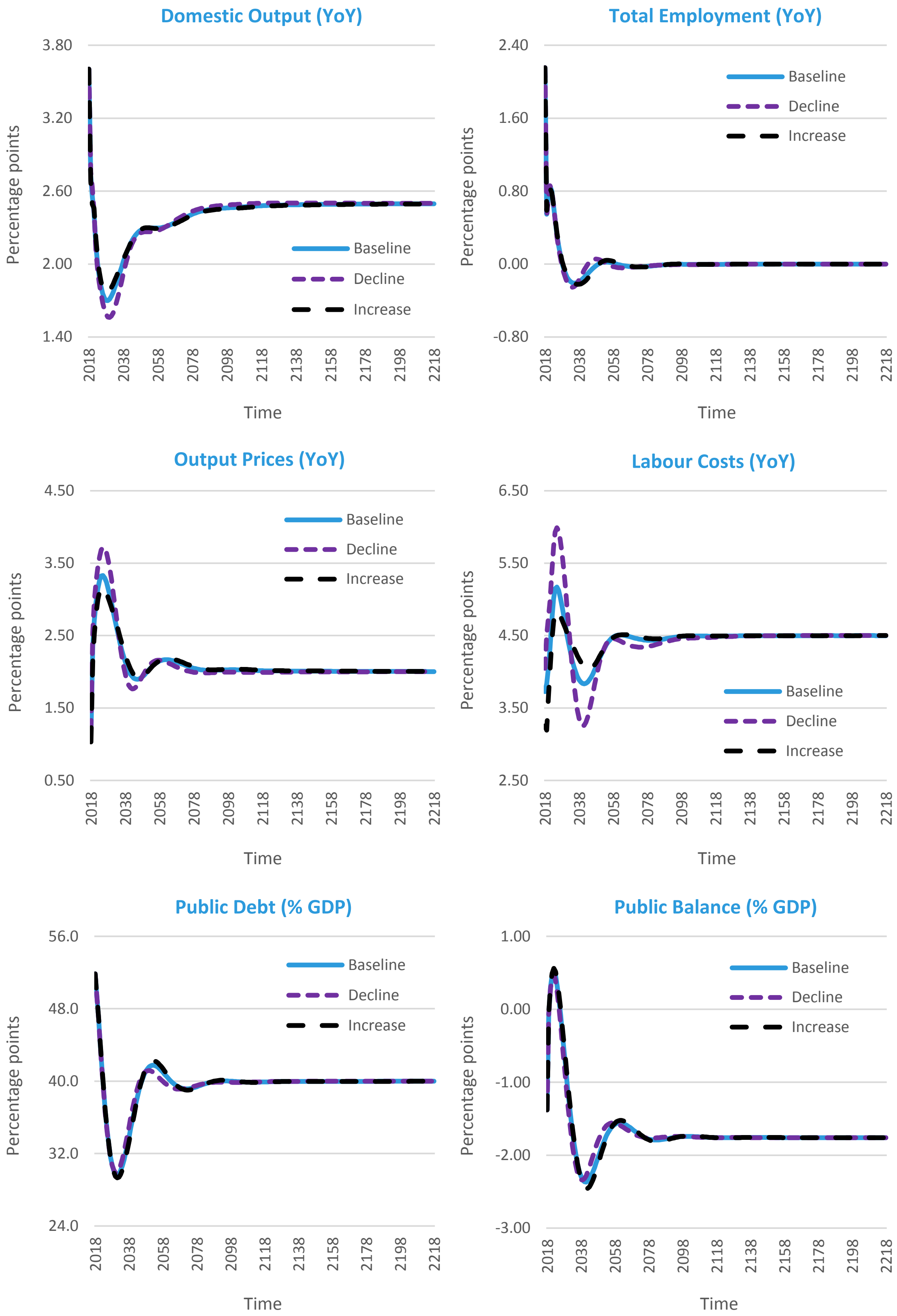


Fig.C2: Convergence properties of model variables under a baseline scenario with a calibration of $wf_9 = 0.10$ and $wg_{11} = 0.05$, a decline scenario with a calibration of $wf_9 = 0.04$ and $wg_{11} = 0.02$ and an increase scenario with a calibration of $wf_9 = 0.20$ and $wg_{11} = 0.10$.

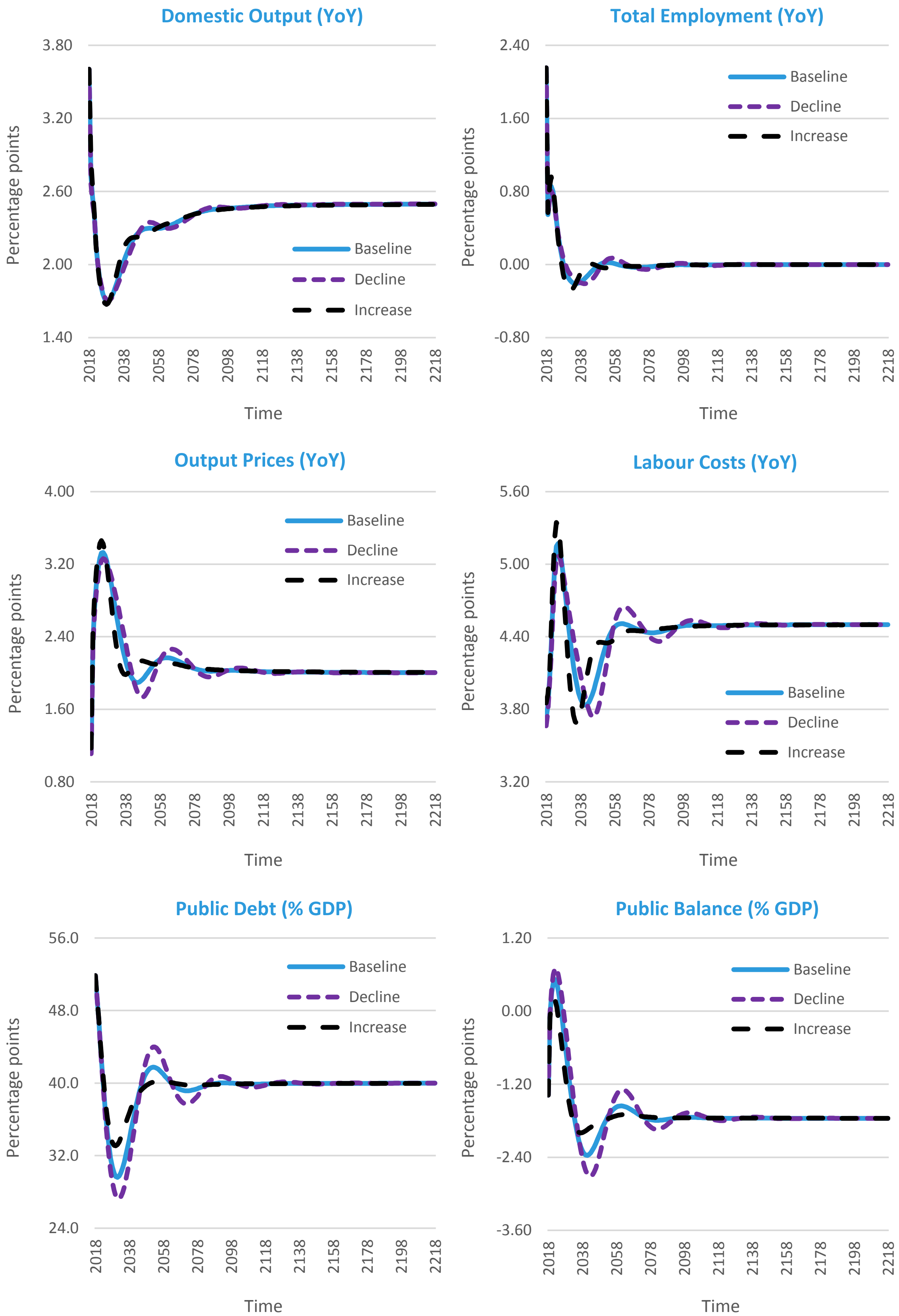


Fig.C3: Convergence properties of model variables under a baseline scenario with a calibration of $ig_4 = 0.40$ and $ic_5 = 0.40$, a decline scenario with a calibration of $ig_4 = 0.20$ and $ic_5 = 0.20$ and an increase scenario with a calibration of $ig_4 = 0.80$ and $ic_5 = 0.80$.

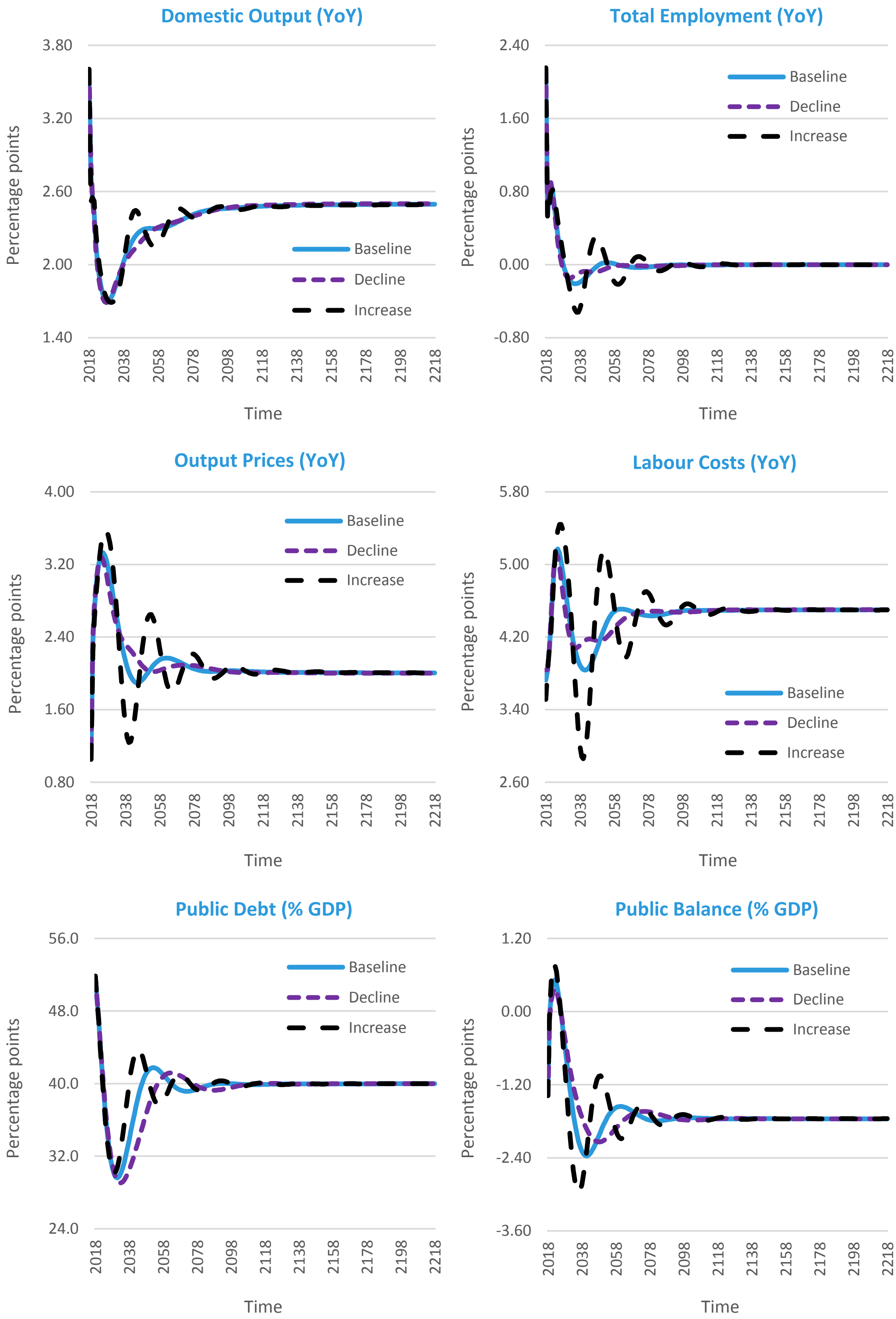


Fig.C4: Convergence properties of model variables under a baseline scenario with a calibration of $ig_5 = 0.10$ and $ic_6 = 0.10$, a decline scenario with a calibration of $ig_5 = 0.05$ and $ic_6 = 0.05$ and an increase scenario with a calibration of $ig_5 = 0.20$ and $ic_6 = 0.20$.

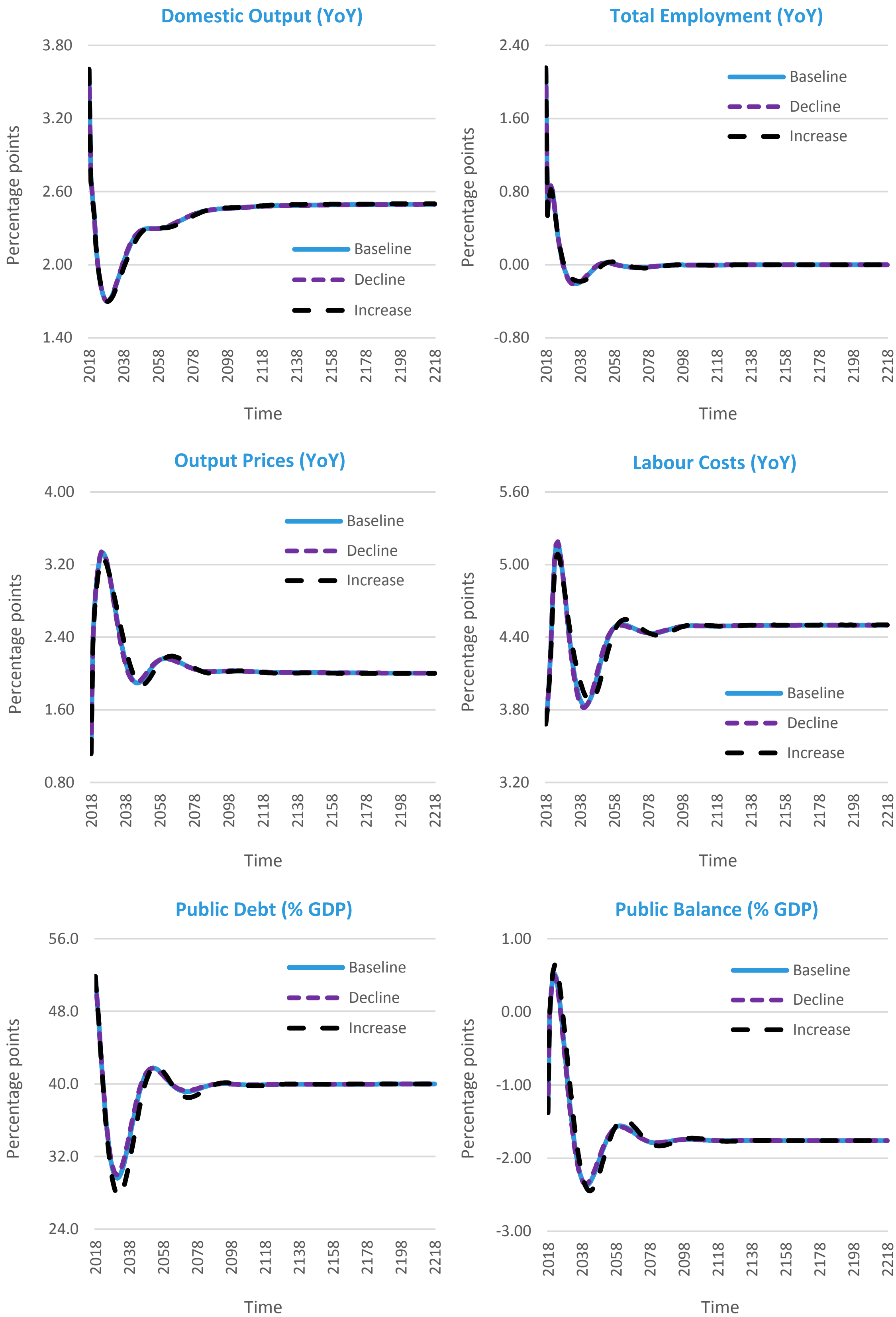


Fig.C5: Convergence properties of model variables under a baseline scenario with a calibration of $\mathrm{ig}_3 = 0.05$ and $\mathrm{ic}_4 = 0.05$, a decline scenario with a calibration of $\mathrm{ig}_3 = 0.01$ and $\mathrm{ic}_4 = 0.01$ and an increase scenario with a calibration of $\mathrm{ig}_3 = 0.25$ and $\mathrm{ic}_4 = 0.25$.

Macroeconomic shocks

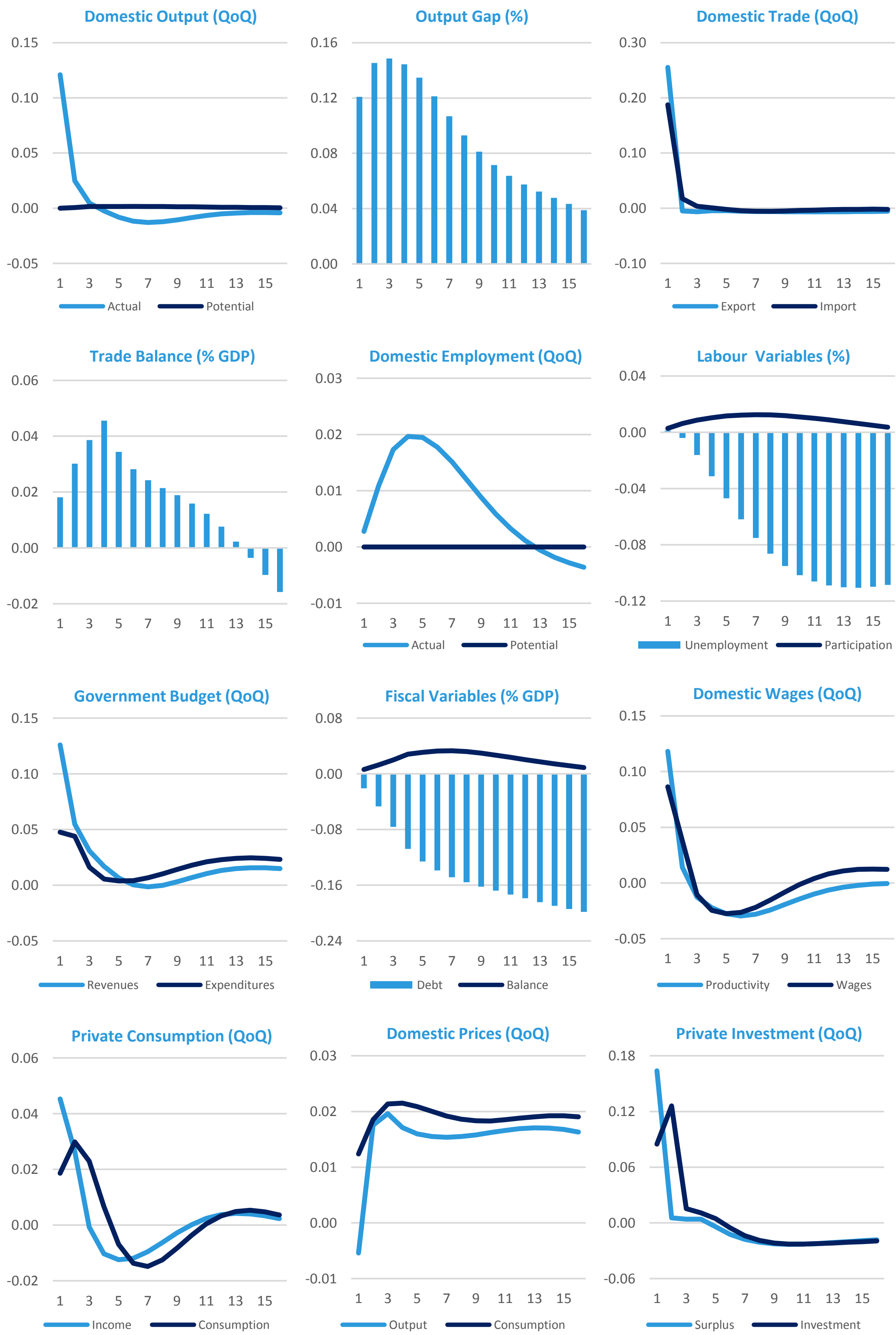


Fig.M1: A permanent shock to a total external demand that corresponds to an increase of a growth rate by 0.25 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

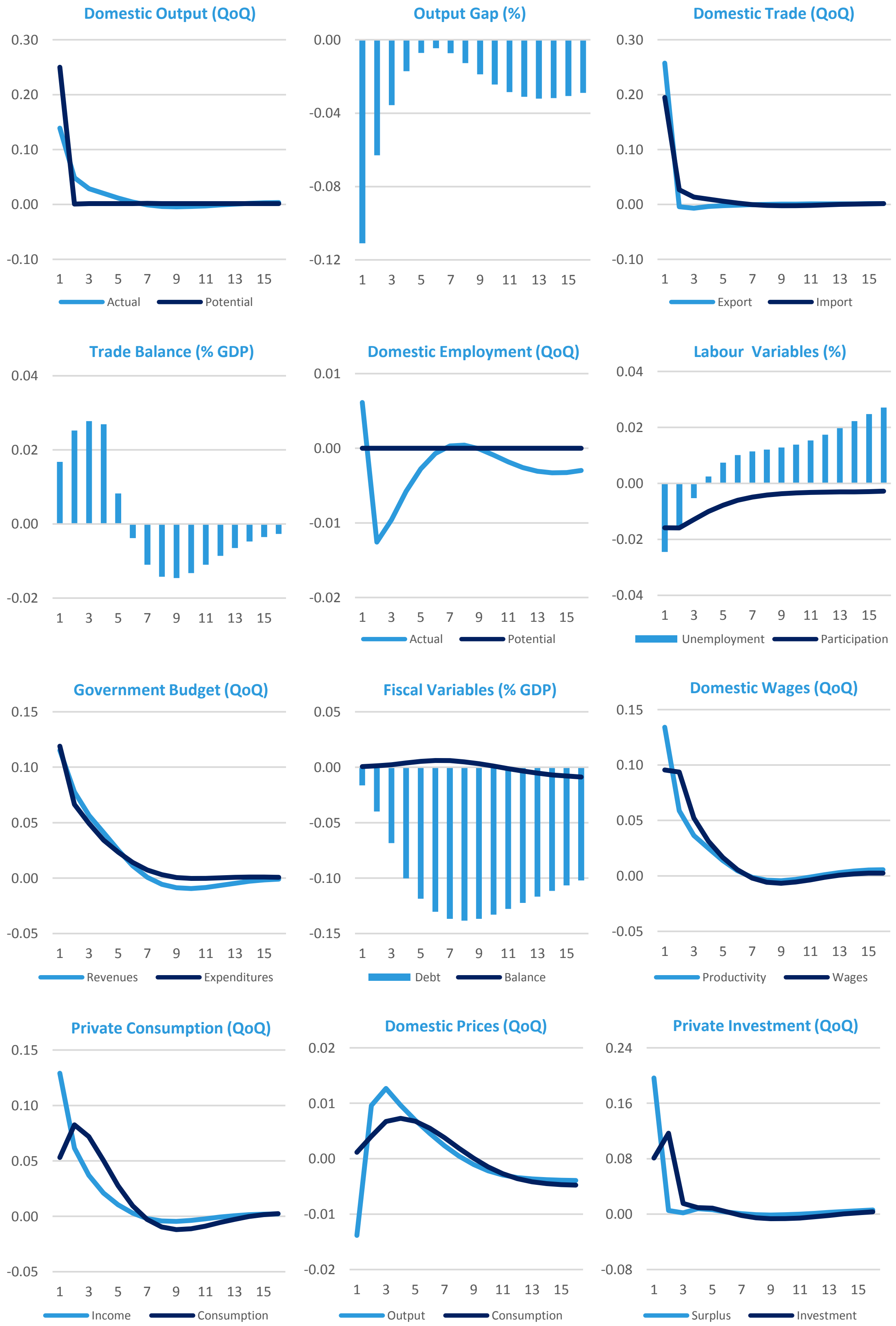


Fig.M2: A permanent shock to a total factor productivity that corresponds to an increase of a growth rate by 0.25 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

