CPB Netherlands Bureau for Economic Policy Analysis

Saffier 3.0: Technical Background

We document the Saffier 3.0 model that is used for macroeconomic projections and scenario-analysis. We discuss in detail estimation results and impulse responses to economic and policy shocks.

The model is estimated on recent quarterly data; is compact and transparent, and allows for forward-looking behaviour in future applications.

CPB Background Document

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1 Non-technical summary

This paper documents the Saffier 3.0 model for macroeconomic projections and scenario-analysis for the short and medium run.[1] The aim of the model is twofold. First, the model will be applied in the CPB-projections of key economic indicators in the short run (one to two years ahead) and the medium run (up to five years). Second, the model will be used for the simulation and evaluation of macroeconomic effects of fiscal policy, like in the assessment of election platforms of Dutch political parties. The model replaces Saffier 2.1 (CPB, 2010).

The model is a new exponent of a long tradition of CPB-models. The basic structure of the model has been unchanged from its predecessors: the interaction between supply and demand and between volume changes and price dynamics and the important role for the public sector in interaction with the market sector. In the good tradition of CPB-models, the new macro model will be part of a suite of models. For projections it is run in cooperation with NiGEM[2], forecasting tools (like BVAR models[3]) and several detailed fiscal models[4]. In addition, detailed models for the labour market and housing market can be combined with the macro model, in particular for scenario analysis.[5]

The main differences of the model with Saffier 2.1 is that the model is estimated on recent quarterly data; that it is more compact and transparent and that it allows for forward-looking behaviour in future applications. First, the estimation covers the period of 1996-2019, for which Statistics Netherlands provides quarterly observations for the main economic variables. This sample includes the quarters before the financial crisis, the crisis of 2008-2009 and the aftermath with a second recession and recovery.[6] Finding significant parameters over this 20-year window is hard, both due to the financial crisis and the flattening of key structural relations like the Phillips curve.[7] Therefore, we combine empirical estimations for the Netherlands in 1996-2019 with parameters from a literature survey, like the elasticity of substitution between labour

[1]We prefer the term projection above forecast in our case. A forecast refers to results that are based on conditions considered most likely, whereas a projection relates to results based on a hypothetical (or what-if) scenario. Since our outcomes are always conditional on assumptions on foreign conditions and policy measures, we call them projections.

[2]NIESR, National Institute Global Econometric Model, `https://nimodel.niesr.ac.uk/index.php?t=0`. Stuut (2019) describes how CPB uses this model.

[3]See de Wind (2015) and Adema et al. (2020).

[4]e.g. the tax-benefit simulator MIMOSI (Koot et al., 2016).

[5]e.g. the microsimulation model for labour supply MICSIM (Jongen et al., 2014).

[6]The Covid-crisis of 2020 is out of sample, and might be included after a period of recovery.

[7]See the references in section 3.4.

and capital and tax-elasticities in the wage equation.[8] Second, the compactness and transparency of the model make it possible to extend the model in a modular way and integrate forward looking behaviour. Third, the model includes expectations and therefore allow for the analysis of anticipating behaviour by economic agents in future use.

The model structure builds on state-of-the-art models that are used by policy institutions for both forecasting and policy simulations. The main sources of inspiration are the FRB/US model developed and maintained at the Federal Reserve Board, the LENS model of the Bank of Canada and the ECB-BASE model of the European Central Bank.[9] Just like these models, Saffier 3.0 is based on optimizing behaviour of economic agents subject to generalized adjustment costs.

Options for future developments include the activation of expectations, extended modules for specific sectors and the remodelling and re-estimation of empirical equations. The current version of the model is meant as a base for further work. First, the model is developed to include expectations for the main behavioural equations, like consumption, investment, labour demand, wage and price setting (see section 2.2). In estimating these relations, we combine backward-looking behaviour (in an error-correction framework) with forward-looking behaviour. We apply the PAC approach (polynomial adjustment cost) of the Federal Reserve Board.[10] In the current use, we restrict the model to static expectations meaning that agents do not anticipate future changes in the economy in their current decisions. In future use, we will apply the model with forward-looking behaviour. Second, the basic version of the model is designed for the analysis of fiscal policy and is weaker in the representation of other sectors. In future applications of the model, extensions like the financial sector or a more elaborate housing market module might be added. The third element of future work is adapting and re-estimating key relations in the model, which might follow new insights from ongoing research in the international literature on e.g. the Phillips curve.

[8] See the detailed discussion in section 3.

[9] See Brayton et al. (2014), Gervais and Gosselin (2014) and Angelini et al. (2019).

[10] See Brayton et al. (2014) and Appendix A.1.