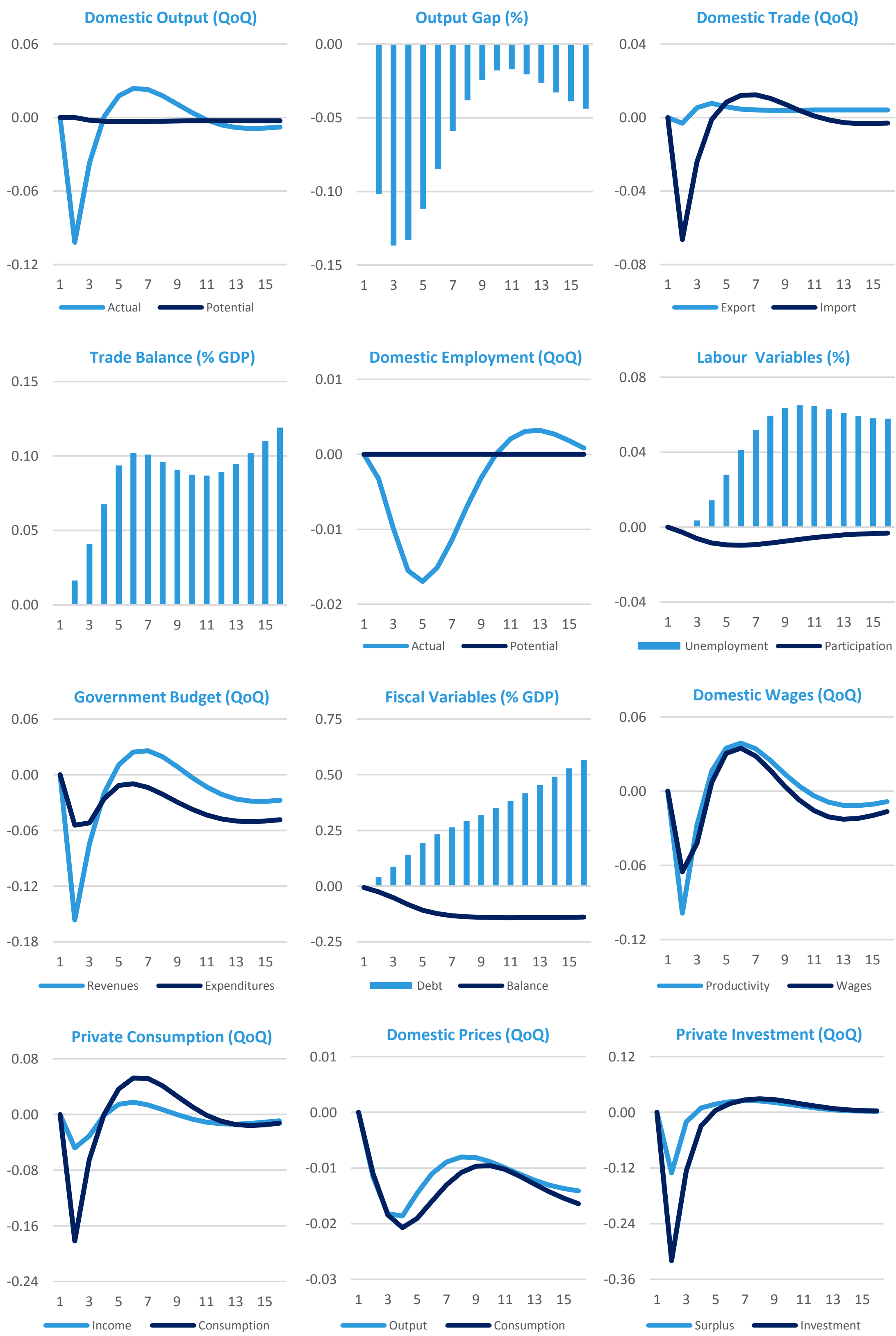


Fig.M3: A permanent shock to nominal interest rates that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

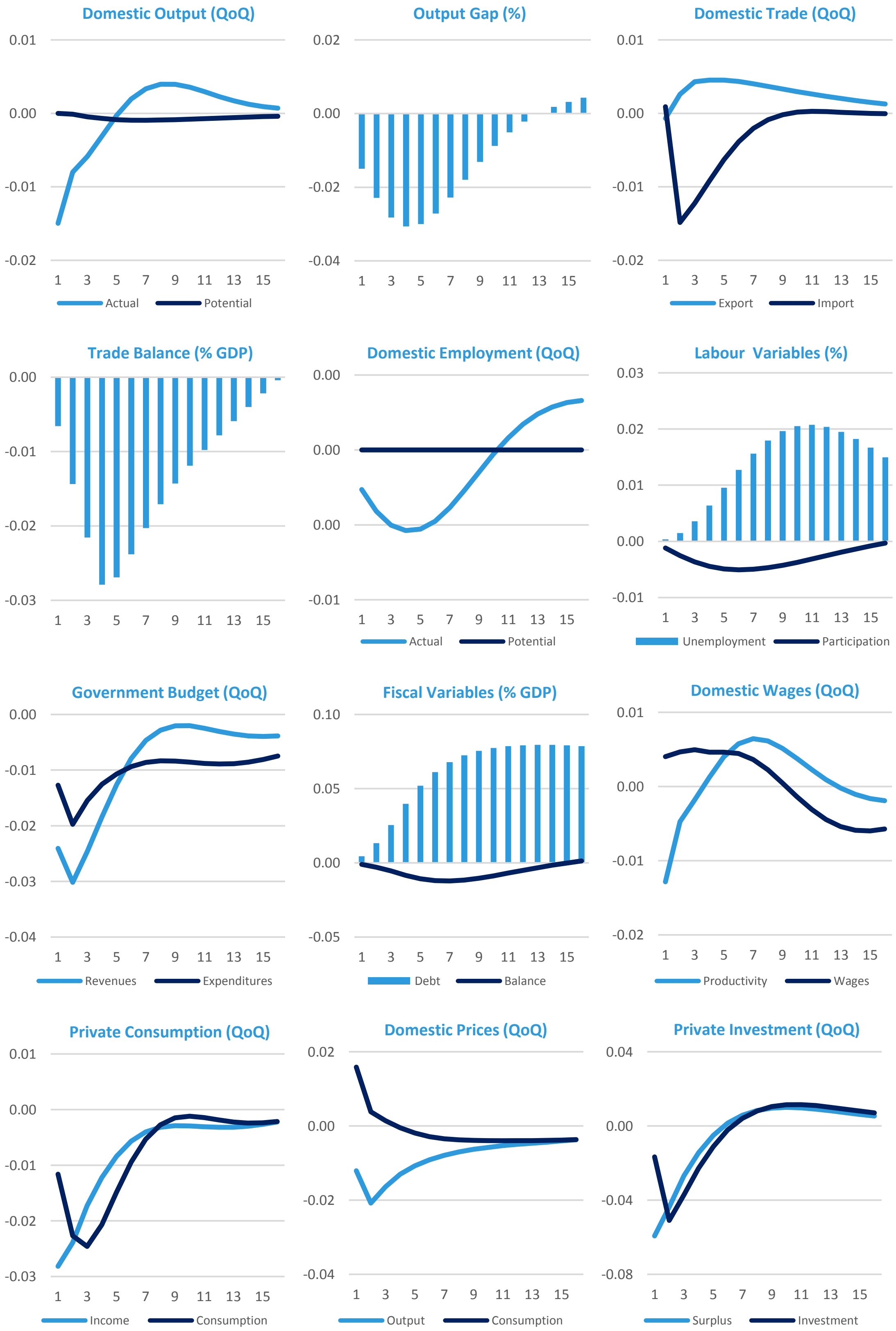


Fig.M4: A permanent shock to world crude oil prices that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

Variation of parameters

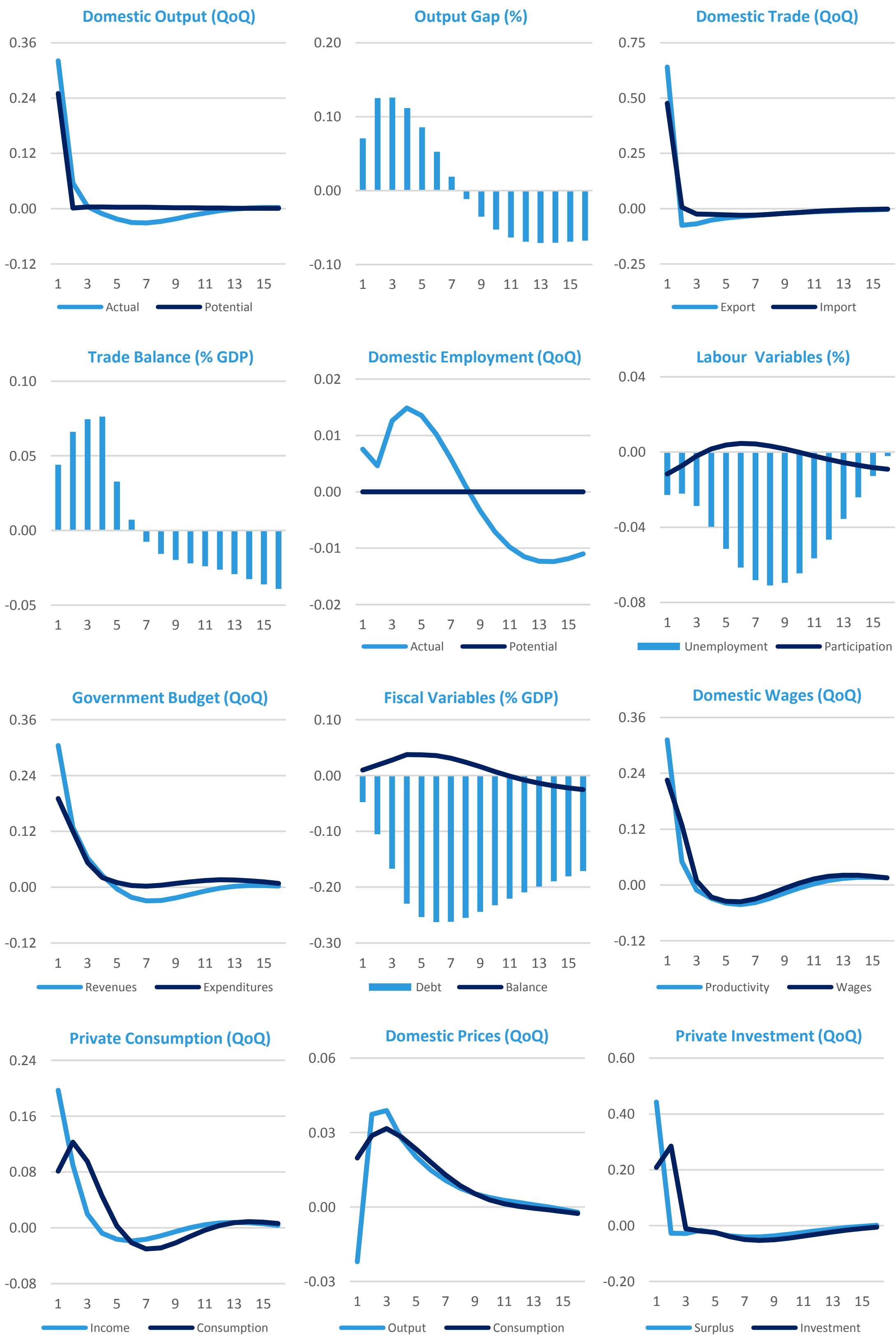


Fig.S1: A permanent shock to a total factor productivity that corresponds to an increase of a growth rate by 0.25 p.p. in the first quarter with the parameter xt_8 set from 1.00 to 2.50. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

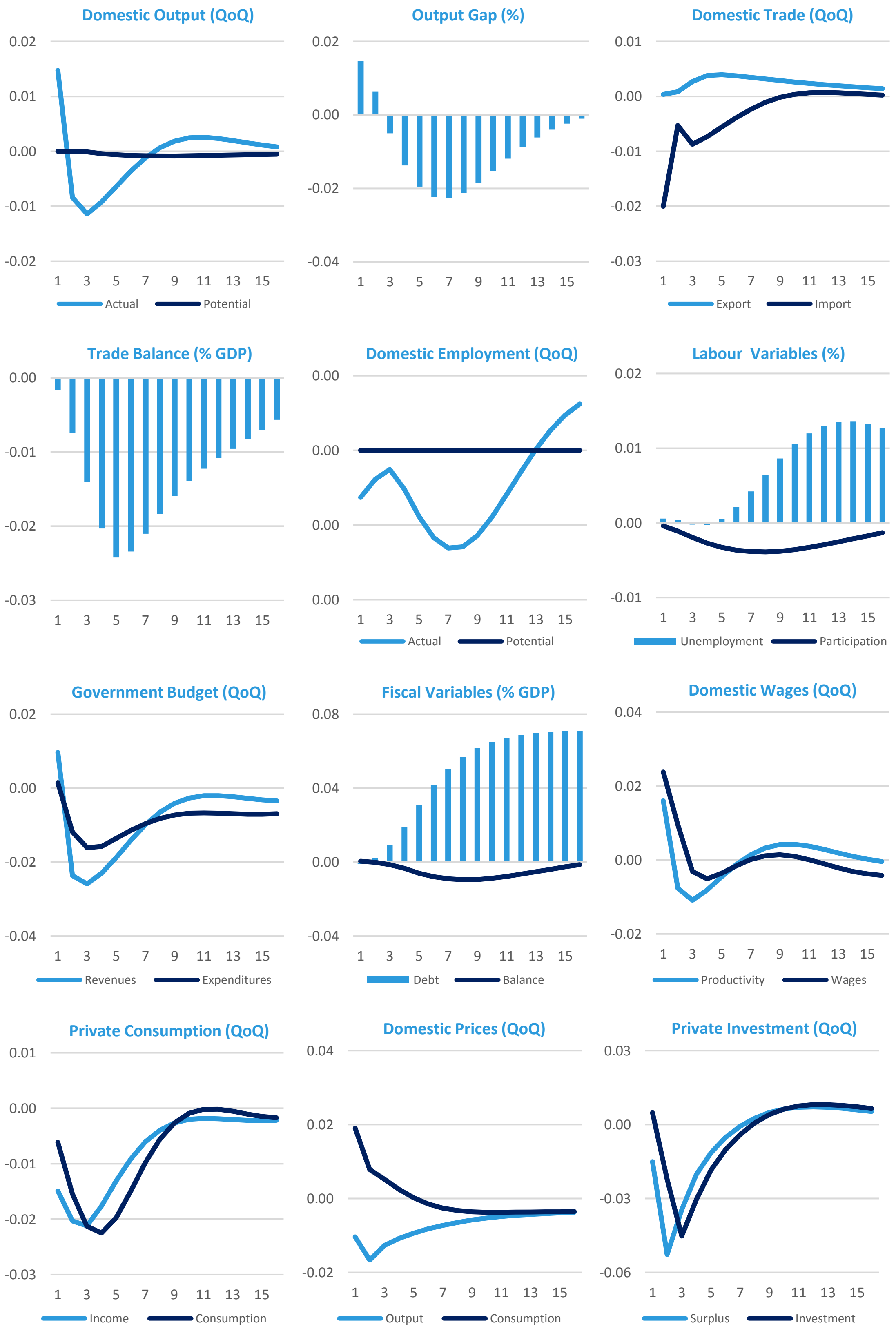


Fig.S2: A permanent shock to world crude oil prices that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter with the parameter mt_8 set from 0.00 to 0.01. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

Shocks to revenues

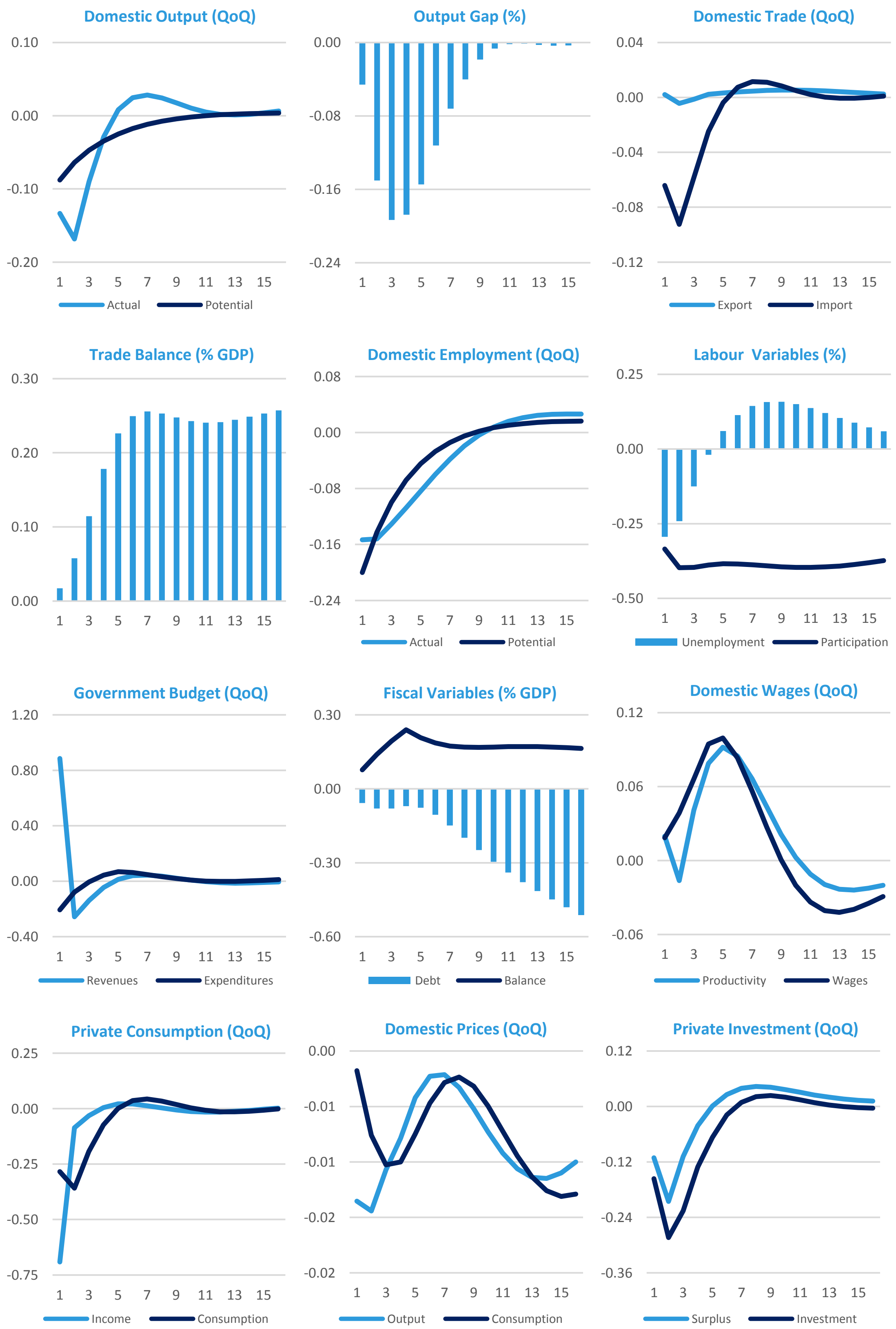


Fig.R1: A permanent shock to labour income taxes that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

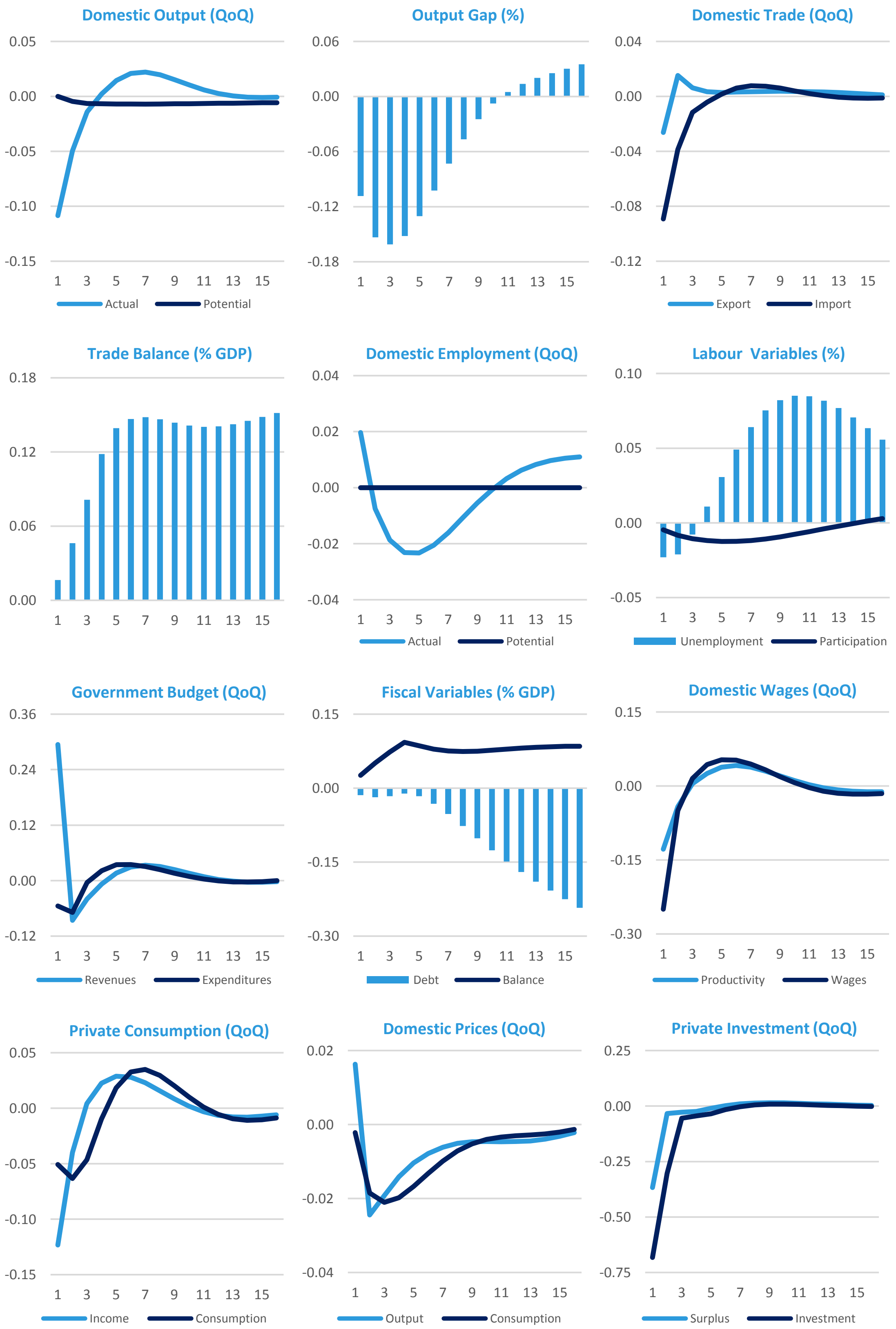


Fig.R2: A permanent shock to capital income taxes that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

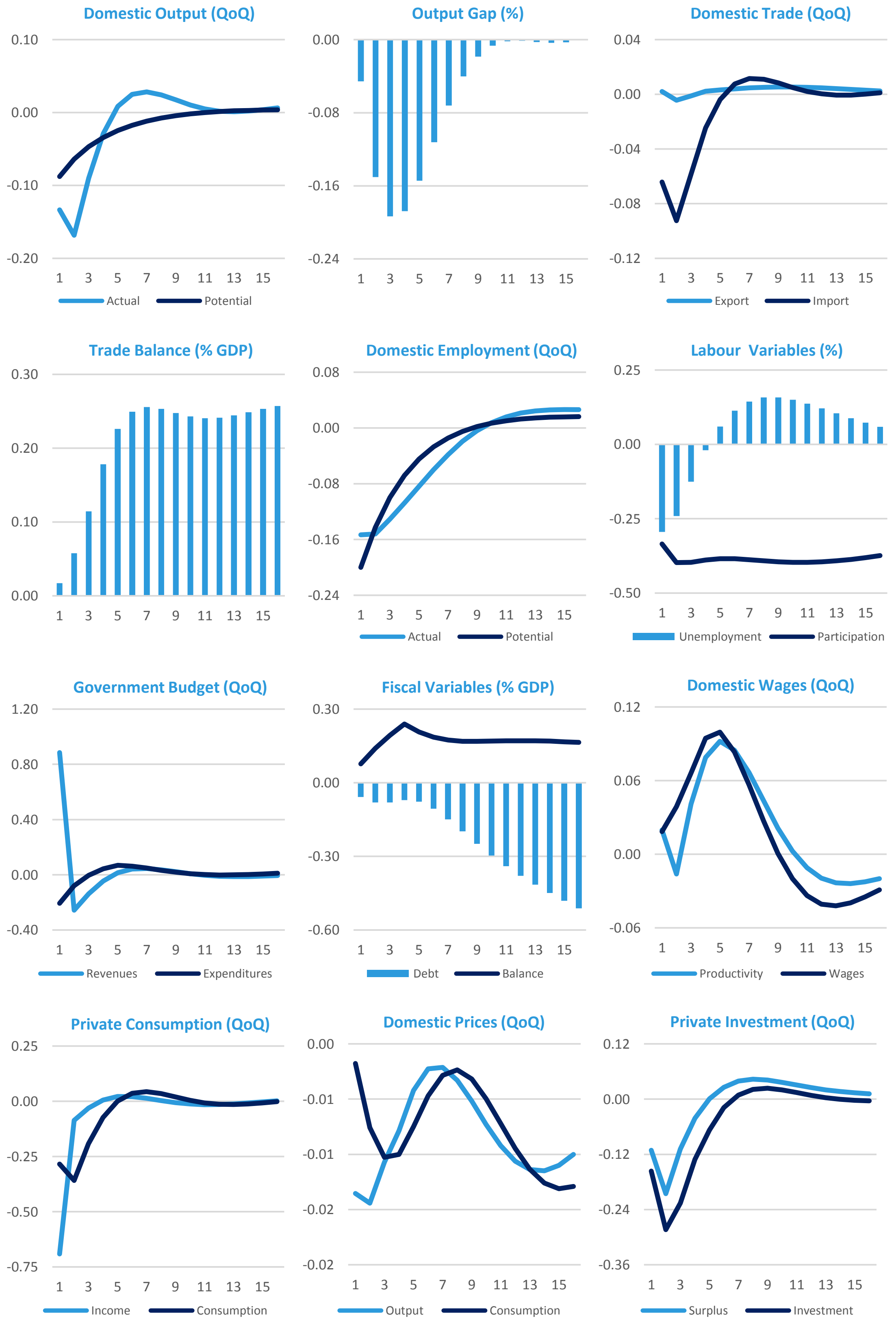


Fig.R3: A permanent shock to contributions of employees that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

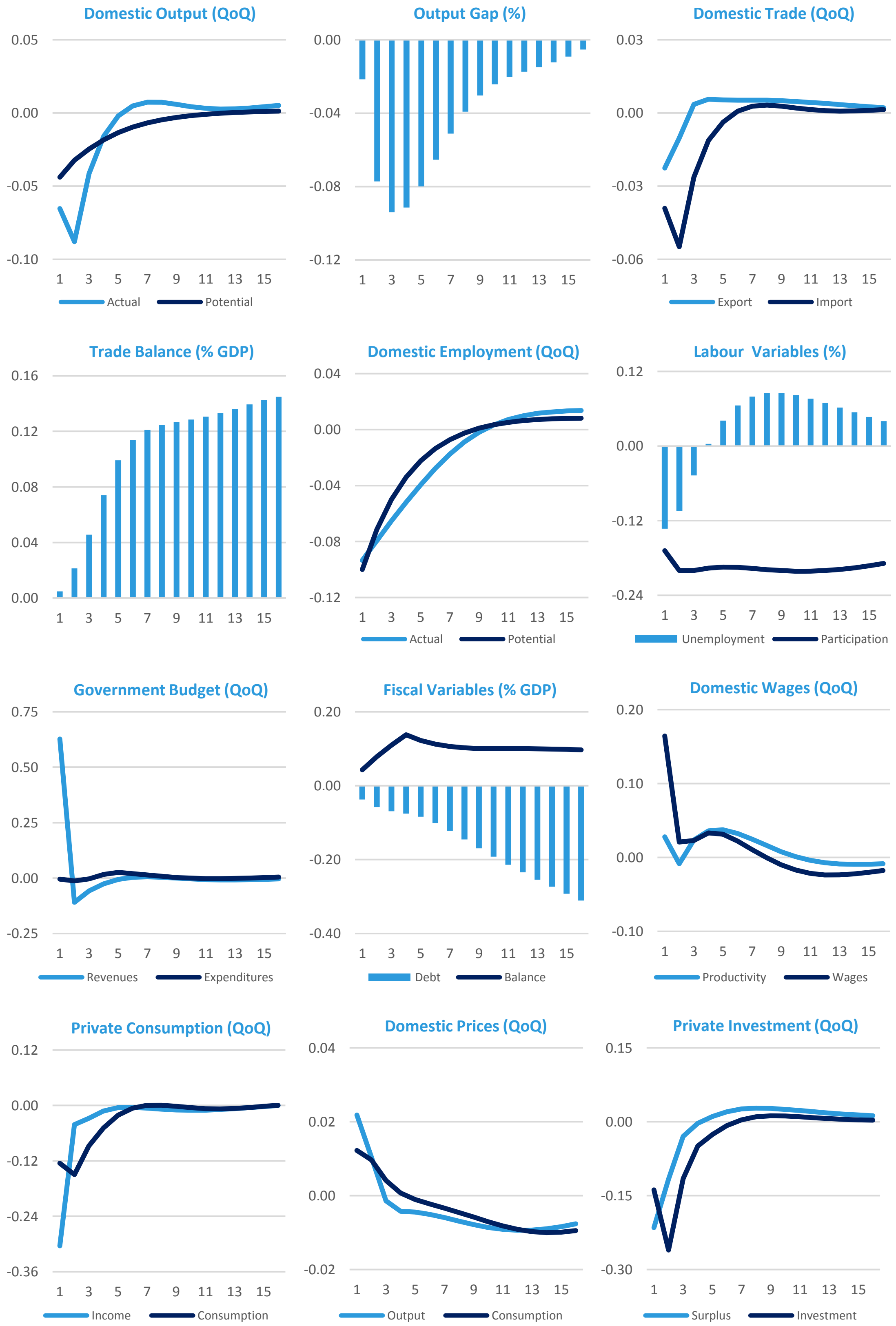


Fig.R4: A permanent shock to contributions of employers that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

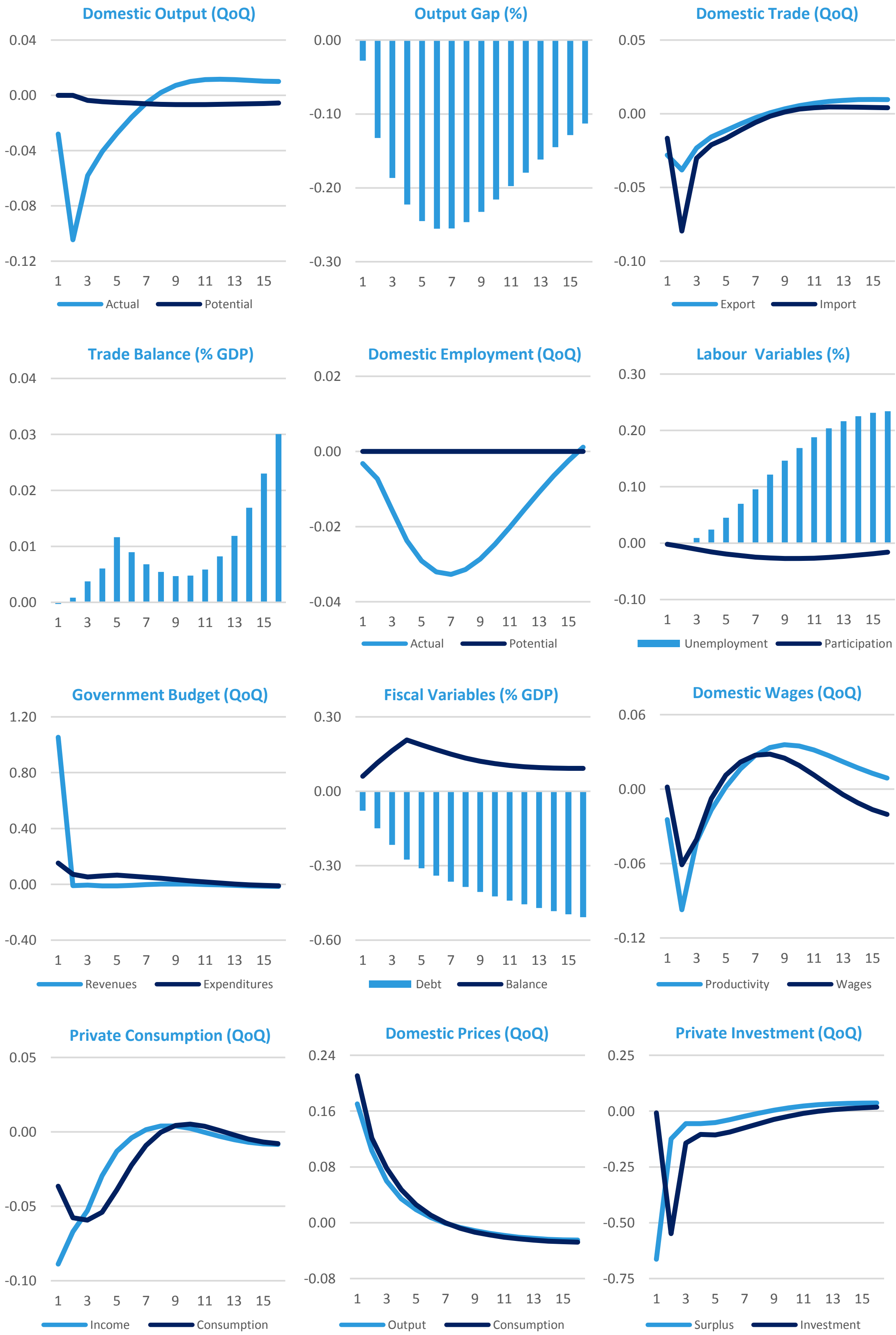


Fig.R5: A permanent shock to value added taxes that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

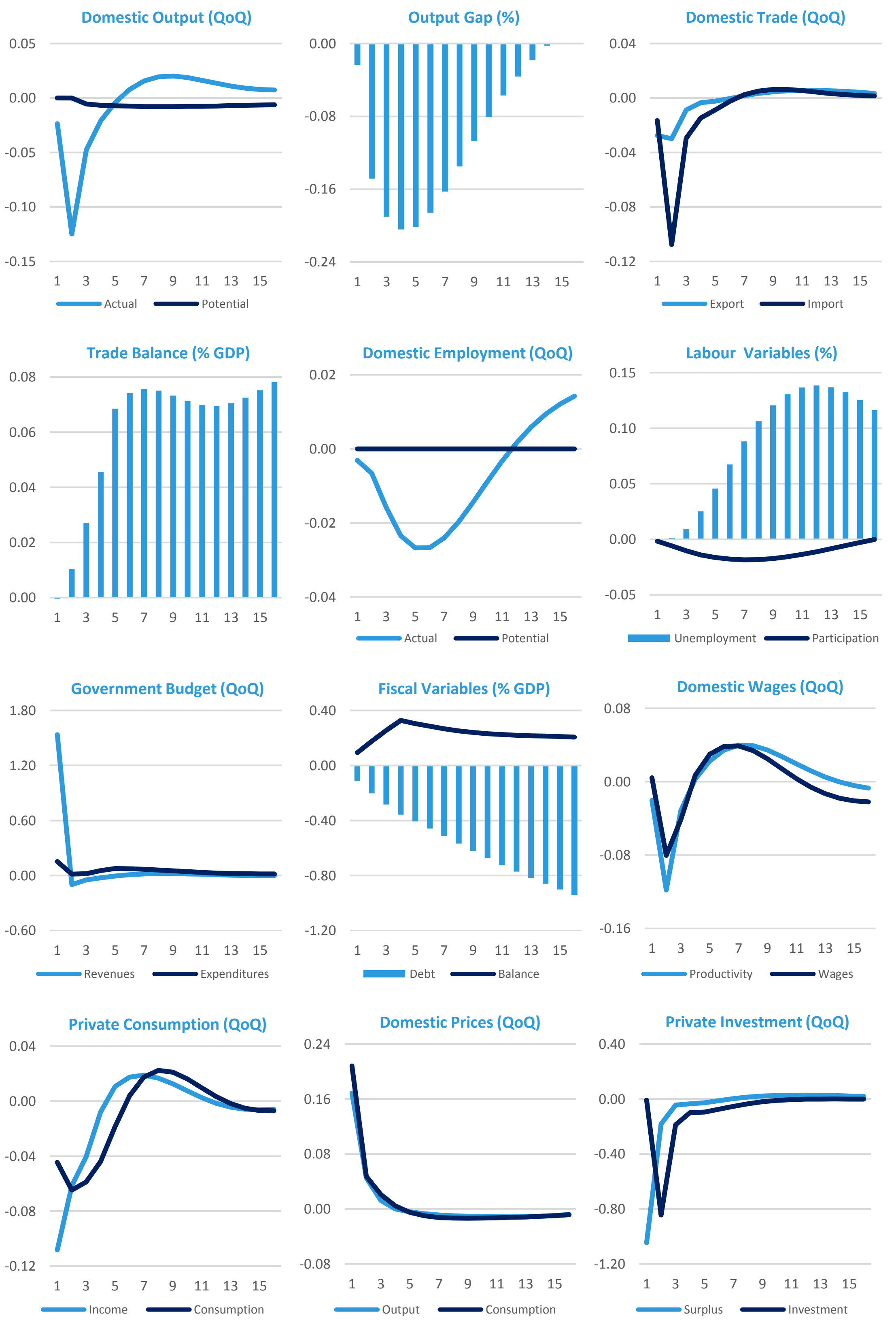


Fig.R6: A permanent shock to net consumption taxes that corresponds to an increase of an effective rate by 1.00 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

Shocks to expenditures

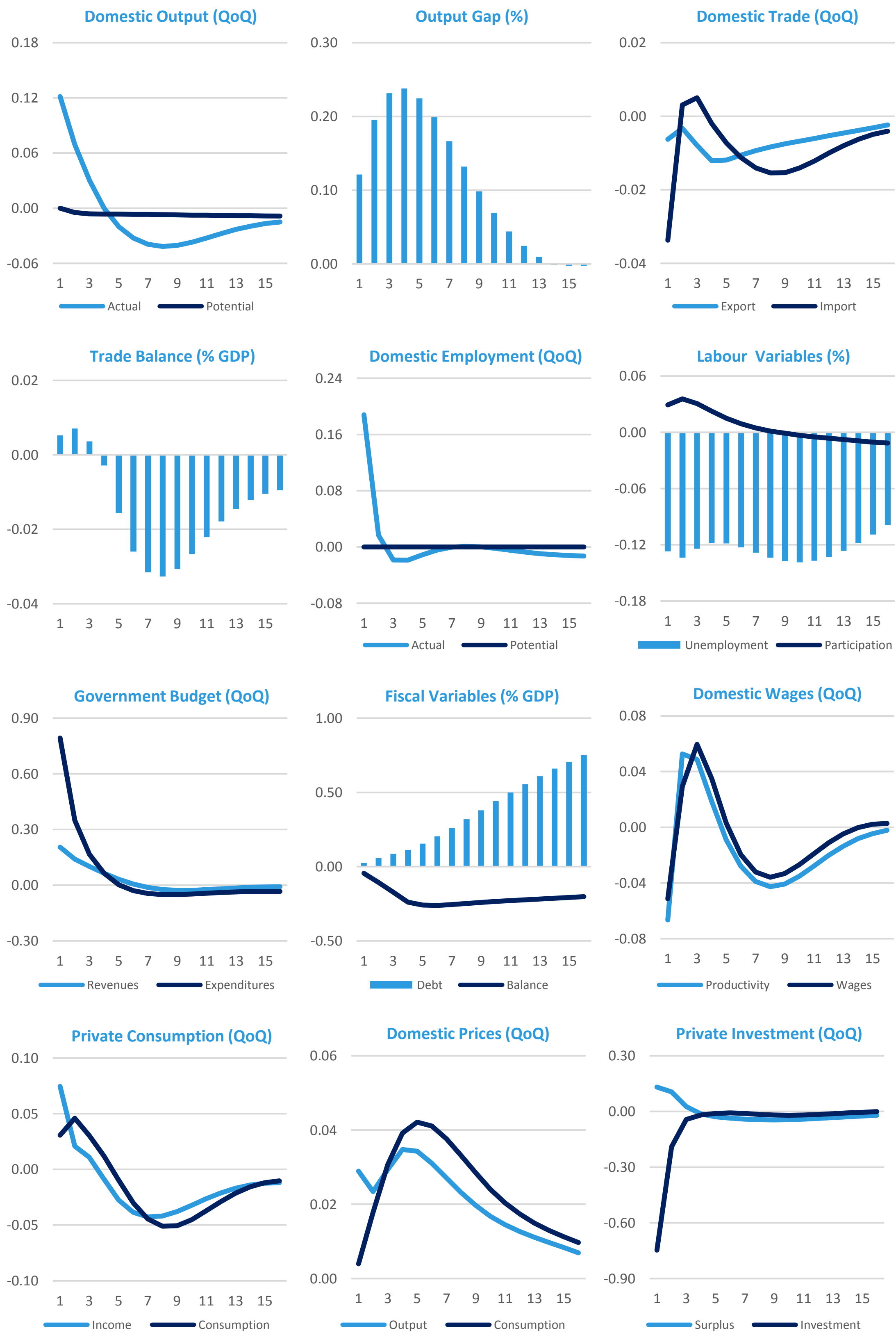


Fig.E1: A permanent shock to public employment that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

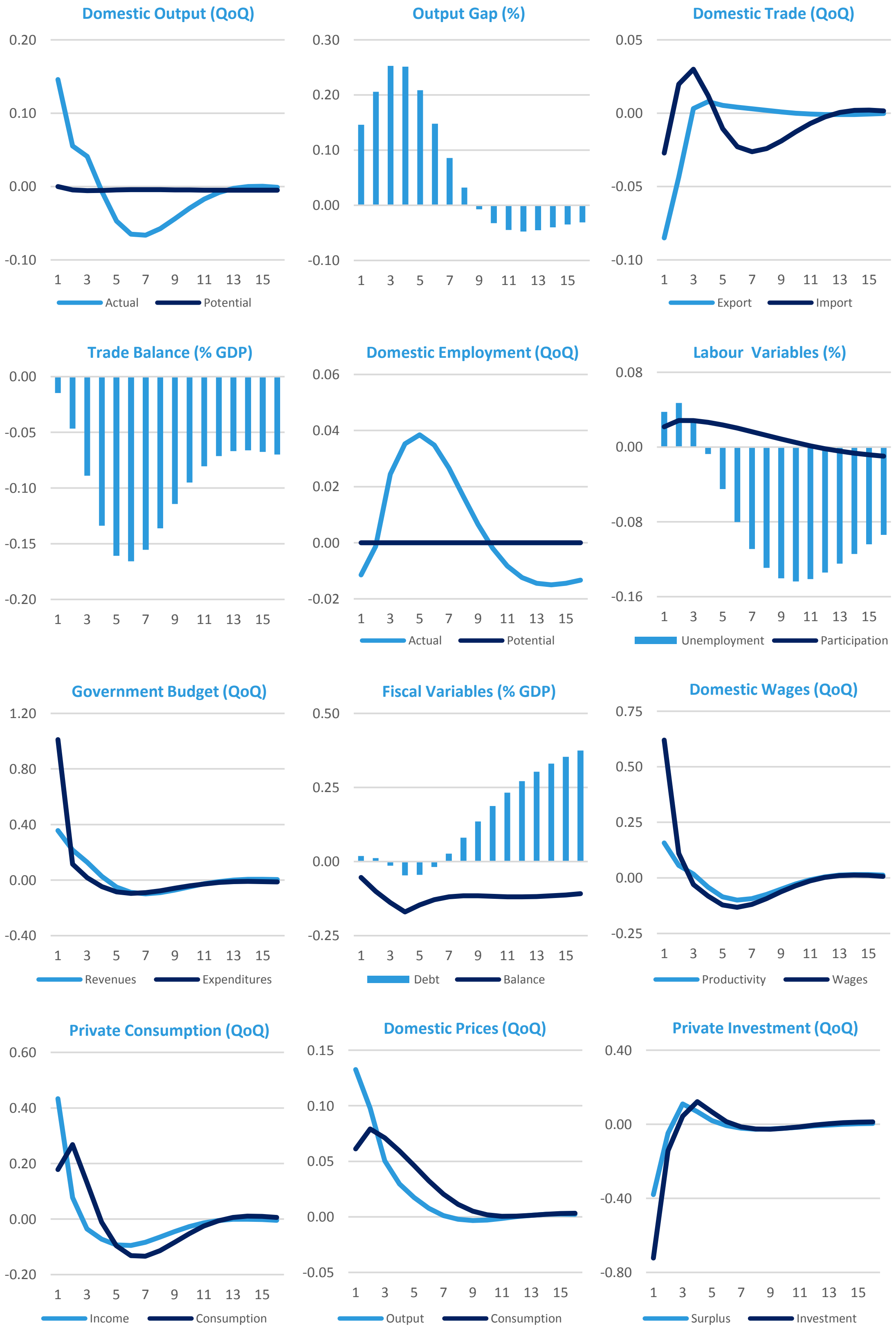


Fig.E2: A permanent shock to public labour costs that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

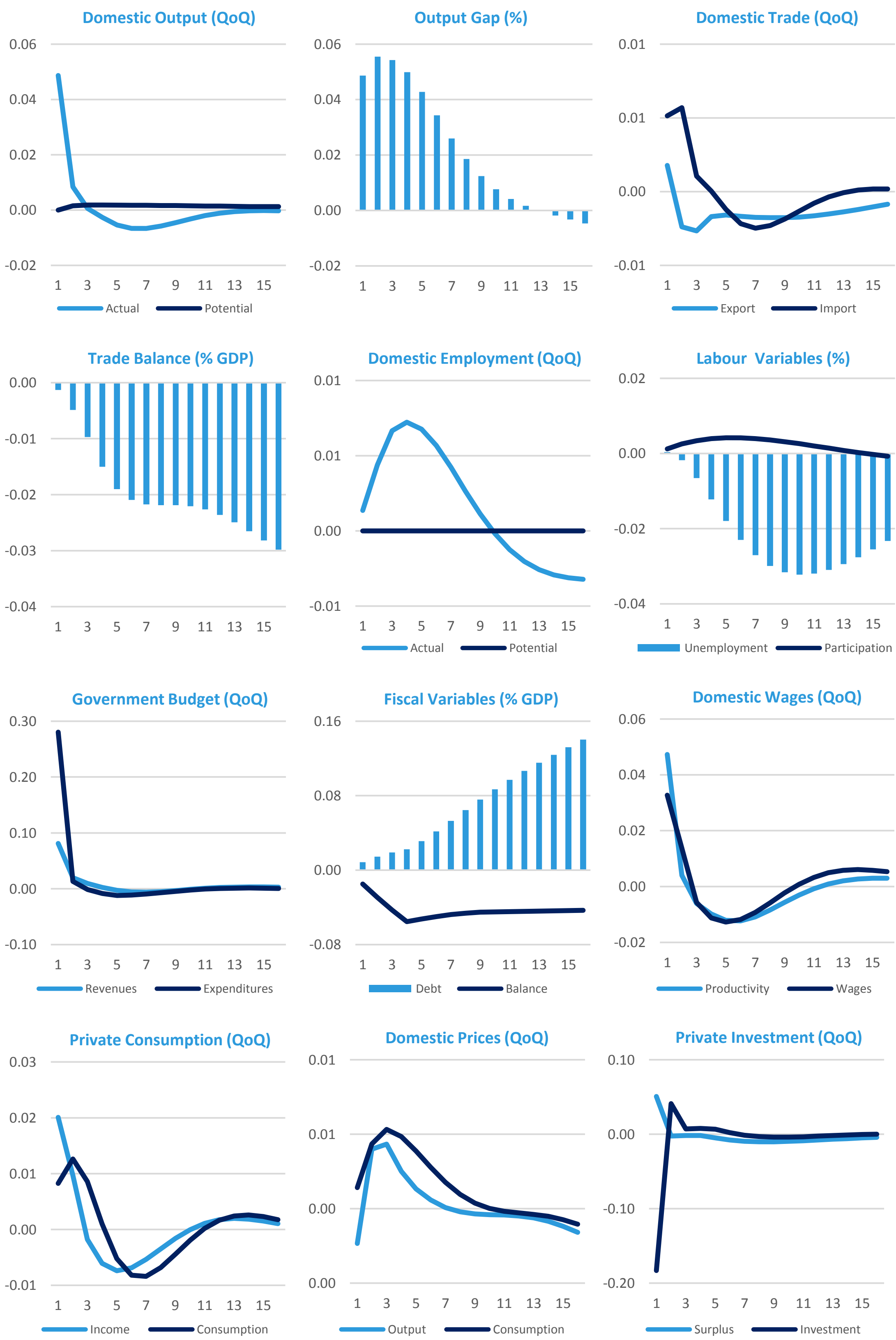


Fig.E3: A permanent shock to government investment that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

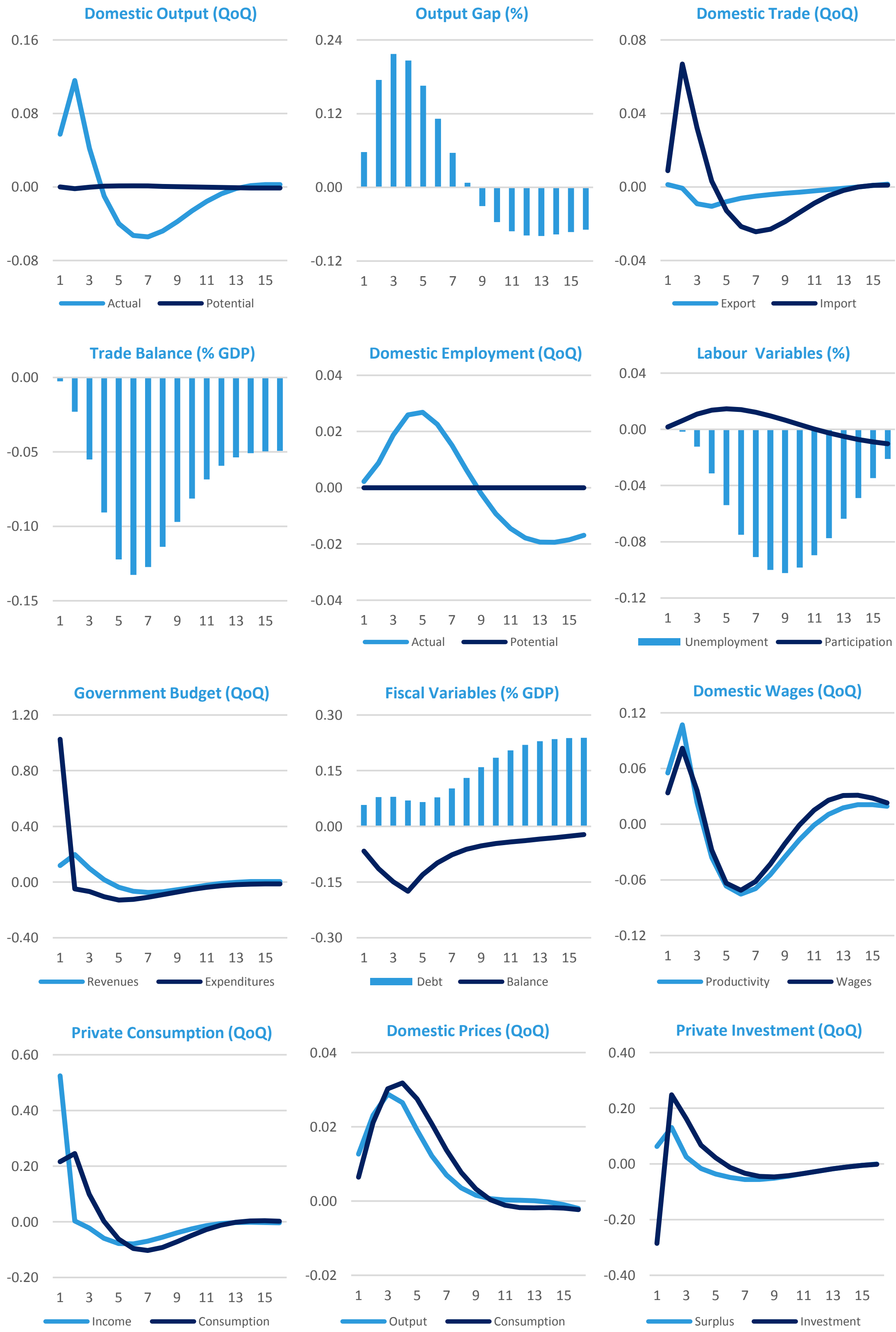


Fig.E4: A permanent shock to public social transfers that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

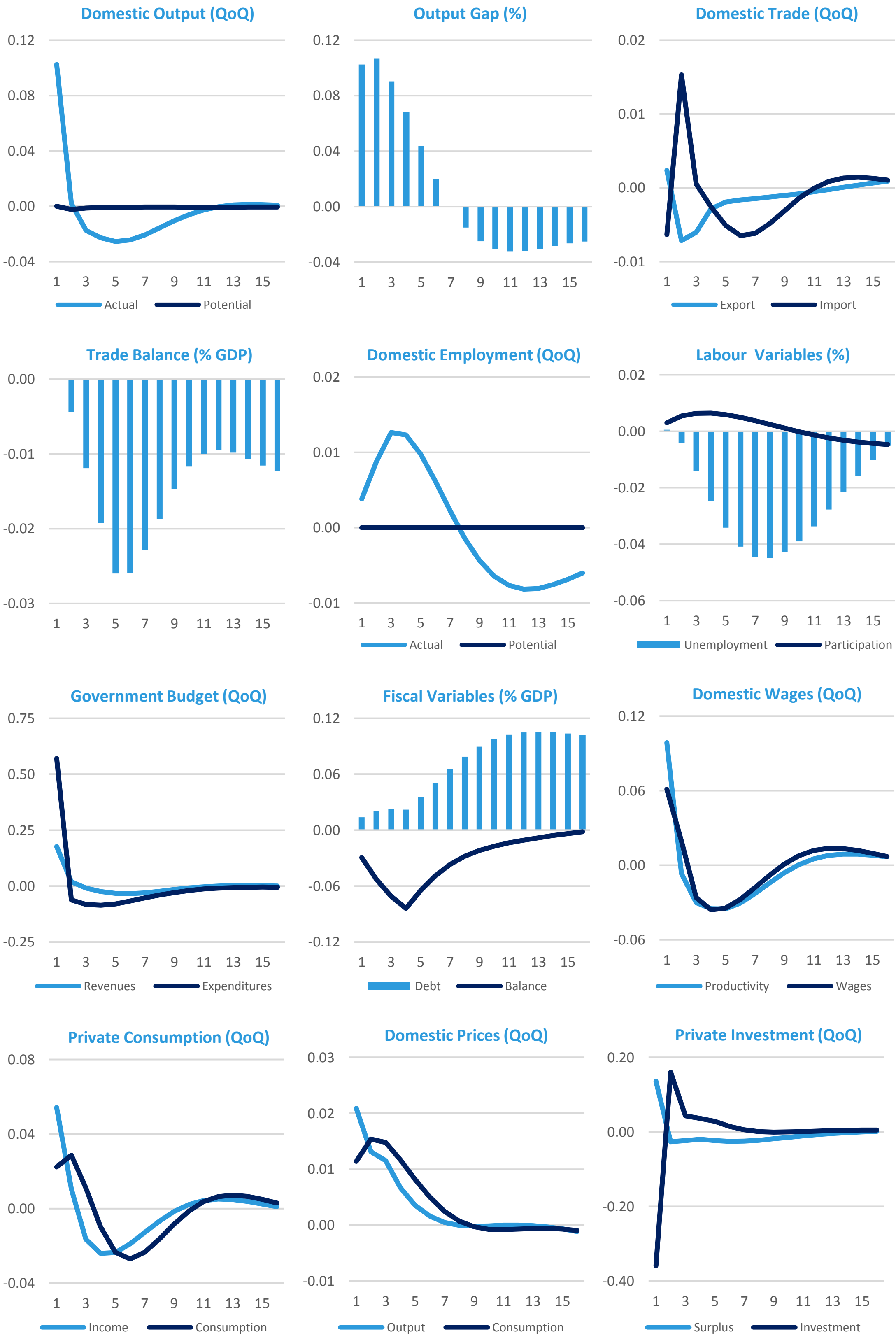


Fig.E5: A permanent shock to intermediate consumption that corresponds to an increase of a growth rate by 2.50 p.p. in the first quarter. X axes label quarters after the shock and Y axes label deviations of model variables from baseline growth rates in percentage points.

Supply side estimation

Private investment

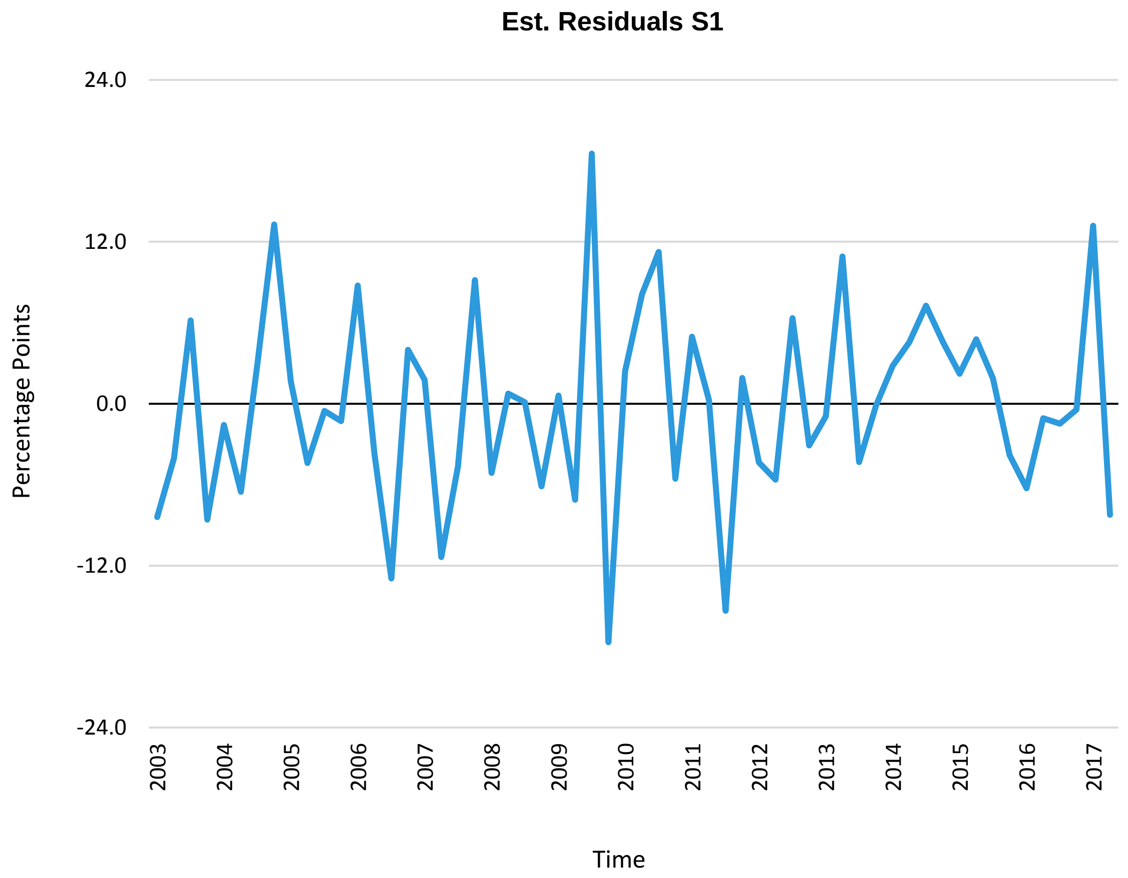
Est. Equation S1: $\mathrm{dlog}(\mathrm{if}_t) = \mathrm{if}_1 * \mathrm{dlog}(\mathrm{yt}_t) - \mathrm{if}_2 * \mathrm{dlog}(\mathrm{ig}_t) + \mathrm{if}_3 * \mathrm{dlog}(\mathrm{ft}_{t-1}) - \mathrm{if}_4 * \mathrm{dlog}(\mathrm{lg}_t) - \mathrm{if}_4 * \mathrm{dlog}(\mathrm{rg}_t) - \mathrm{if}_5 * \mathrm{dlog}(\mathrm{rc}_t) - \mathrm{if}_6 * \mathrm{dlog}(\mathrm{rt}_t) - \mathrm{if}_7 * \mathrm{diff}(\tau_t^{ci}) - \mathrm{if}_8 * \mathrm{diff}(\mathrm{lr}_{t-1}) + \mathrm{if}_9 * \mathrm{cor}(\mathrm{it}_{t-1}) + \varepsilon_t^{if}$

Model Calibration: $\mathrm{if}_2 = 0.10$; $\mathrm{if}_4 = 0.40$; $\mathrm{if}_5 = 0.20$; $\mathrm{if}_6 = 0.20$; $\mathrm{if}_7 = 0.80$; $\mathrm{if}_8 = 0.25$; $\mathrm{if}_9 = 0.10$;

Model Restrictions: $\mathrm{if}_1 = 1 - \mathrm{if}_2 - \mathrm{if}_3 - \mathrm{if}_4 - \mathrm{if}_5 - \mathrm{if}_6$

Standard R^2: 0.36 **Adjusted R^2:** 0.36 **First Period:** 2003Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
if_3	0.60	0.12	5.11	0.00



Personal investment

Est. Equation S2: $\mathrm{dlog(ih_t) = ih_1 * dlog(hi_t) - ih_2 * dlog(ig_t) + ih_3 * dlog(hi_{t-1}) - ih_4 * dlog(lg_t) - ih_4 * dlog(rg_t) - ih_5 * dlog(rc_t) - ih_6 * dlog(rt_t) - ih_7 * diff(\tau_t^{ci}) - ih_8 * diff(lr_{t-1}) + ih_9 * cor(it_{t-1}) - ih_{10} * 2004Q1 + \varepsilon_t^{ih}}$

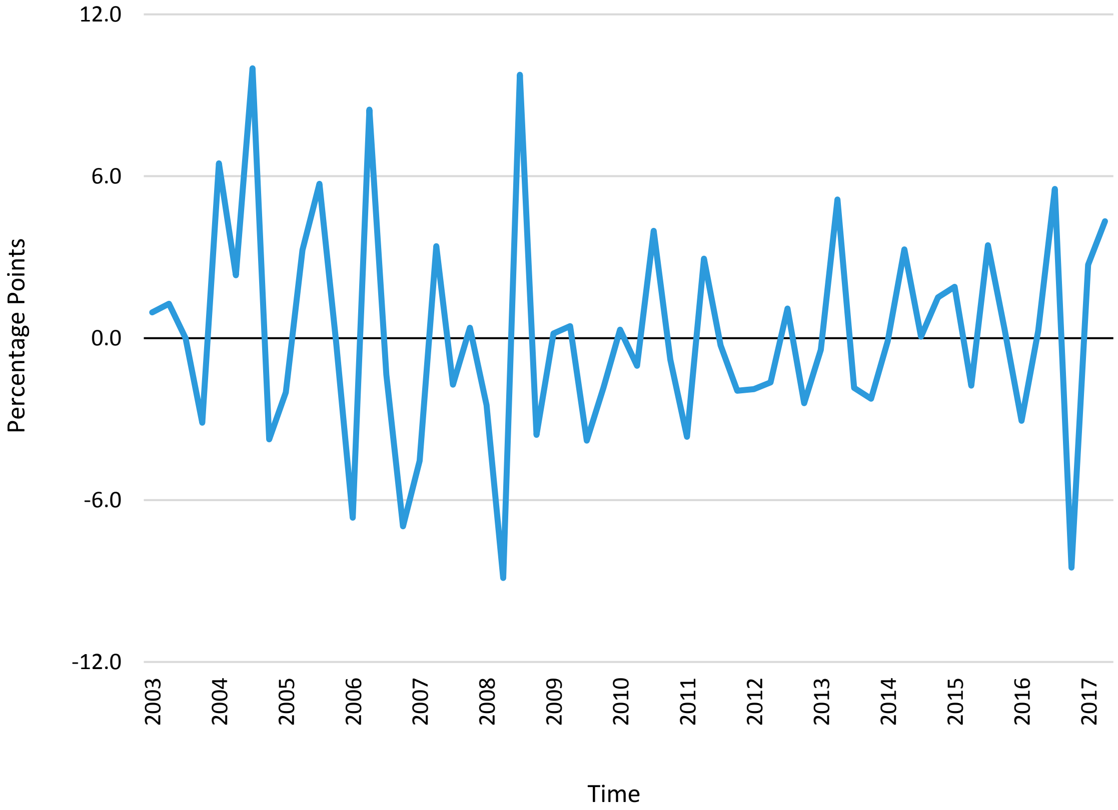
Model Calibration: $\mathrm{ih_2 = 0.05}$; $\mathrm{ih_4 = 0.20}$; $\mathrm{ih_5 = 0.10}$; $\mathrm{ih_6 = 0.10}$; $\mathrm{ih_7 = 0.00}$; $\mathrm{ih_8 = 0.15}$; $\mathrm{ih_9 = 0.05}$;

Model Restrictions: $\mathrm{ih_1 = 1 - ih_2 - ih_3 - ih_4 - ih_5 - ih_6}$

Standard R^2: 0.12 **Adjusted R^2:** 0.11 **First Period:** 2003Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
$\mathrm{ih_3}$	0.61	0.14	4.31	0.00
$\mathrm{ih_{10}}$	0.16	0.04	3.92	0.00

Est. Residuals S2



Public investment

Est. Equation S3: $\mathrm{dlog}(\mathrm{ig}_t) = \mathrm{ig}_1 * \mathrm{dlog}(\mathrm{yt}_t^*) + \mathrm{ig}_2 * \mathrm{dlog}(\mathrm{yt}_t) - \mathrm{ig}_3 * \mathrm{gap}(\mathrm{yt}_{t-1}) + \mathrm{ig}_4 * \mathrm{dev}(\mathrm{bp}_{t-1}^*) - \mathrm{ig}_5 * \mathrm{dev}(\mathrm{dp}_{t-1}^*) + \mathrm{ig}_6 * \mathrm{cor}(\mathrm{it}_{t-1}) - \mathrm{ig}_7 * 2016Q1 + \varepsilon_t^{\mathrm{ig}}$

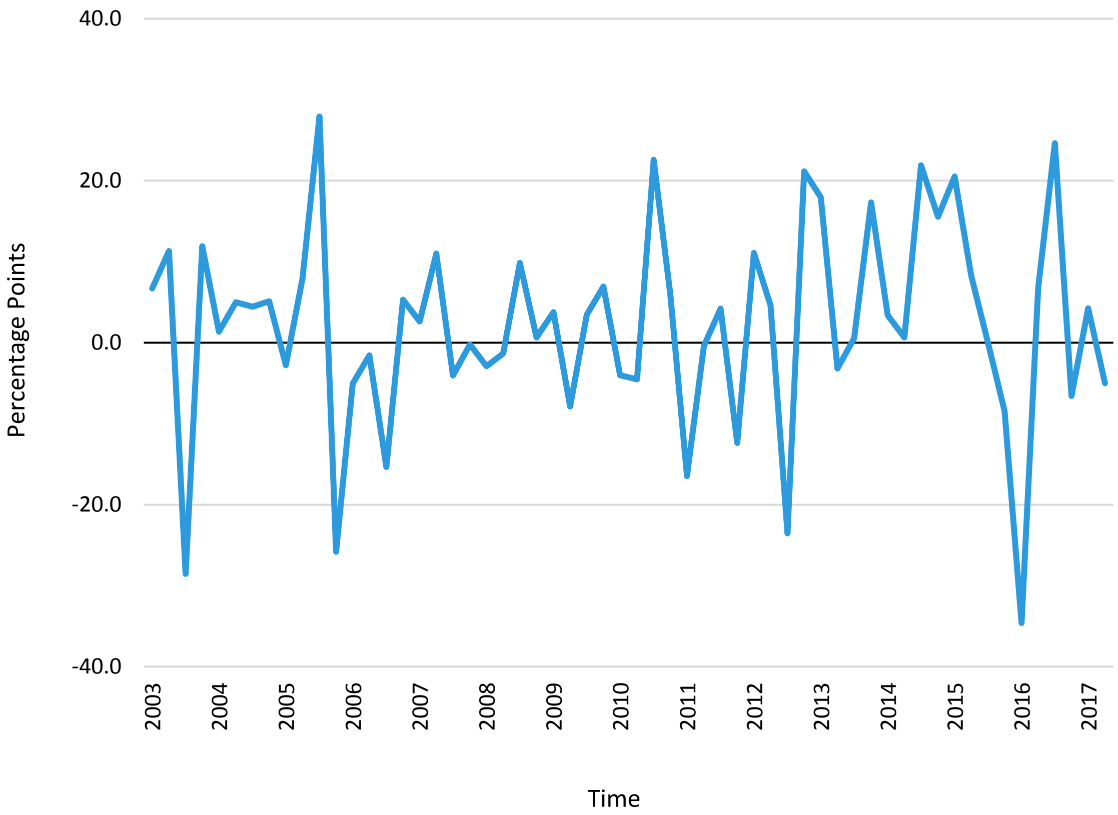
Model Calibration: $\mathrm{ig}_3 = 0.05$; $\mathrm{ig}_4 = 0.40$; $\mathrm{ig}_5 = 0.10$; $\mathrm{ig}_6 = 0.00$;

Model Restrictions: $\mathrm{ig}_1 = 1 - \mathrm{ig}_2$

Standard R^2: 0.27 **Adjusted R^2:** 0.25 **First Period:** 2003Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ig_2	0.33	1.08	0.30	0.76
ig_7	0.59	0.13	4.55	0.00

Est. Residuals S3



Domestic labour force

Est. Equation S4: $\mathrm{dlog}(\mathrm{ls}_t) = \mathrm{ls}_1 * \mathrm{dlog}(\mathrm{np}_t) + \mathrm{ls}_2 * \mathrm{dlog}(\mathrm{lt}_t) + \mathrm{ls}_3 * \mathrm{dlog}(\mathrm{ls}_{t-1}) + \mathrm{ls}_4 * \mathrm{dtfp}(\mathrm{rn}_t) - \mathrm{ls}_5 * \mathrm{diff}(\tau_t^{tc}) - \mathrm{ls}_6 * \log(\mathrm{ls}_{t-1}/\mathrm{ls}^*_{t-1}) + \varepsilon_t^{ls}$

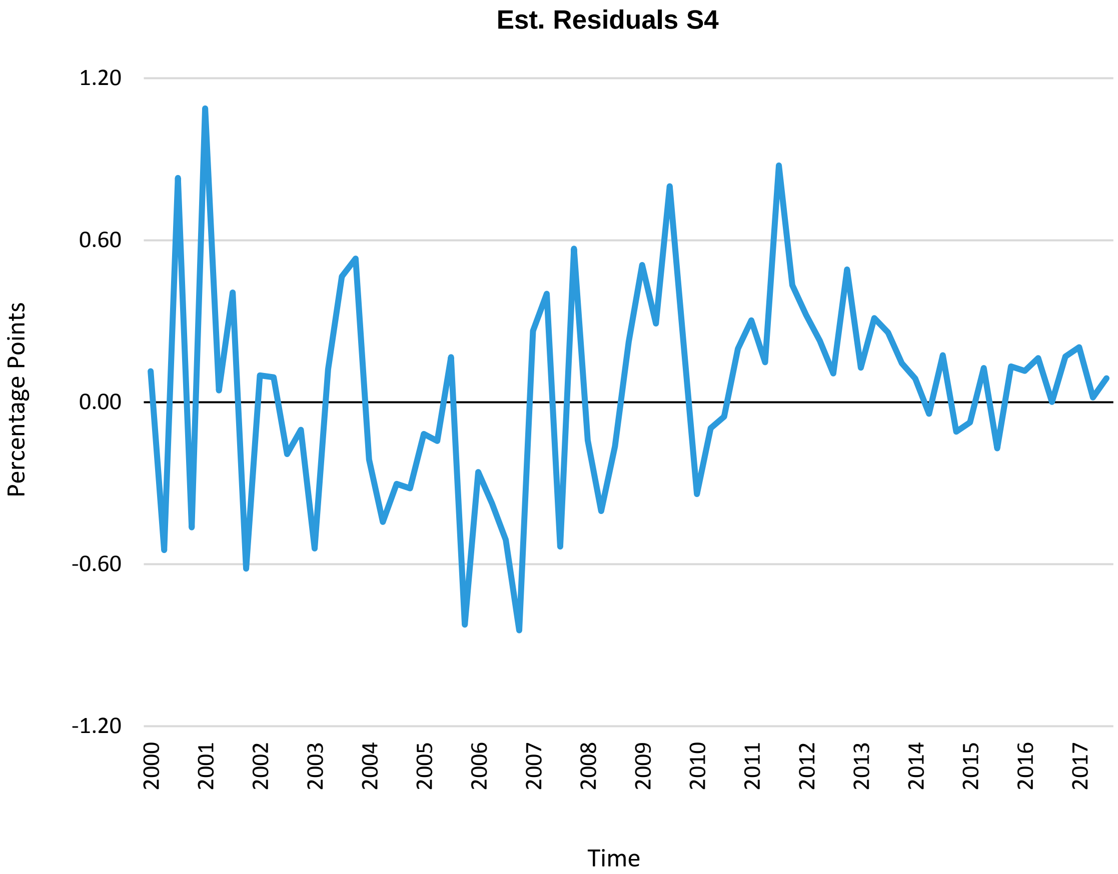
Est. Equation S8: $\mathrm{diff}(\tau_t^{tc}) = \mathrm{ls}_7 * \mathrm{diff}(\tau_t^{li}) + \mathrm{ls}_8 * \mathrm{diff}(\tau_t^{pi}) + \mathrm{ls}_9 * \mathrm{diff}(\tau_t^{lc}) + \mathrm{ls}_{10} * \mathrm{diff}(\tau_t^{pc}) + \mathrm{ls}_{11} * \mathrm{diff}(\tau_t^{gc}) + \mathrm{ls}_{12} * \mathrm{diff}(\tau_t^{fc})$

Model Calibration: $\mathrm{ls}_4 = 0.05$; $\mathrm{ls}_5 = 0.50$; $\mathrm{ls}_7 = 0.80$; $\mathrm{ls}_8 = 0.20$; $\mathrm{ls}_9 = 0.80$; $\mathrm{ls}_{10} = 0.20$; $\mathrm{ls}_{11} = 0.40$; $\mathrm{ls}_{12} = 0.00$;

Model Restrictions: $\mathrm{ls}_1 = 1 - \mathrm{ls}_2 - \mathrm{ls}_3$

Standard R^2: 0.06 **Adjusted R^2:** 0.03 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ls_2	0.24	0.08	3.05	0.00
ls_3	0.25	0.12	2.17	0.03
ls_6	0.14	0.08	1.71	0.09



Private employment

Est. Equation S5: $\mathrm{dlog(lf_t) = lf_1 * dlog(lt_t^*) - lf_2 * dlog(lg_t) + lf_3 * dlog(lf_{t-1}) +}$
$\mathrm{lf_4 * dtfp(yt_t) - lf_5 * dtfp(rf_t) + lf_6 * cor(lt_{t-1}) + \varepsilon_t^{lf}}$

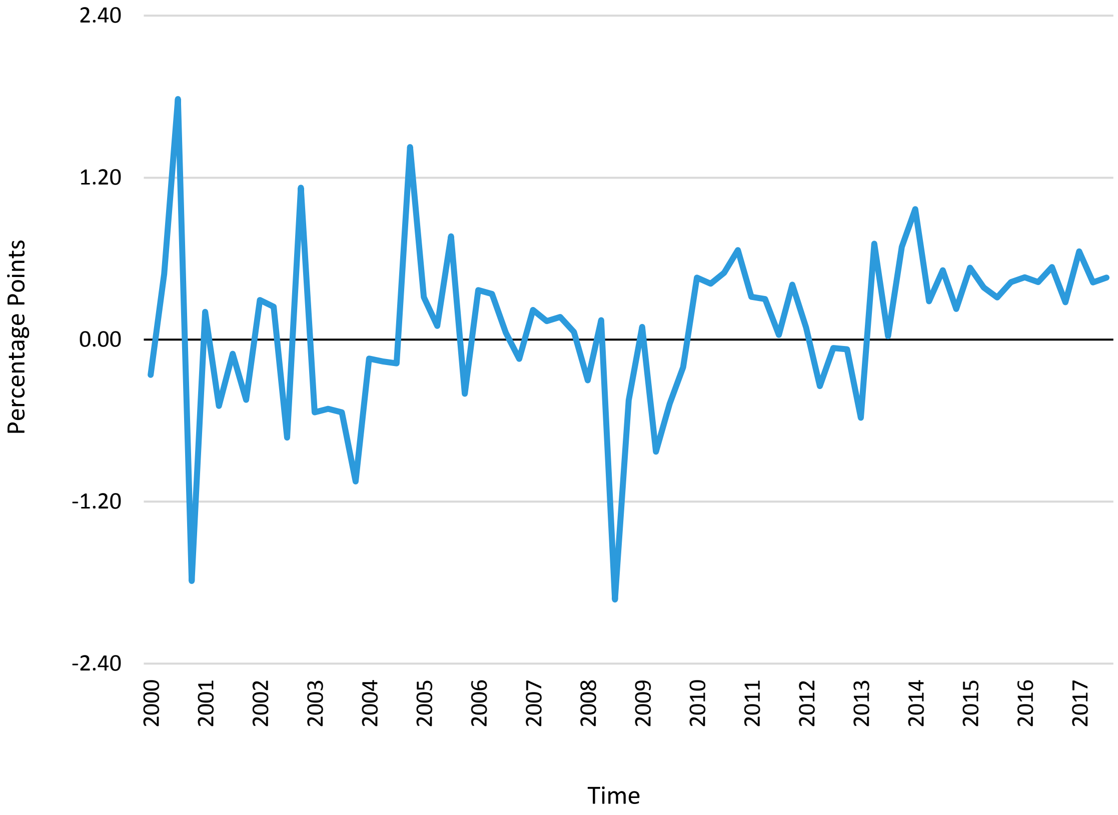
Model Calibration: $\mathrm{lf_2 = 0.15}$

Model Restrictions: $\mathrm{lf_1 = 1 - lf_2 - lf_3 - lf_4}$

Standard R^2: 0.41 **Adjusted R^2:** 0.38 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
$\mathrm{lf_3}$	0.12	0.11	1.14	0.26
$\mathrm{lf_4}$	0.14	0.05	2.68	0.01
$\mathrm{lf_5}$	0.12	0.04	2.81	0.00
$\mathrm{lf_6}$	0.13	0.05	2.72	0.01

Est. Residuals S5



Personal employment

Est. Equation S6: $\mathrm{dlog(lh_t) = lh_1 * dlog(lt_t^*) - lh_2 * dlog(lg_t) + lh_3 * dlog(lh_{t-1}) +}$
$\mathrm{lh_4 * dtfp(yt_t) - lh_5 * dtfp(rt_t) + lh_6 * cor(lt_{t-1}) + \varepsilon_t^{lh}}$

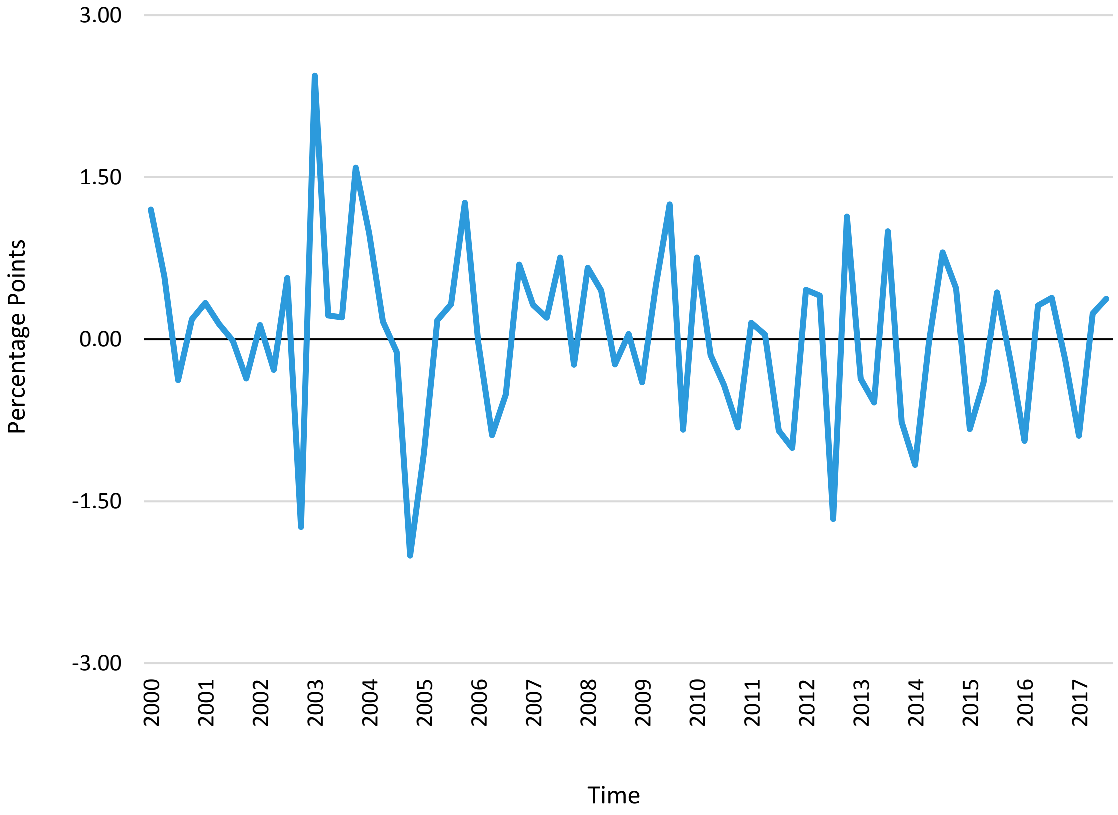
Model Calibration: $\mathrm{lh_2 = 0.15}$

Model Restrictions: $\mathrm{lh_1 = 1 - lh_2 - lh_3 - lh_4}$

Standard R^2: 0.68 **Adjusted R^2:** 0.67 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
$\mathrm{lh_3}$	0.72	0.07	10.0	0.00
$\mathrm{lh_4}$	0.05	0.07	0.69	0.50
$\mathrm{lh_5}$	0.18	0.06	2.98	0.00
$\mathrm{lh_6}$	0.10	0.06	1.76	0.08

Est. Residuals S6



Public employment

Est. Equation S7: $dlog(lg_t) = lg_1 * dlog(lt_t^*) + lg_2 * dlog(lg_{t-1}) + lg_3 * dtfp(yt_t) - lg_4 * dtfp(rg_t) + lg_5 * cor(lt_{t-1}) + \varepsilon_t^{lg}$

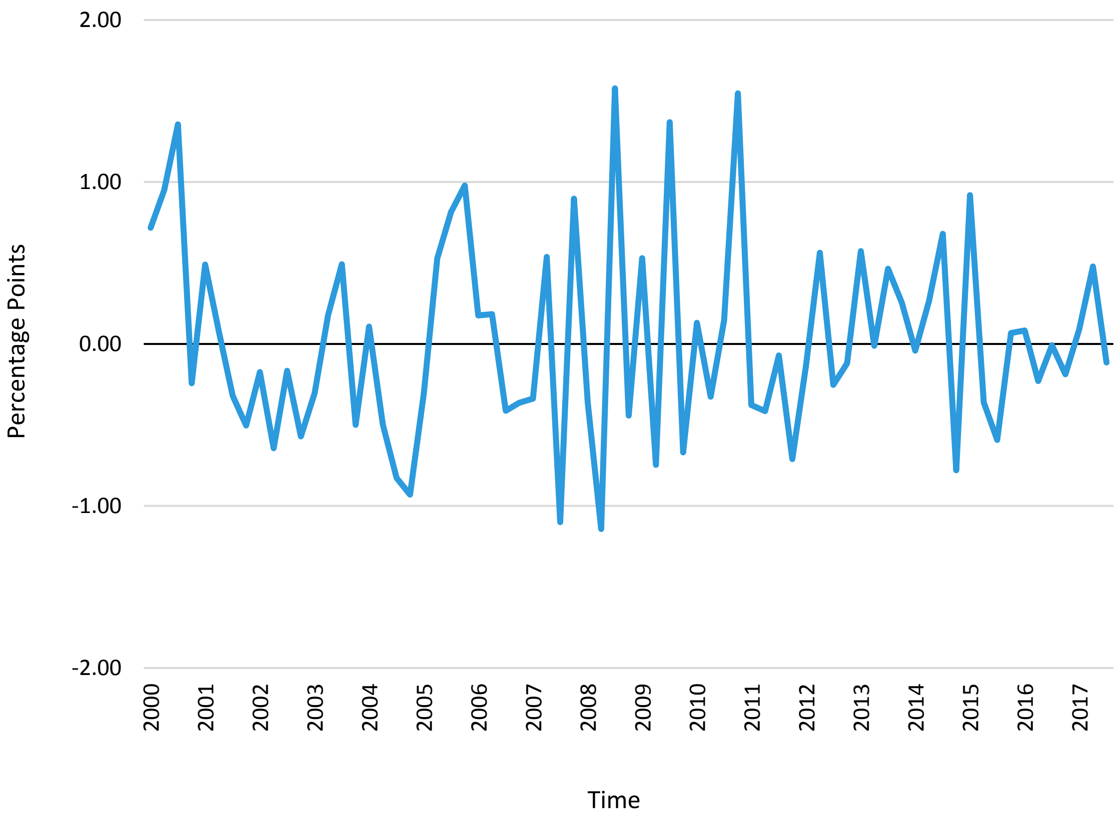
Model Calibration: $lg_5 = 0.00$

Model Restrictions: $lg_1 = 1 - lg_2 - lg_3$

Standard R^2: 0.30 **Adjusted R^2:** 0.28 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
lg_2	0.41	0.10	4.23	0.00
lg_3	0.14	0.04	3.28	0.00
lg_4	0.03	0.02	1.66	0.10

Est. Residuals S7



Demand side estimation

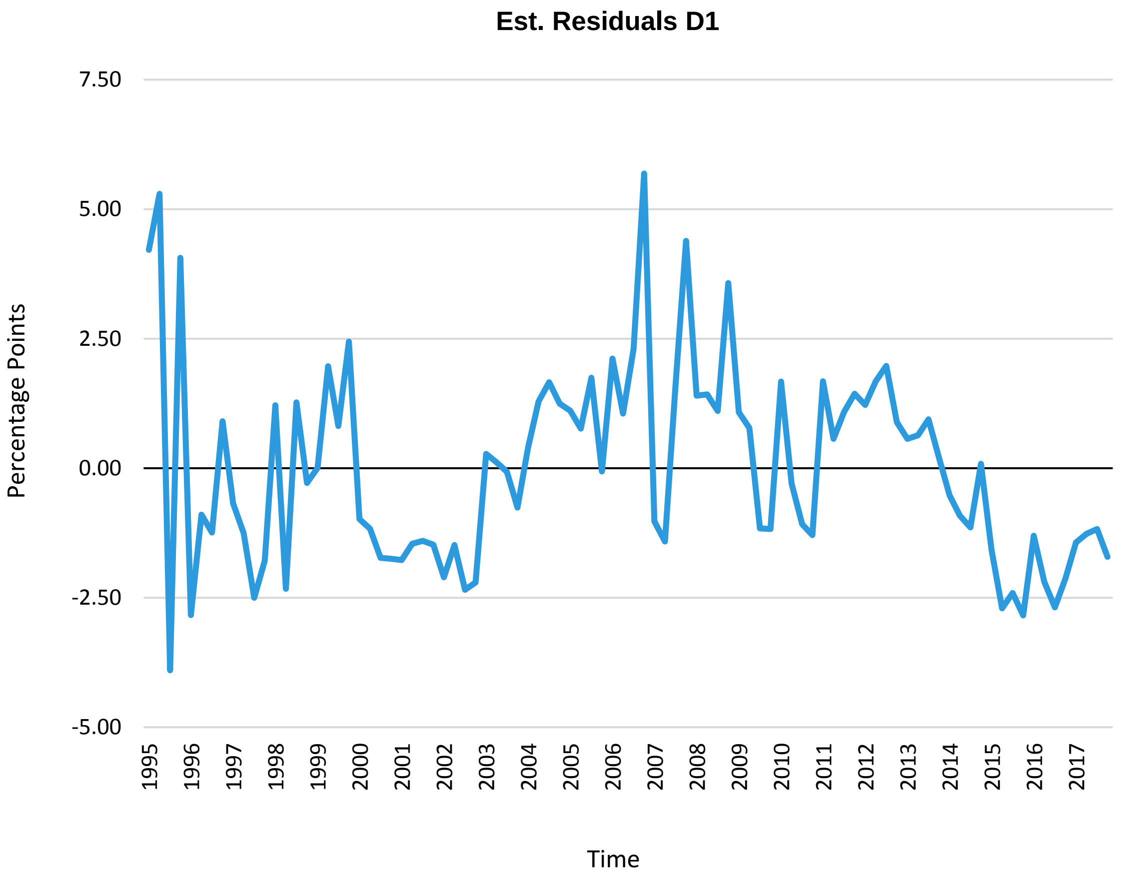
Potential consumption

Est. Equation D1: $\log(ct_t^*) = ct_1 - ct_2/\text{sqrt}(t) + ct_3 * \log(hc_t) + \zeta_t^{ct}$

Model Calibration: $ct_3 = 1.00$

Standard R^2: 0.99 **Adjusted R^2:** 0.99 **First Period:** 1995Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ct_1	-0.03	0.00	-10.1	0.00
ct_2	0.09	0.01	15.2	0.00



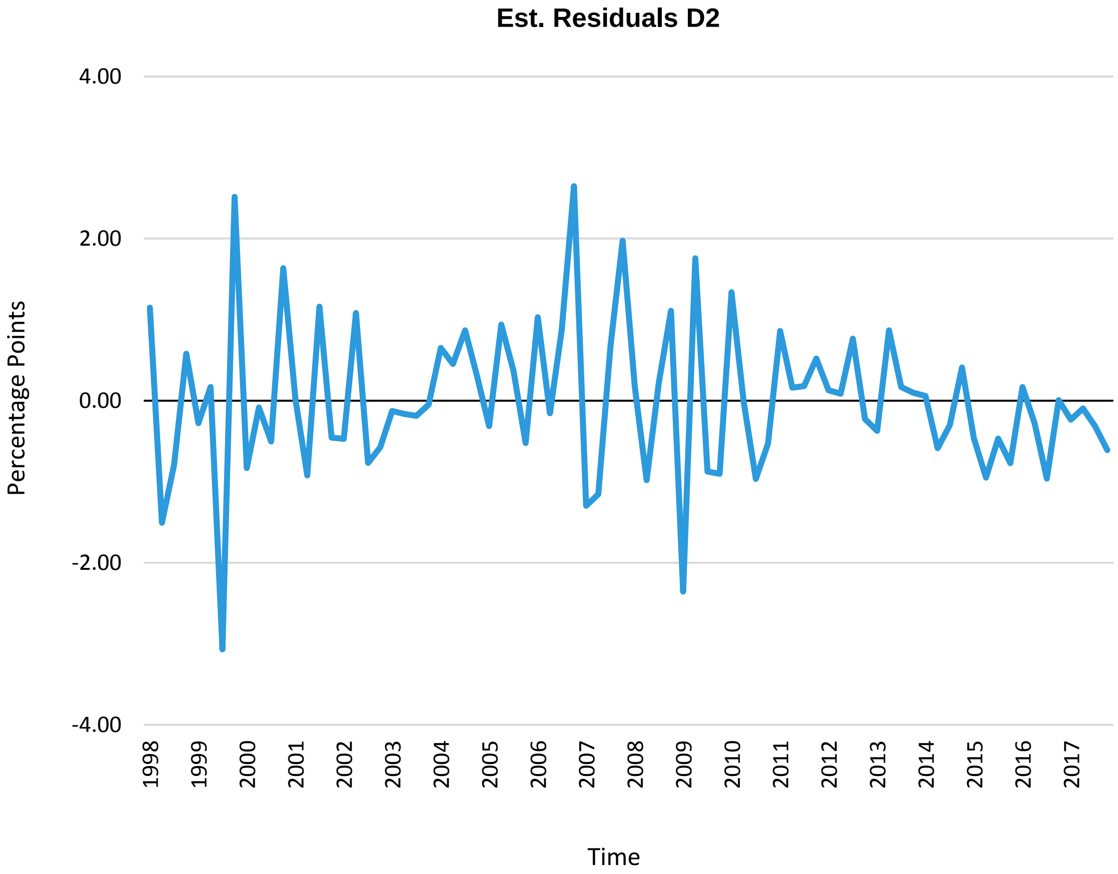
Private consumption

Est. Equation D2: $\mathrm{dlog}(\mathrm{ct}_t) = \mathrm{ct}_4 * \mathrm{dlog}(\mathrm{hc}_t) + \mathrm{ct}_5 * \mathrm{dlog}(\mathrm{ct}_{t-1}) + \mathrm{ct}_6 * \mathrm{dlog}(\mathrm{hc}_{t-1}) - \mathrm{ct}_7 * \mathrm{diff}(\mathrm{sr}_{t-1}) - \mathrm{ct}_8 * \log(\mathrm{ct}_{t-1}/\mathrm{ct}^*_{t-1}) + \varepsilon^{ct}_t$

Model Restrictions: $\mathrm{ct}_4 = 1 - \mathrm{ct}_5 - \mathrm{ct}_6$

Standard R^2: 0.23 **Adjusted R^2:** 0.19 **First Period:** 1998Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ct_5	0.39	0.09	4.18	0.00
ct_6	0.20	0.07	2.70	0.01
ct_7	0.16	0.05	3.22	0.00
ct_8	0.18	0.07	2.45	0.02



Total potential export

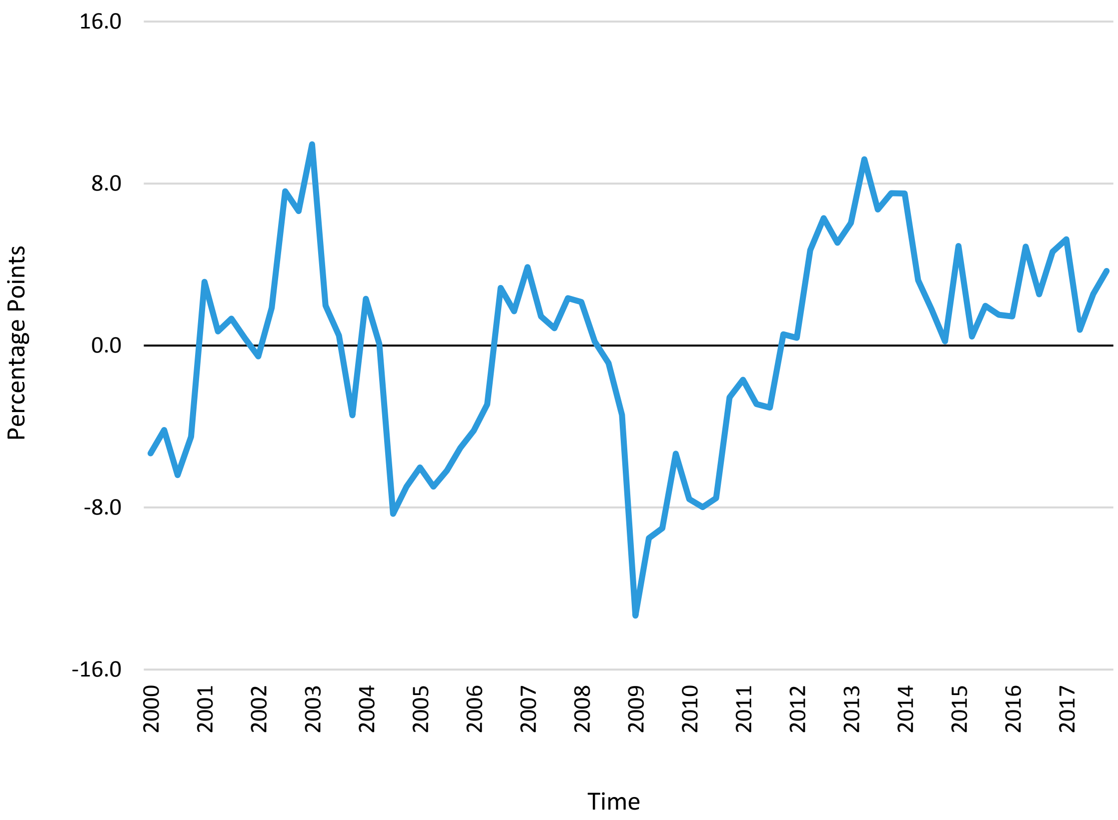
Est. Equation D3: $\log(xt_t^*) = xt_1 - xt_2/\text{sqrt}(t) + xt_3 * \log(dx_t) + xt_4 * \log(zx_t) + xt_5 * \log(da_t) + \zeta_t^{xt}$

Model Calibration: $xt_3 = 1.00$; $xt_5 = 1.00$;

Standard R^2: 0.99 **Adjusted R^2:** 0.99 **First Period:** 2000Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
xt_1	9.98	0.03	356	0.00
xt_2	0.40	0.05	7.78	0.00
xt_4	0.47	0.14	3.28	0.00

Est. Residuals D3



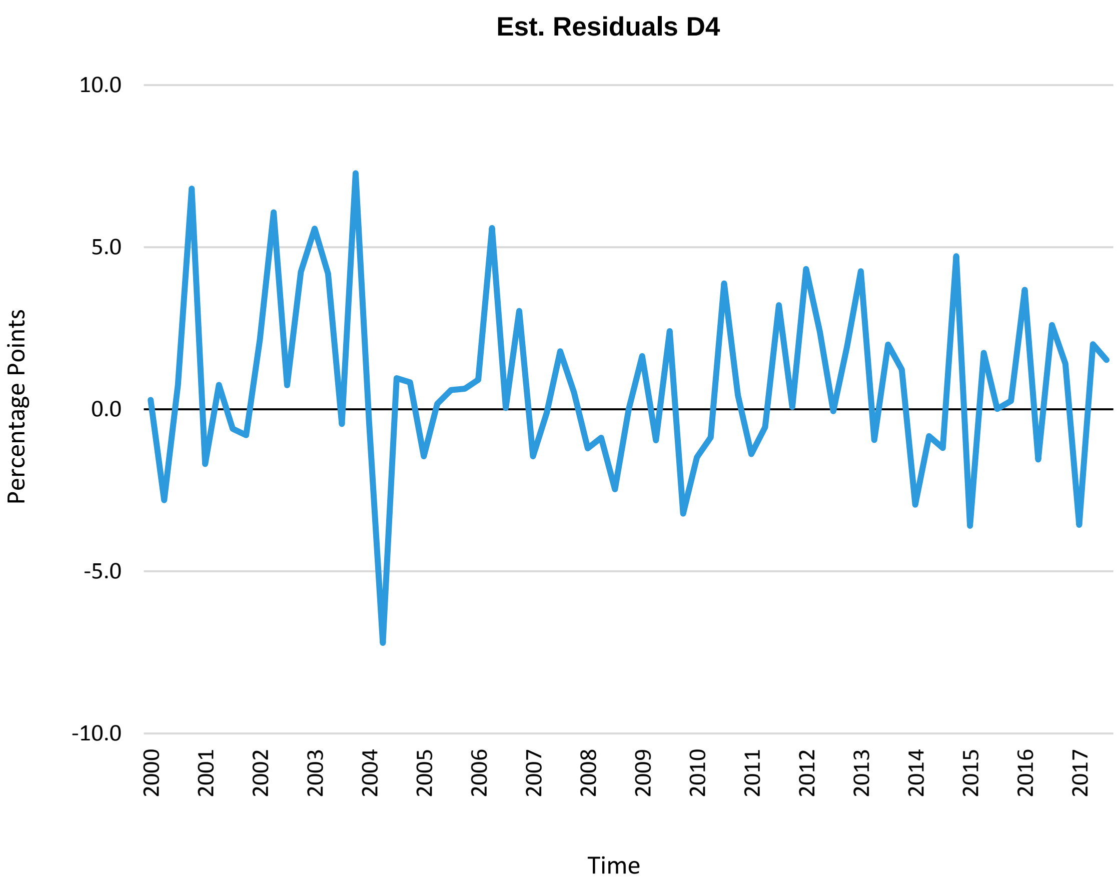
Total domestic export

Est. Equation D4: $\mathrm{dlog}(xt_t) = xt_6 * \mathrm{dlog}(dx_t) + xt_7 * \mathrm{dlog}(zx_t) + xt_8 * \mathrm{dlog}(da_t) - xt_9 * \log(xt_{t-1}/xt^*_{t-1}) - xt_{10} * 2009Q1 + \varepsilon_t^{xt}$

Model Calibration: $xt_6 = 1.00;$ $xt_8 = 1.00;$

Standard R^2: 0.58 **Adjusted R^2:** 0.57 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
xt_7	0.54	0.17	3.17	0.00
xt_9	0.17	0.07	2.44	0.02
xt_{10}	0.10	0.03	3.30	0.00



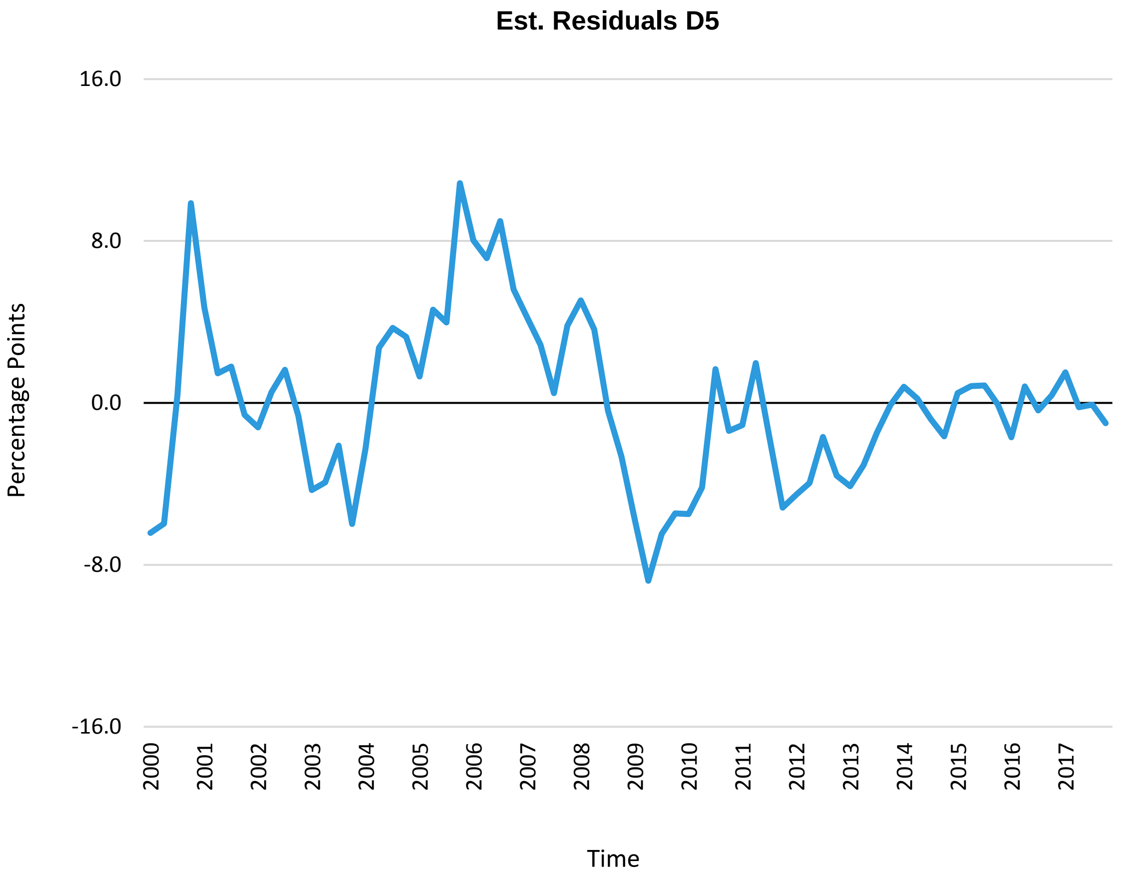
Total potential import

Est. Equation D5: $\log(mt_t^*) = mt_1 - mt_2/sqrt(t) + mt_3 * \log(dm_t) - mt_4 * \log(zm_t) - mt_5 * \log(do_t) + \zeta_t^{mt}$

Model Calibration: $mt_3 = 1.00;\quad mt_4 = 0.20;\quad mt_5 = 0.02;$

Standard R^2: 0.99 **Adjusted R^2:** 0.99 **First Period:** 2000Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
mt_1	0.10	0.01	13.2	0.00
mt_2	0.11	0.02	4.34	0.00



Total domestic import

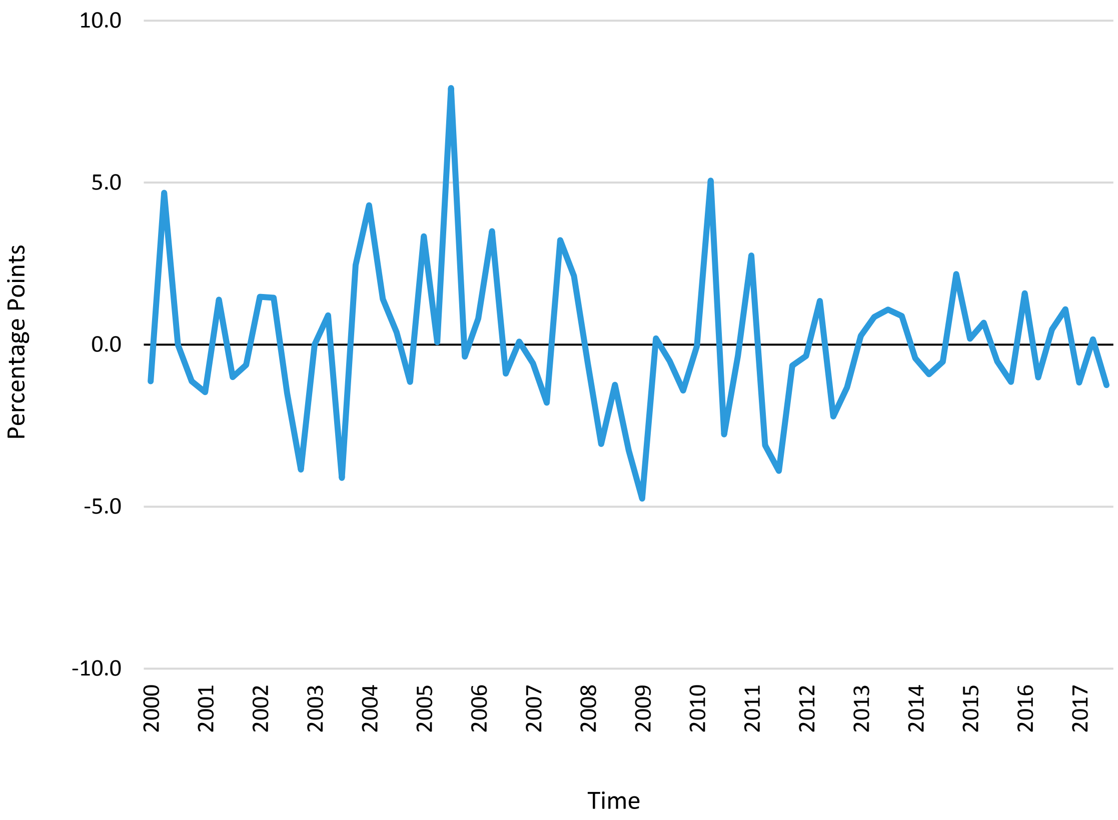
Est. Equation D6: $\mathrm{dlog}(\mathrm{mt_t}) = \mathrm{mt_6} * \mathrm{dlog}(\mathrm{dm_t}) - \mathrm{mt_7} * \mathrm{dlog}(\mathrm{zm_t}) - \mathrm{mt_8} * \mathrm{dlog}(\mathrm{do_t}) - \mathrm{mt_9} * \log(\mathrm{mt_{t-1}}/\mathrm{mt^*_{t-1}}) + \mathrm{mt_{10}} * 2000Q4 + \varepsilon_t^{mt}$

Model Calibration: $\mathrm{mt_6} = 1.00$; $\mathrm{mt_7} = 0.20$; $\mathrm{mt_8} = 0.00$;

Standard R^2: 0.75 **Adjusted R^2:** 0.74 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
$\mathrm{mt_9}$	0.22	0.07	3.39	0.00
$\mathrm{mt_{10}}$	0.13	0.02	5.67	0.00

Est. Residuals D6



Labour cost estimation

Private labour costs

Est. Equation W1: $\mathrm{dlog}(\mathrm{rf}_t) = \mathrm{wf}_1 * \mathrm{dlog}(\mathrm{lp}_t) + \mathrm{wf}_2 * \mathrm{dlog}(\mathrm{rg}_{t-1}) + \mathrm{wf}_3 * \mathrm{dlog}(\mathrm{lp}_{t-1}) + \mathrm{wf}_4 * \mathrm{dlog}(\mathrm{pc}_t) - \mathrm{wf}_4 * \mathrm{dlog}(\mathrm{py}_t) - \mathrm{wf}_5 * \mathrm{gap}(\mu_t) + \mathrm{wf}_6 * \mathrm{diff}(\tau_t^{gc}) + \mathrm{wf}_7 * \mathrm{diff}(\tau_t^{fc}) - \mathrm{wf}_8 * \mathrm{diff}(\tau_t^{ci}) - \mathrm{wf}_9 * \log(\mathrm{wt}_{t-1}/\mathrm{wt}_{t-1}^*) - \mathrm{wf}_{10} * 2008Q4 + \mathrm{wf}_{11} * 2009Q1 + \varepsilon_t^{wf}$

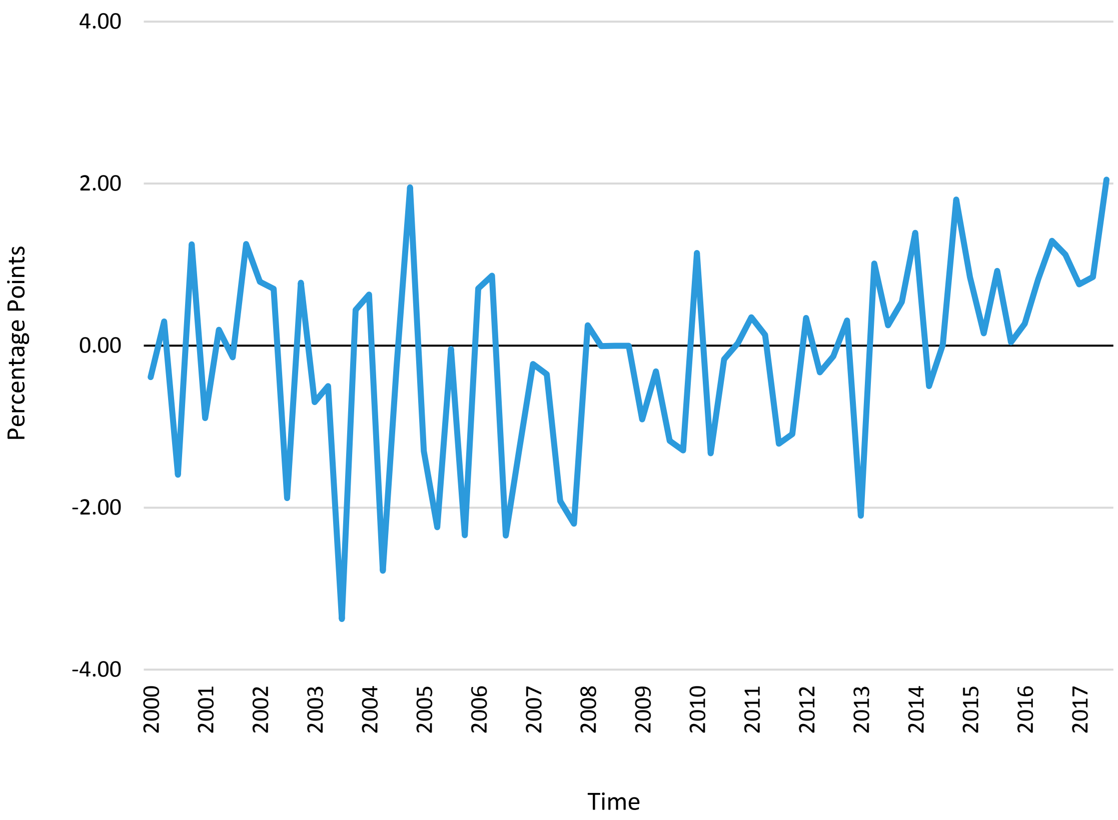
Model Calibration: $\mathrm{wf}_2 = 0.05$; $\mathrm{wf}_6 = 0.15$; $\mathrm{wf}_7 = 0.15$; $\mathrm{wf}_8 = 0.20$; $\mathrm{wf}_9 = 0.10$;

Model Restrictions: $\mathrm{wf}_1 = 1 - \mathrm{wf}_2 - \mathrm{wf}_3$

Standard R^2: 0.46 **Adjusted R^2:** 0.42 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
wf_3	0.22	0.09	2.39	0.02
wf_4	0.52	0.18	2.88	0.00
wf_5	0.12	0.09	1.40	0.17
wf_{10}	0.05	0.01	3.74	0.00
wf_{11}	0.08	0.01	5.02	0.00

Est. Residuals W1



Public labour costs

Est. Equation W2: $\mathrm{dlog}(\mathrm{rg}_t) = \mathrm{wg}_1 * \mathrm{dlog}(\mathrm{lp}_t) + \mathrm{wg}_2 * \mathrm{dlog}(\mathrm{rf}_{t-1}) + \mathrm{wg}_3 * \mathrm{dlog}(\mathrm{lp}_{t-1}) + \mathrm{wg}_4 * \mathrm{dlog}(\mathrm{pc}_t) - \mathrm{wg}_4 * \mathrm{dlog}(\mathrm{py}_t) - \mathrm{wg}_5 * \mathrm{gap}(\mu_t) + \mathrm{wg}_6 * \mathrm{diff}(\tau_t^{gc}) + \mathrm{wg}_7 * \mathrm{diff}(\tau_t^{fc}) - \mathrm{wg}_8 * \mathrm{gap}(\mathrm{yt}_{t-1}) + \mathrm{wg}_9 * \mathrm{dev}(\mathrm{bp}_{t-1}^*) - \mathrm{wg}_{10} * \mathrm{dev}(\mathrm{dp}_{t-1}^*) - \mathrm{wg}_{11} * \log(\mathrm{wt}_{t-1}/\mathrm{wt}_{t-1}^*) - \mathrm{wg}_{12} * 2004\mathrm{Q}1 + \varepsilon_t^{wg}$

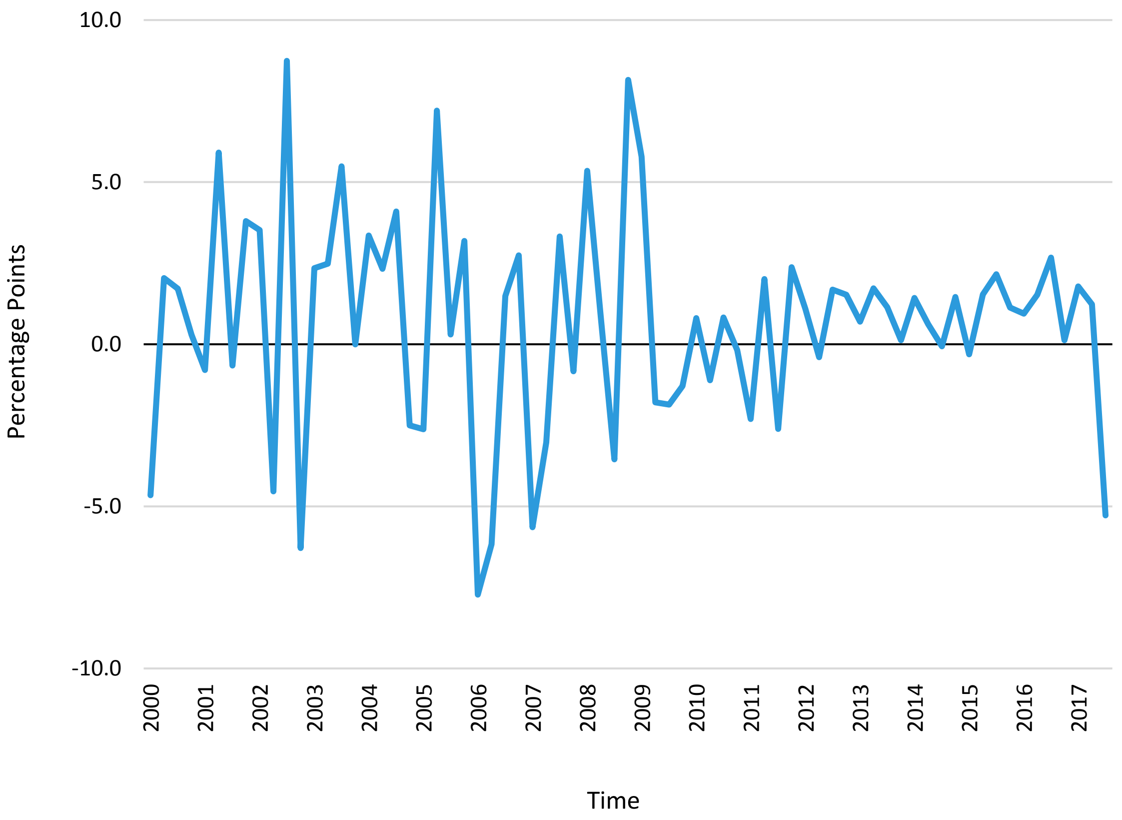
Model Calibration: $\mathrm{wg}_2 = 0.25$; $\mathrm{wg}_5 = 0.00$; $\mathrm{wg}_6 = 0.15$; $\mathrm{wg}_7 = 0.15$; $\mathrm{wg}_8 = 0.01$; $\mathrm{wg}_9 = 0.08$; $\mathrm{wg}_{10} = 0.02$; $\mathrm{wg}_{11} = 0.05$;

Model Restrictions: $\mathrm{wg}_1 = 1 - \mathrm{wg}_2 - \mathrm{wg}_3$

Standard R²: 0.20 **Adjusted R²:** 0.18 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
wg_3	0.34	0.21	1.59	0.12
wg_4	0.19	0.50	0.38	0.70
wg_{12}	0.18	0.04	5.05	0.00

Est. Residuals W2



Inflation rate estimation

Core potential prices

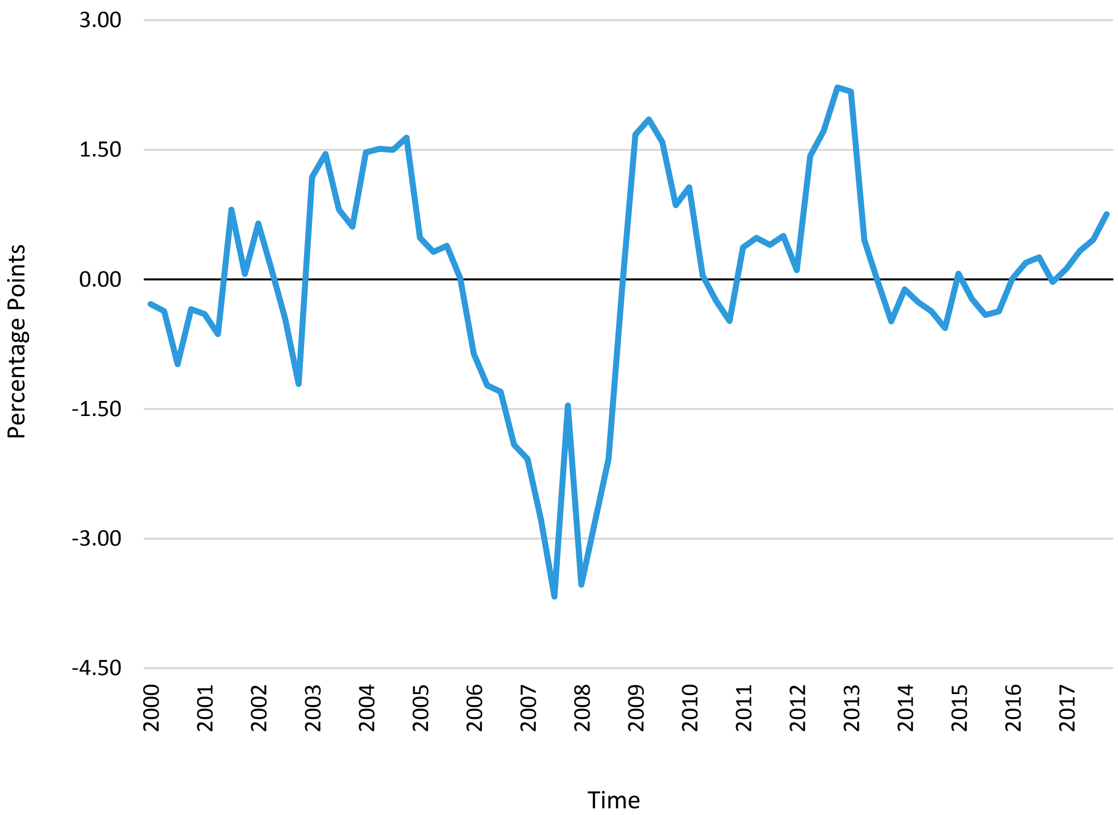
Est. Equation P1: $\log(pn_t^*) = pn_1 - pn_2/\mathrm{sqrt}(t) + pn_3 * \log(py_t) + pn_4 * \log(pm_t) + pn_5 * \log(bs_t) + \zeta_t^{pn}$

Model Restrictions: $pn_3 = 1 - pn_4$

Standard R^2: 0.99 **Adjusted R^2:** 0.99 **First Period:** 2000Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pn_1	4.02	0.04	95.7	0.00
pn_2	0.07	0.01	11.5	0.00
pn_4	0.31	0.05	6.32	0.00
pn_5	0.30	0.02	14.2	0.00

Est. Residuals P1



Core consumer prices

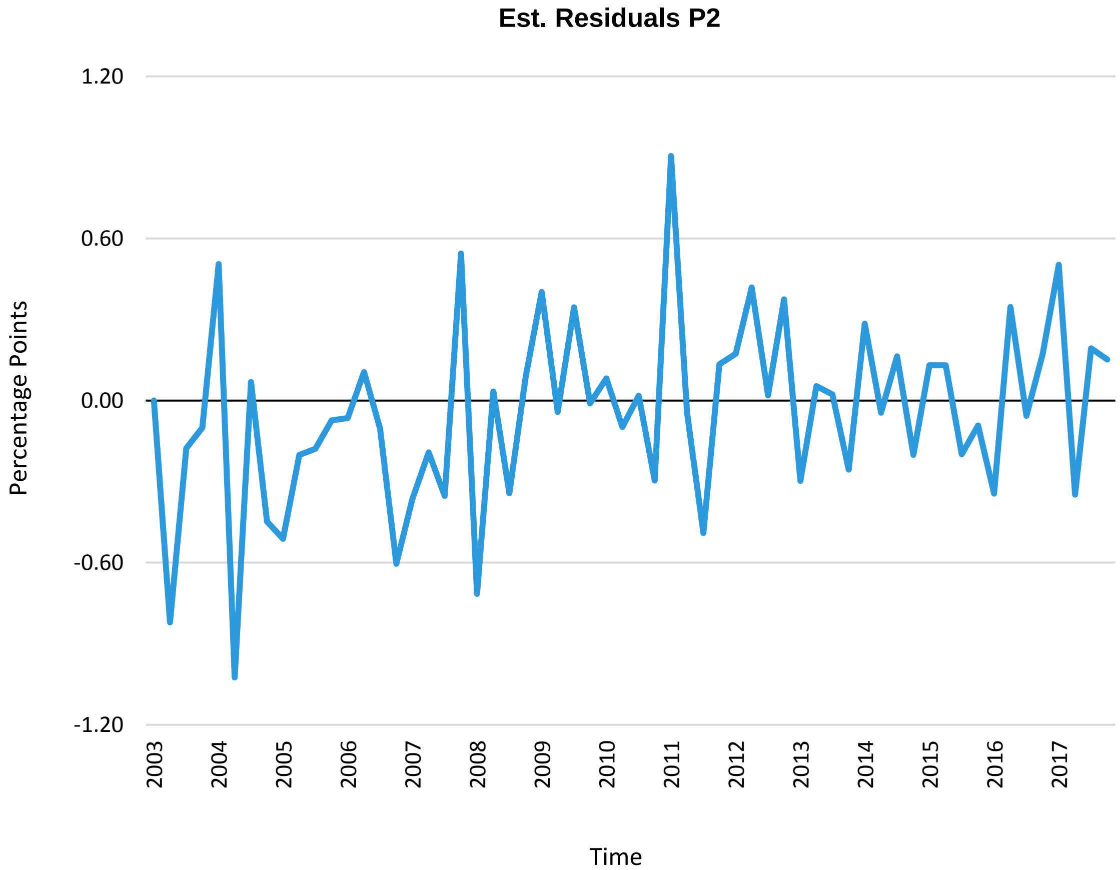
Est. Equation P2: $\mathrm{dlog}(pn_t) = pn_6 * \mathrm{dlog}(pp_t) + pn_7 * \mathrm{dlog}(pl_t) + pn_8 * \mathrm{dlog}(pm_t) + pn_9 * \mathrm{dlog}(pn_{t-1}) + pn_{10} * \mathrm{dlog}(bs_t) + pn_{11} * \mathrm{gap}(yt_t) + pn_{12} * \mathrm{up}(\tau_t^{va}) + pn_{13} * \mathrm{down}(\tau_t^{va}) + pn_{14} * \mathrm{up}(\tau_t^{cn}) + pn_{15} * \mathrm{down}(\tau_t^{cn}) - pn_{16} * \log(pn_{t-1}/pn_{t-1}^{*}) + pn_{17} * 2003Q1 + \varepsilon_t^{pn}$

Model Calibration: $pn_{12} = 0.20$; $pn_{13} = 0.10$; $pn_{14} = 0.10$; $pn_{15} = 0.05$; $pn_{16} = 0.00$;

Model Restrictions: $pn_6 = 1 - pn_7 - pn_8 - pn_9$

Standard R^2: 0.62 **Adjusted R^2:** 0.58 **First Period:** 2003Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pn_7	0.14	0.10	1.43	0.16
pn_8	0.08	0.03	2.48	0.02
pn_9	0.66	0.10	6.59	0.00
pn_{10}	0.09	0.05	1.84	0.07
pn_{11}	0.06	0.03	2.08	0.04
pn_{17}	0.01	0.00	3.83	0.00



Energy potential prices

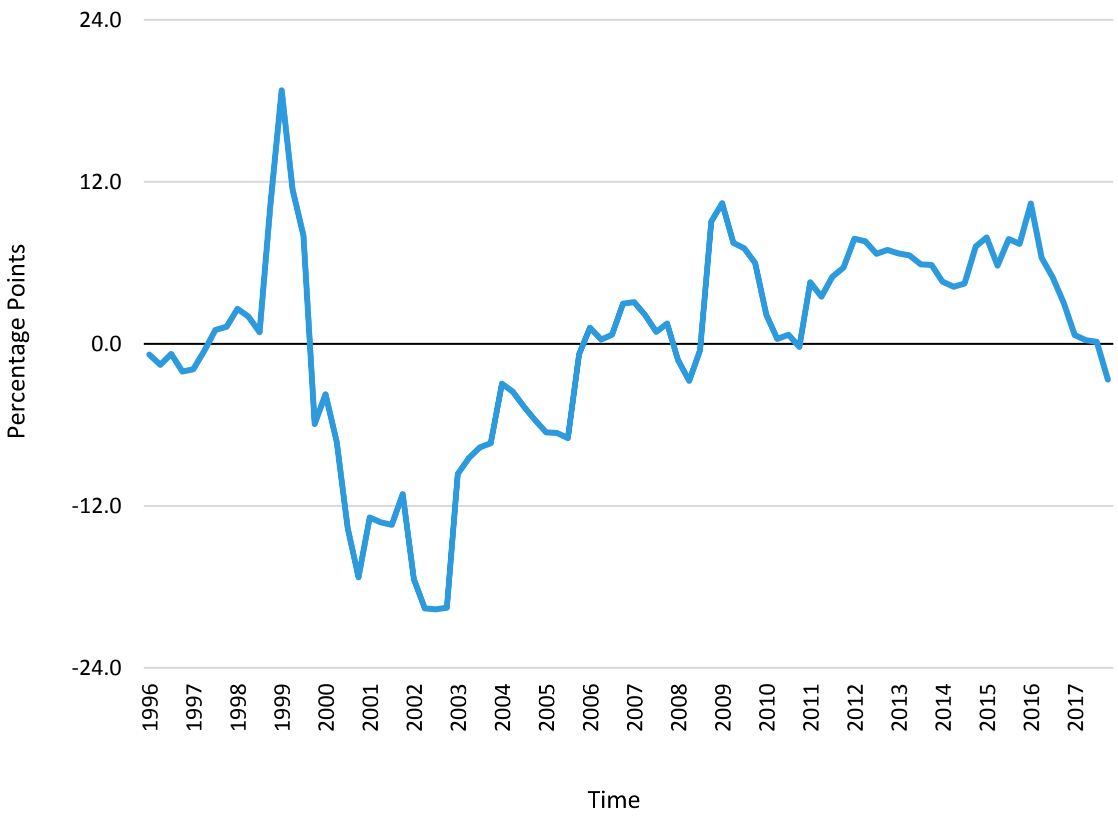
Est. Equation P3: $\log(pe_t^*) = pe_1 - pe_2/\mathrm{sqrt}(t) + pe_3 * \log(py_t) + pe_4 * \log(oil_t) + pe_4 * \log(us_t) + \zeta_t^{pe}$

Model Restrictions: $pe_3 = 1 - pe_4$

Standard R²: 0.98 **Adjusted R²:** 0.98 **First Period:** 1996Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pe_1	3.57	0.26	14.0	0.00
pe_2	1.01	0.04	27.4	0.00
pe_4	0.15	0.03	4.30	0.00

Est. Residuals P3



Energy consumer prices

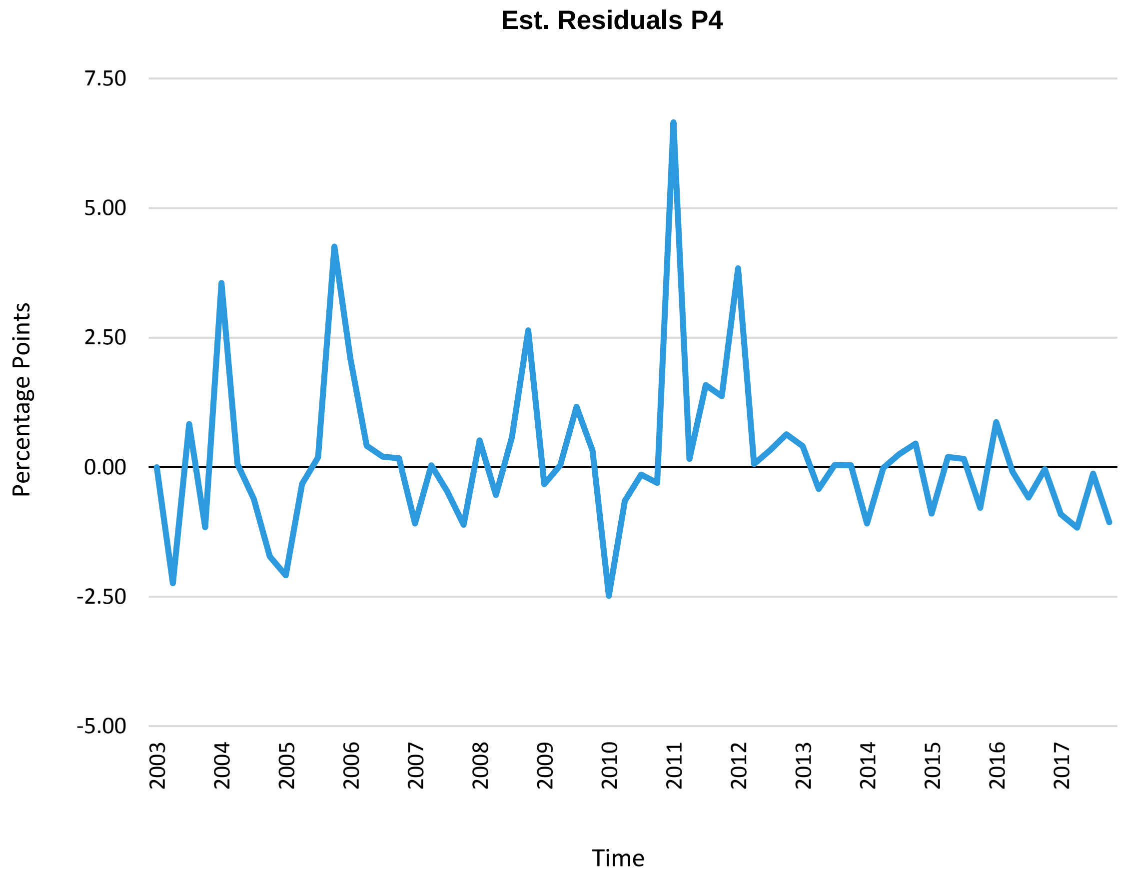
Est. Equation P4: $\text{dlog}(\text{pe}_t) = \text{pe}_5 * \text{dlog}(\text{pp}_t) + \text{pe}_6 * \text{dlog}(\text{pl}_t) + \text{pe}_7 * \text{dlog}(\text{oil}_t) + \text{pe}_7 * \text{dlog}(\text{us}_t) + \text{pe}_8 * \text{up}(\tau_t^{va}) + \text{pe}_9 * \text{down}(\tau_t^{va}) + \text{pe}_{10} * \text{up}(\tau_t^{cn}) + \text{pe}_{11} * \text{down}(\tau_t^{cn}) - \text{pe}_{12} * \log(\text{pe}_{t-1}/\text{pe}_{t-1}^{*}) + \text{pe}_{13} * 2003\text{Q}1 + \varepsilon_t^{pe}$

Model Calibration: $\text{pe}_8 = 0.20;\quad \text{pe}_9 = 0.10;\quad \text{pe}_{10} = 0.80;\quad \text{pe}_{11} = 0.40;$

Model Restrictions: $\text{pe}_5 = 1 - \text{pe}_6 - \text{pe}_7$

Standard R^2: 0.64 **Adjusted R^2:** 0.62 **First Period:** 2003Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pe_6	0.72	0.20	3.60	0.00
pe_7	0.04	0.01	3.11	0.00
pe_{12}	0.13	0.04	3.45	0.00
pe_{13}	0.08	0.02	4.47	0.00



Total production prices

Est. Equation P5: $\mathrm{dlog}(pp_t) = pp_1 * \mathrm{dlog}(ulc_t) + pp_2 * \mathrm{dlog}(pl_t) + pp_3 * \mathrm{dlog}(ulc_{t-1}) + pp_4 * \mathrm{up}(\tau_t^{ci}) + pp_5 * \mathrm{down}(\tau_t^{ci}) - pp_6 * \log(py_{t-1}/py_{t-1}^*) - pp_7 * 2009Q2 + \varepsilon_t^{pp}$

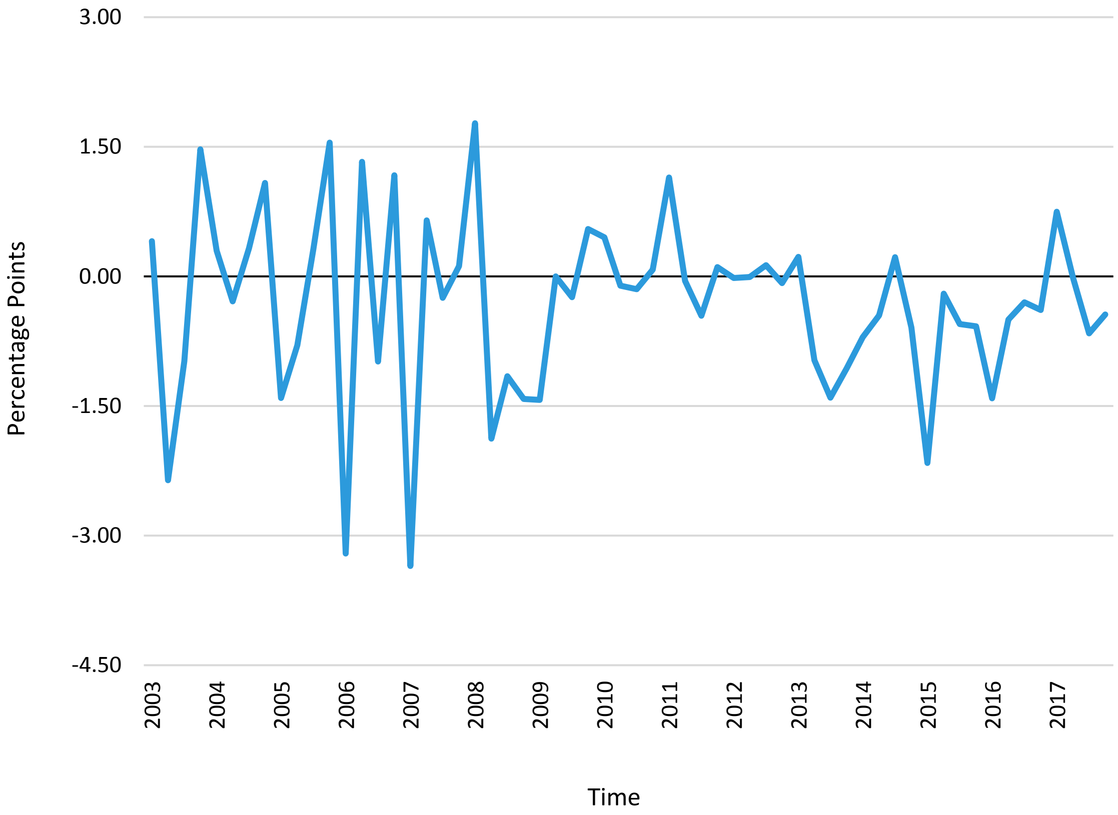
Model Calibration: $pp_4 = 0.10$; $pp_5 = 0.05$; $pp_6 = 0.00$;

Model Restrictions: $pp_1 = 1 - pp_2 - pp_3$

Standard R^2: 0.26 **Adjusted R^2:** 0.24 **First Period:** 2003Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pp_2	0.53	0.14	3.75	0.00
pp_3	0.13	0.10	1.27	0.21
pp_7	0.04	0.01	2.48	0.02

Est. Residuals P5



Price deflator estimation

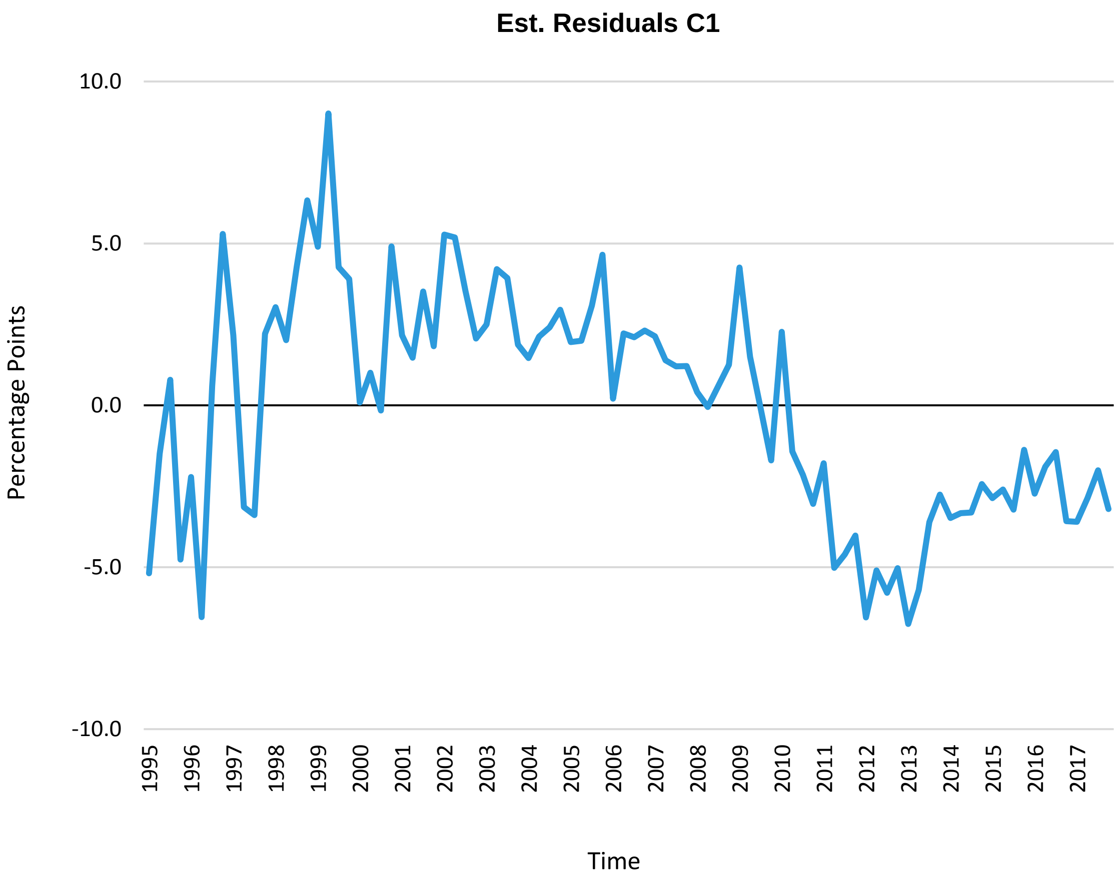
Potential capital prices

Est. Equation C1: $\log(\mathrm{pi}_t^*) = \mathrm{pi}_1 + \mathrm{pi}_2 * \log(\mathrm{py}_t) + \mathrm{pi}_3 * \log(\mathrm{pm}_t) + \zeta_t^{\mathrm{pi}}$

Model Restrictions: $\mathrm{pi}_2 = 1 - \mathrm{pi}_3$

Standard R^2: 0.96 **Adjusted R^2:** 0.96 **First Period:** 1995Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pi_1	0.01	0.00	2.66	0.01
pi_3	0.55	0.06	9.87	0.00



Domestic capital prices

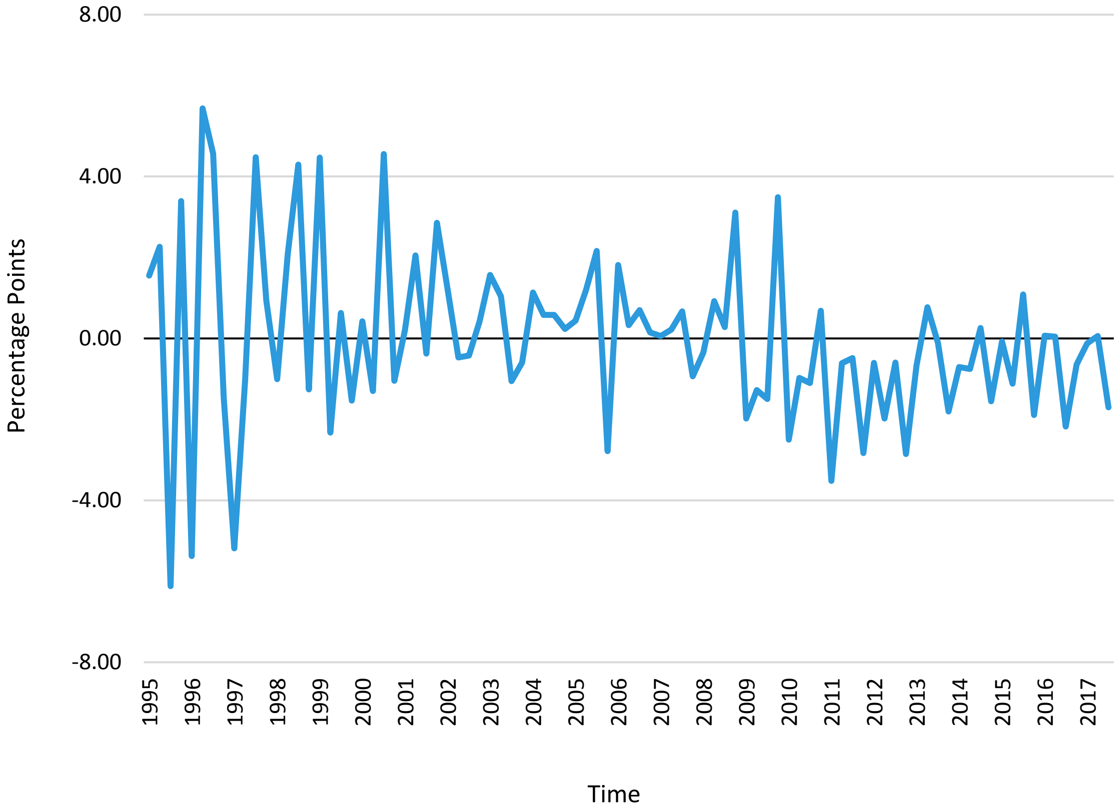
Est. Equation C2: $\text{dlog}(\text{pi}_t) = \text{pi}_4 * \text{dlog}(\text{pp}_t) + \text{pi}_5 * \text{dlog}(\text{pm}_t) - \text{pi}_6 * \log(\text{pi}_{t-1}/\text{pi}^*_{t-1}) + \varepsilon^{\text{pi}}_t$

Model Restrictions: $\text{pi}_4 = 1 - \text{pi}_5$

Standard R^2: 0.41 **Adjusted R^2:** 0.41 **First Period:** 1995Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pi_5	0.36	0.09	4.13	0.00
pi_6	0.23	0.07	3.53	0.00

Est. Residuals C2



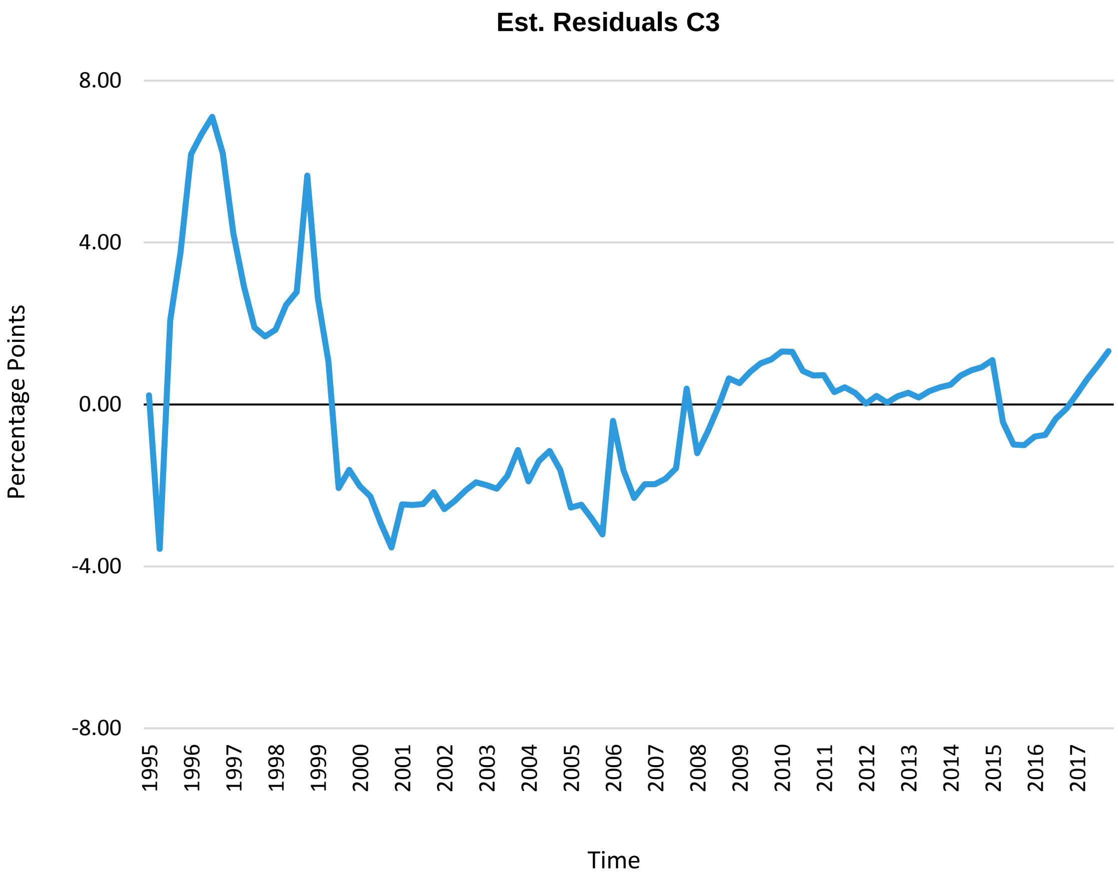
Potential public prices

Est. Equation C3: $\log(pg_t^*) = pg_1 - pg_2/\mathrm{sqrt}(t) + pg_3 * \log(py_t) + pg_4 * \log(pc_t) + \zeta_t^{pg}$

Model Restrictions: $pg_3 = 1 - pg_4$

Standard R^2: 0.99 **Adjusted R^2:** 0.99 **First Period:** 1995Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pg_1	0.05	0.01	4.05	0.00
pg_2	0.06	0.01	4.36	0.00
pg_4	0.44	0.04	9.85	0.00



Domestic public prices

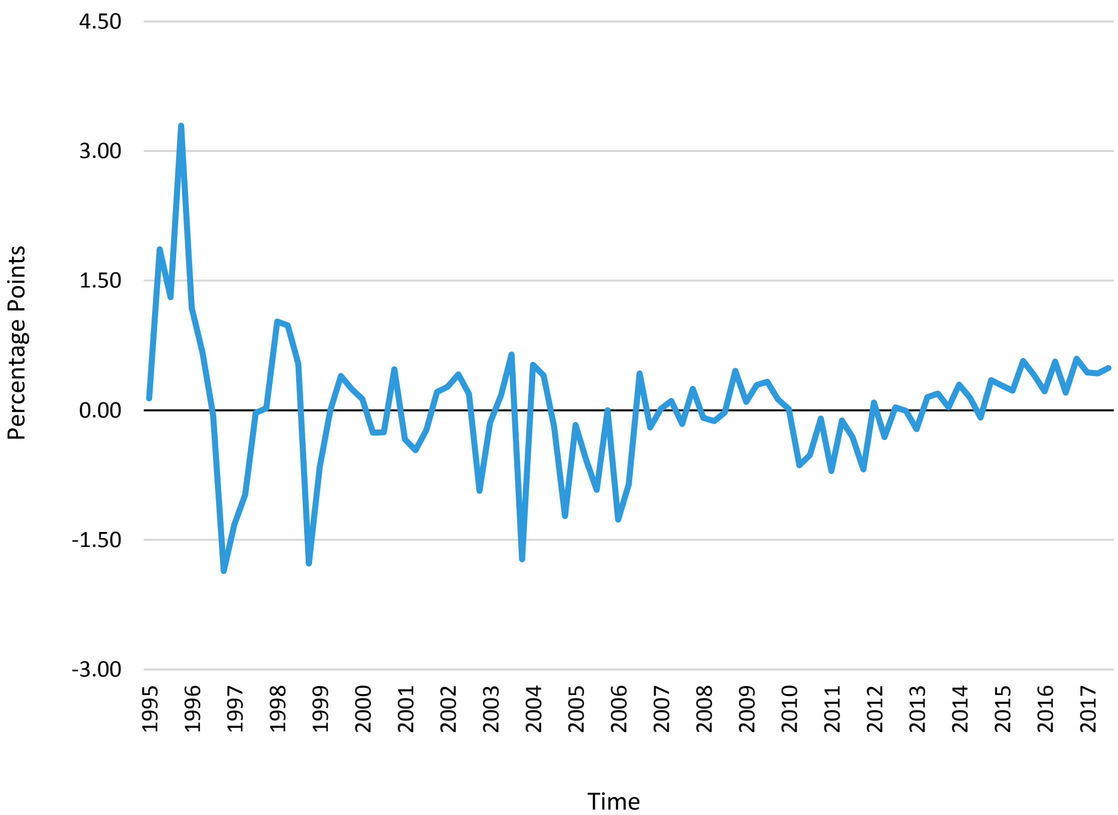
Est. Equation C4: $\mathrm{dlog}(\mathrm{pg}_t) = \mathrm{pg}_5 * \mathrm{dlog}(\mathrm{pp}_t) + \mathrm{pg}_6 * \mathrm{dlog}(\mathrm{pc}_t) - \mathrm{pg}_7 * \log(\mathrm{pg}_{t-1}/\mathrm{pg}^*_{t-1}) - \mathrm{pg}_8 * 1999Q4 + \mathrm{pg}_9 * 2006Q2 + \varepsilon_t^{pg}$

Model Restrictions: $\mathrm{pg}_5 = 1 - \mathrm{pg}_6$

Standard R²: 0.33 **Adjusted R²:** 0.30 **First Period:** 1995Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pg_6	0.89	0.05	19.3	0.00
pg_7	0.04	0.03	1.18	0.24
pg_8	0.06	0.01	7.20	0.00
pg_9	0.02	0.01	3.06	0.00

Est. Residuals C4



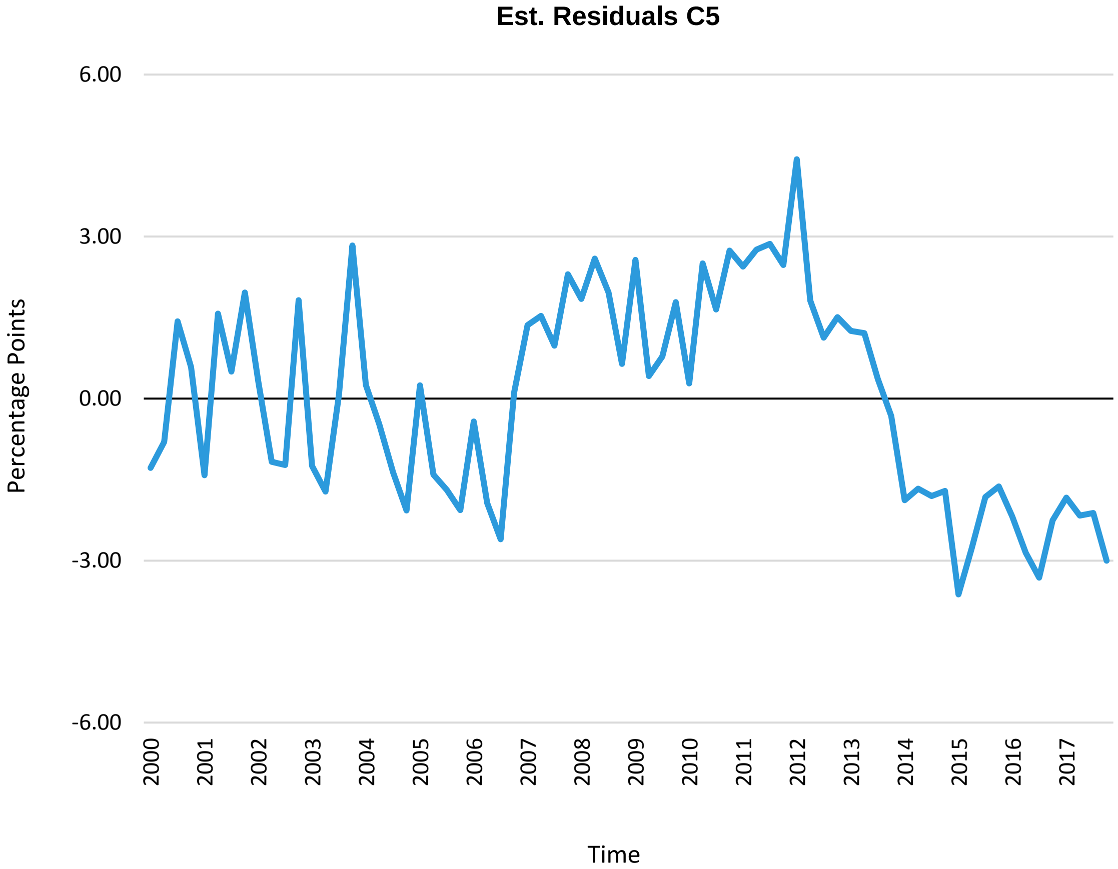
Potential export prices

Est. Equation C5: $\log(px_t^*) = px_1 + px_2 * \log(py_t) + px_3 * \log(pw_t) + px_3 * \log(er_t) + \zeta_t^{px}$

Model Restrictions: $px_2 = 1 - px_3$

Standard R^2: 0.82 **Adjusted R^2:** 0.82 **First Period:** 2000Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
px_1	0.04	0.00	18.6	0.00
px_3	0.36	0.01	27.8	0.00



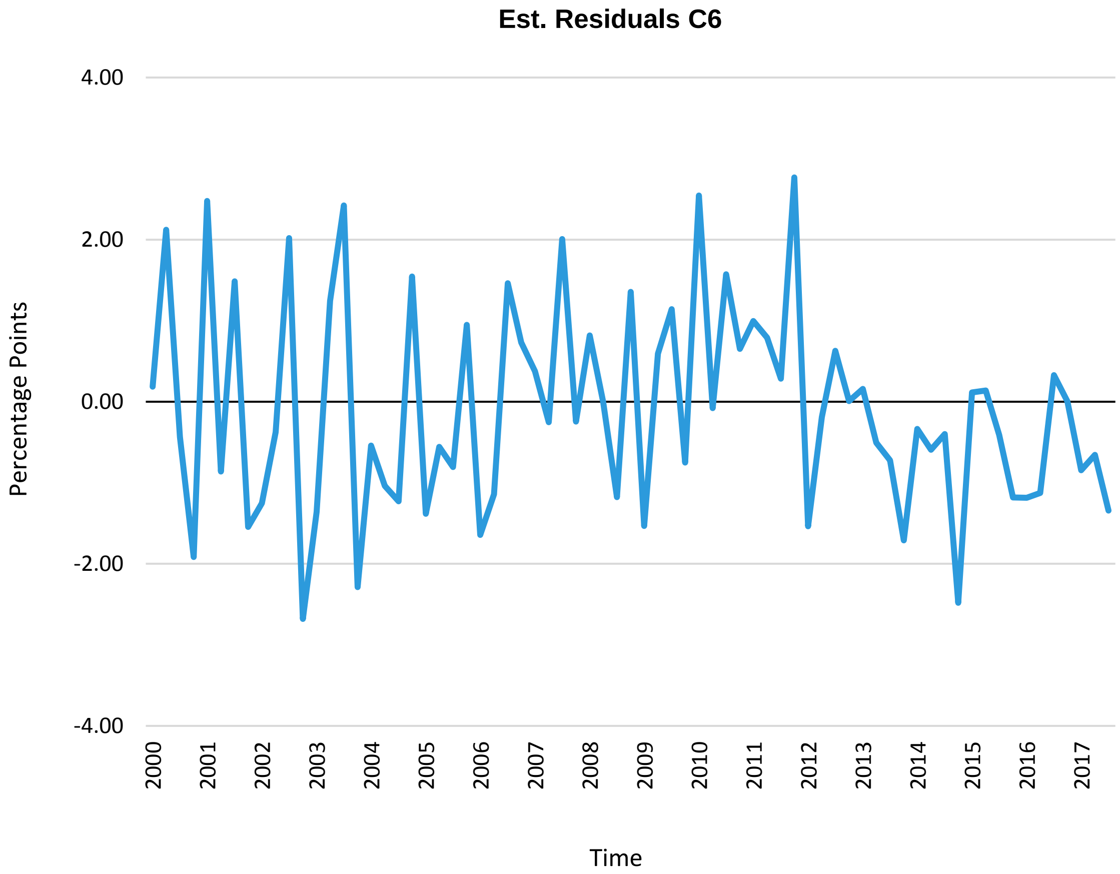
Domestic export prices

Est. Equation C6: $\mathrm{dlog}(\mathrm{px}_t) = \mathrm{px}_4 * \mathrm{dlog}(\mathrm{pp}_t) + \mathrm{px}_5 * \mathrm{dlog}(\mathrm{pw}_t) + \mathrm{px}_5 * \mathrm{dlog}(\mathrm{er}_t) - \mathrm{px}_6 * \log(\mathrm{px}_{t-1}/\mathrm{px}^*_{t-1}) + \varepsilon_t^{px}$

Model Restrictions: $\mathrm{px}_4 = 1 - \mathrm{px}_5$

Standard R^2: 0.36 **Adjusted R^2:** 0.35 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
px_5	0.25	0.07	3.58	0.00
px_6	0.25	0.08	3.10	0.00



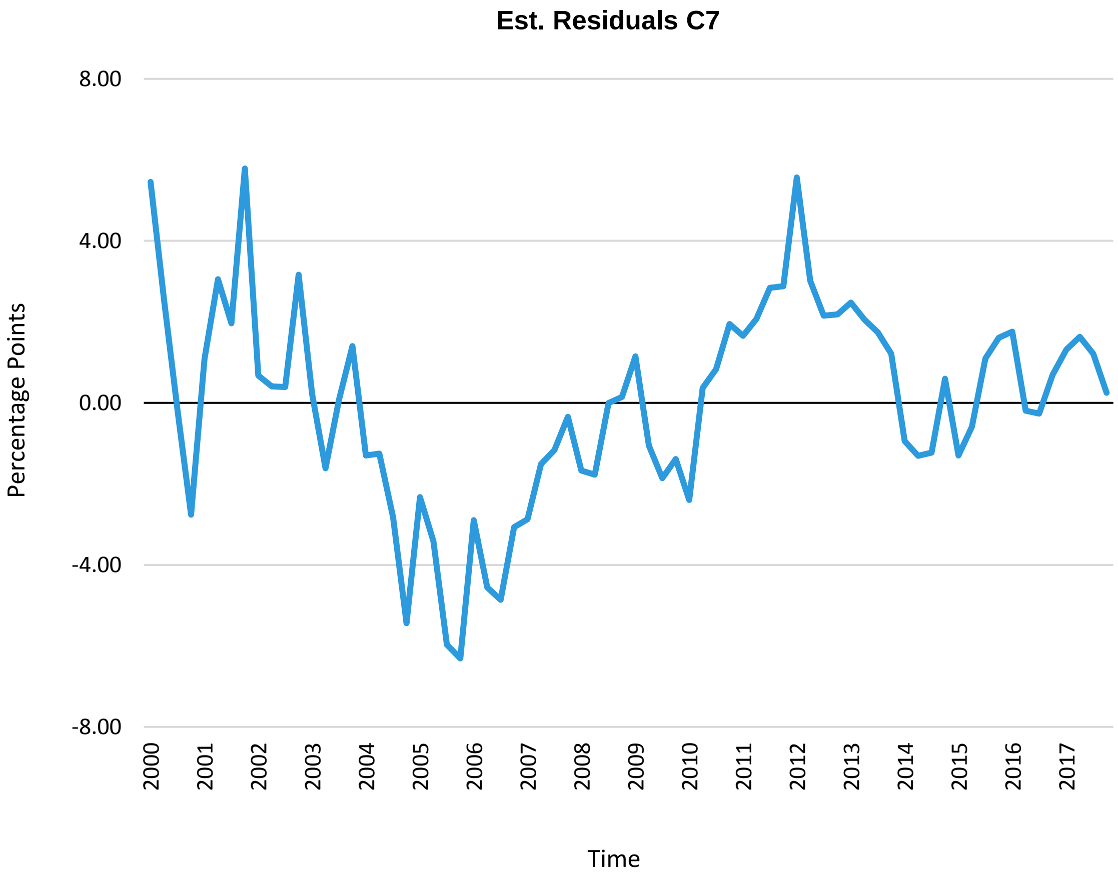
Potential import prices

Est. Equation C7: $\log(\mathrm{pm}_t^*) = \mathrm{pm}_1 + \mathrm{pm}_2 * \log(\mathrm{py}_t) + \mathrm{pm}_3 * \log(\mathrm{pw}_t) + \mathrm{pm}_3 * \log(\mathrm{er}_t) + \mathrm{pm}_4 * \log(\mathrm{oil}_t) + \mathrm{pm}_4 * \log(\mathrm{us}_t) + \zeta_t^{\mathrm{pm}}$

Model Restrictions: $\mathrm{pm}_2 = 1 - \mathrm{pm}_3 - \mathrm{pm}_4$

Standard R^2: 0.90 **Adjusted R^2:** 0.89 **First Period:** 2000Q1 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pm_1	-0.32	0.09	-3.70	0.00
pm_3	0.16	0.02	8.97	0.00
pm_4	0.05	0.01	3.91	0.00



Domestic import prices

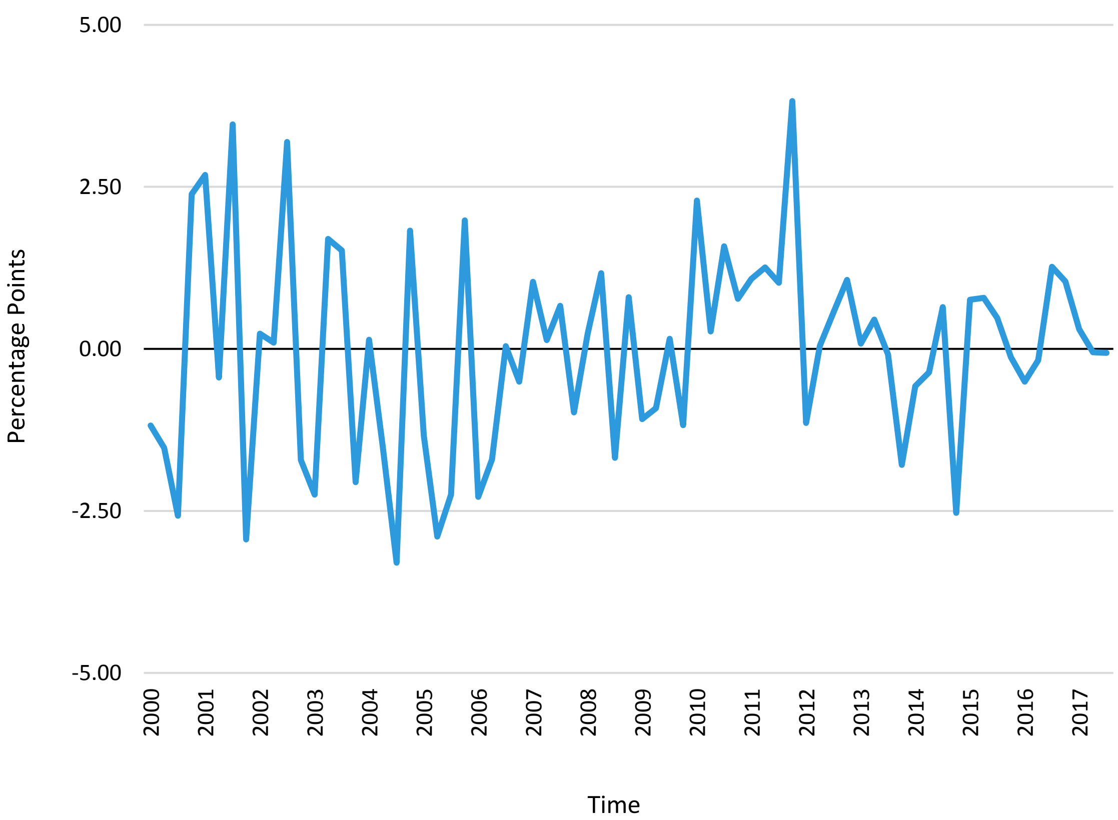
Est. Equation C8: $\text{dlog}(\text{pm}_t) = \text{pm}_5 * \text{dlog}(\text{pp}_t) + \text{pm}_6 * \text{dlog}(\text{pw}_t) + \text{pm}_6 * \text{dlog}(\text{er}_t) + \text{pm}_7 * \text{dlog}(\text{oil}_t) + \text{pm}_7 * \text{dlog}(\text{us}_t) - \text{pm}_8 * \log(\text{pm}_{t-1}/\text{pm}^*_{t-1}) + \varepsilon_t^{\text{pm}}$

Model Restrictions: $\text{pm}_5 = 1 - \text{pm}_6 - \text{pm}_7$

Standard R^2: 0.18 **Adjusted R^2:** 0.15 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
pm_6	0.26	0.11	2.45	0.02
pm_7	0.01	0.01	0.75	0.46
pm_8	0.29	0.08	3.83	0.00

Est. Residuals C8



Interest rate estimation

Domestic risk premium

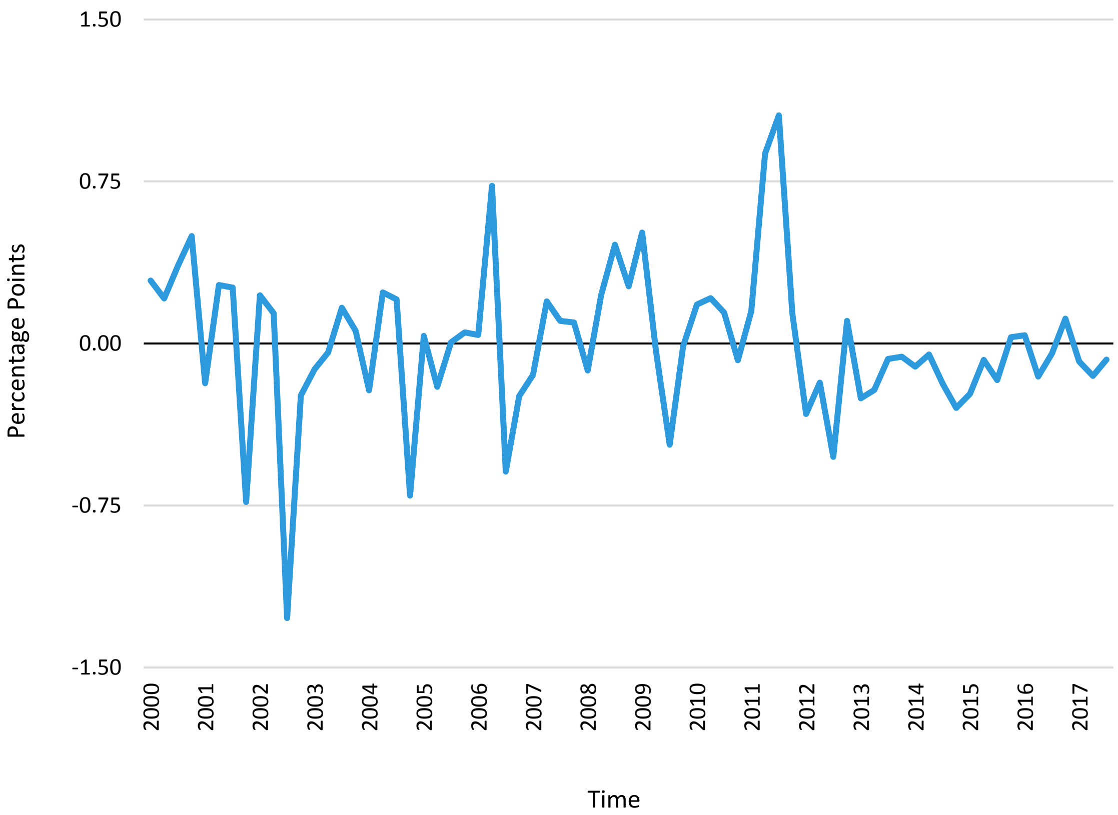
Est. Equation F1: $pr_t = \phi_1 + \phi_2 * pr_{t-1} + \phi_3 * dp_t^* - \phi_4 * ca_t^* + \varepsilon_t^{pr}$

Model Calibration: $\phi_3 = 0.0052; \quad \phi_4 = 0.0055;$

Standard R^2: 0.86 **Adjusted R^2:** 0.86 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ϕ_1	-0.13	0.00	-1.84	0.07
ϕ_2	0.89	0.04	20.0	0.00

Est. Residuals F1



Households estimation

Private mixed surplus

Est. Equation H1: $\text{dlog}(\text{ms}_t) = \text{ms}_1 * \text{dlog}(\text{yn}_t^*) + \text{ms}_2 * \text{dlog}(\text{ds}_t) + \text{ms}_3 * \text{cor}(\text{ms}_{t-1}) + \varepsilon_t^{\text{ms}}$

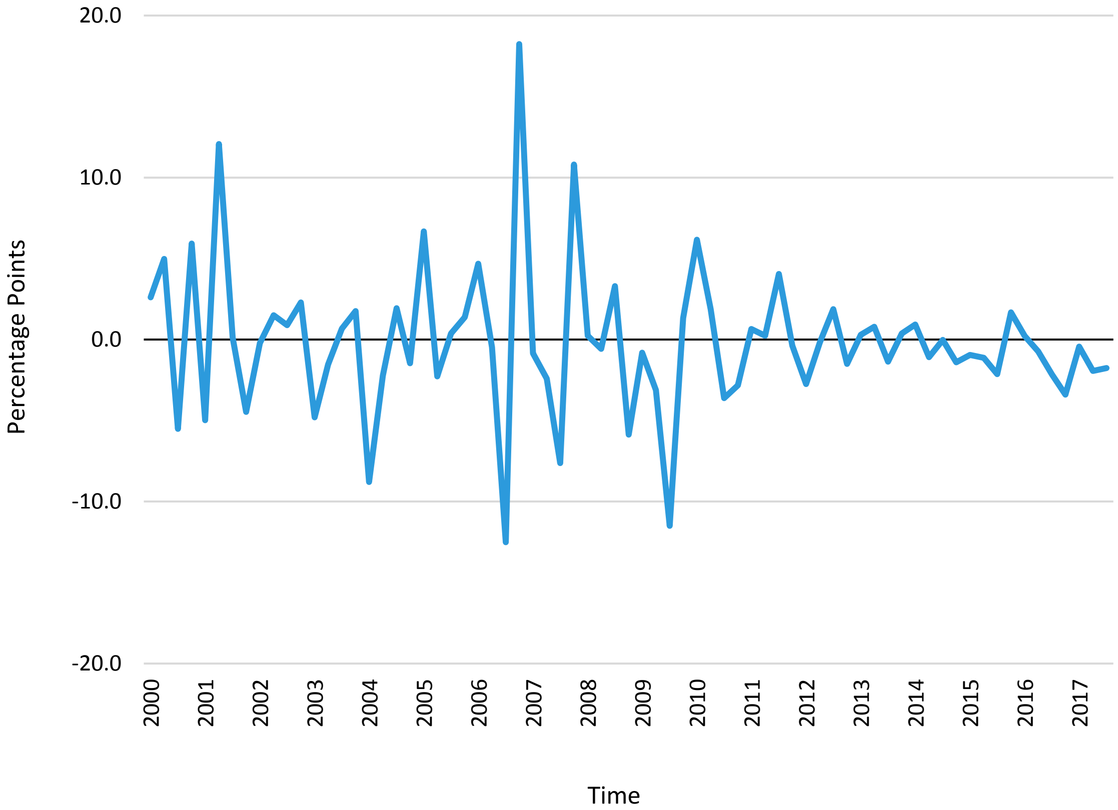
Model Calibration: $\text{ms}_3 = 0.00;$

Model Restrictions: $\text{ms}_1 = 1 - \text{ms}_2$

Standard R^2: 0.06 **Adjusted R^2:** 0.06 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ms_2	0.15	0.10	1.55	0.13

Est. Residuals H1



Government estimation

Intermediate consumption

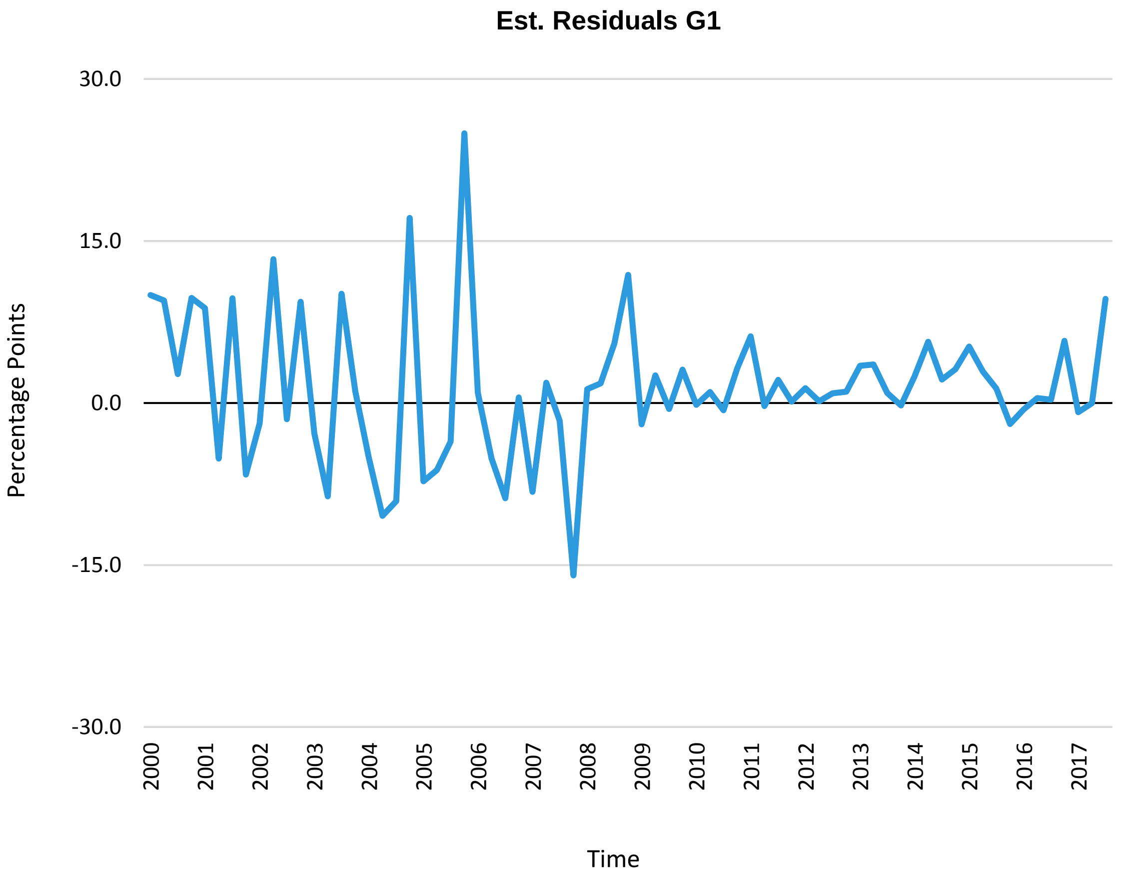
Est. Equation G1: $\text{dlog}(\text{ic}_t) = \text{ic}_2 * \text{dlog}(\text{yn}_t^*) + \text{ic}_3 * \text{dlog}(\text{yn}_t) - \text{ic}_4 * \text{gap}(\text{yt}_{t-1}) + \text{ic}_5 * \text{dev}(\text{bp}_{t-1}^*) - \text{ic}_6 * \text{dev}(\text{dp}_{t-1}^*) + \text{ic}_7 * \text{cor}(\text{ic}_{t-1}) + \varepsilon_t^{ic}$

Model Calibration: $\text{ic}_4 = 0.05; \quad \text{ic}_5 = 0.40; \quad \text{ic}_6 = 0.10; \quad \text{ic}_7 = 0.15;$

Model Restrictions: $\text{ic}_2 = 1 - \text{ic}_3$

Standard R^2: 0.02 **Adjusted R^2:** 0.02 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
ic_3	0.74	0.55	1.34	0.19



Public social transfers

Est. Equation G2: $\text{dlog}(\text{st}_t) = \text{st}_2 * \text{dlog}(\text{yn}^*_t) + \text{st}_3 * \text{dlog}(\text{lt}_t) + \text{st}_3 * \text{dlog}(\text{wt}_t) + \text{st}_4 * \text{dlog}(\eta_t) + \text{st}_4 * \text{dlog}(\mu_t) - \text{st}_5 * \text{gap}(\text{yt}_{t-1}) + \text{st}_6 * \text{dev}(\text{bp}^*_{t-1}) - \text{st}_7 * \text{dev}(\text{dp}^*_{t-1}) + \text{st}_8 * \text{cor}(\text{st}_{t-1}) + \varepsilon^{st}_t$

Model Calibration: $\text{st}_4 = 0.05$; $\text{st}_5 = 0.01$; $\text{st}_6 = 0.08$; $\text{st}_7 = 0.02$;

Model Restrictions: $\text{st}_2 = 1 - \text{st}_3$

Standard R^2: 0.08 **Adjusted R^2:** 0.07 **First Period:** 2000Q2 **Last Period:** 2017Q4

Parameter	Est. Mean	Std. Error	T-Statistics	P-Value
st_3	0.32	0.38	0.82	0.41
st_8	0.11	0.06	1.98	0.05

Est. Residuals G2