2 A brief overview of the model

The aim of the Saffier 3.0 model is twofold: make projections for the Dutch economy and assess the macroeconomic responses to fiscal policy changes. The evaluation horizon for both applications is about one to five years. CPB publishes projections for a one-to-two-year horizon on a quarterly basis and for a five-year horizon annually. Important policy evaluations include the assessment of election platforms and coalition agreements for the upcoming period of government. Important indicators in these assessments are the economic effects (in terms of GDP, (un)employment, wages etc.) and the implied changes in the government budget. This dual purpose of the model brings with it particular desirable characteristics and limitations.

This twofold aim defines the structure of the model. We develop an empirical macro economic model for the Netherlands, including a rich fiscal policy block, paying attention to both short-run and medium-run responses and with sufficient flexibility to add (temporary) extensions to the model. Moreover, knowing that agents are partly forward looking, we include expectations formation in the setup of the model. This feature requires further development before it can be used in model applications and is part of the research agenda. The model is of an error-correction type, where economic theory defines long-run or target relations in the levels of variables and empirical fit determines relation between growth rates and the gradual adjustment (the error correction) to target levels.[11] In view of the complexity of the model and the limited sample size, we chose to estimate the behavioural equations separately (see section 2.3).

Saffier 3.0 is part of a suite of models. For both purposes of projections and policy evaluations, CPB applies a number of models. Detailed results from both government budget models but also a microeconometric simulation model for the labour market (MICSIM, see Jongen et al. (2014)) may be fed into the macro model. For example, the macro model includes the labour market responses of a cross-the-board change in labour and income taxes. A policy aimed to stimulate labour supply by enlarging the gap between wage income and unemployment benefits can be assessed in the microsimulation model: the labour supply response generated by this model will be added as a separate impulse to the macro model.

[11] Section 2.3 briefly describes the extension with forward-looking components in the empirical equations.

2.1 Structure of the model

The core of the model consists of supply and demand blocks with wages and prices as main balancing mechanisms. To end up with a compact and transparent model, we rely on aggregates as much as possible (as practical). We only add detail if the structure of the Dutch economy or the key properties of the institutions in the Netherlands urge us to do so, or if model users demand more detailed outcomes. We include three production sectors (market sector, public sector and health care), two production factors (labour and capital) and up to eleven demand categories and price variables. Examples of added details include the separation between domestically produced and re-exported goods and services and labour incomes of employees and incomes of self-employed.

We model the Dutch economy as a medium-sized open economy. In view of heterogeneity between domestic and foreign goods, exporting firms have some market power, in particular in the short run. The Dutch economy is, however, unable to affect foreign economies, implying that world trade and foreign prices are exogenously given. Moreover, the Netherlands is a member of the European Monetary Union. We do not include monetary policy rules and consider the European interest rates as exogenously given.[12]

In particular to allow policy analysis, we model the public sector in quite some detail.[13] The modelling of revenues and expenditures of the public sector covers many instruments for economic policy. Most of the equations in the public sector block reflect rules of thumb rather than behavioural relationships. Indeed, while it may be argued that some aspects of policy are endogenous, we purposely made no attempt to model government policy, so as to be able to separately analyse the effects of actual and proposed government policy. That is, all simulations with the model have to be made conditional on a specific policy stand.

The model contains target and dynamic equations. A target equation gives the equilibrium value of a variable in a frictionless economy. A dynamic equation specifies how the growth rate of a variable depends on the deviation from the target value and growth rates of other variables. All variables converge to their long-run or balanced growth path values.

[12]We do not model the volumes of foreign investment; factor income flowing to or from foreigners is a fixed fraction of GDP. Immigration is exogenous and projections are taken from Statistics Netherlands.

[13]Note that further details of the tax-and-benefit system, public health care, public spending and second-pillar pensions are included in other operational models at CPB, see `https://www.cpb.nl/modellen`.

2.1.1 Supply side

Goods and services are produced in three sectors (market, health care and government sector) or are imported.[14] Long-run production in the market sector is determined by labour supply and labour-augmenting technical progress, which are both exogenously given, and on the capital intensity, which in turn depends on relative capital-to-labour costs. Given the assumption of limited market power, changes in terms of trade have permanent effects on relative cost prices and production. Note that the growth rates of labour supply and labour-augmenting technical progress determine, together with the inflation rate, the main trends in the long run. Production, employment and investment in the public sectors (government and health care) are exogenously given.[15] Given the relative small size of the economy, we assume that the world-wide production of goods and services is sufficient to meet any changes in demand from the Netherlands (at constant prices).

Labour- and investment demand in the market sector depend on its output and relative labour/capital costs. This follows from cost-minimization where target production in the market sector is modelled by a CES production function in labour and capital. The demand functions describe the equilibrium, or target relations for labour and investment. Short-run dynamics are modelled as error-correction processes aiming to close the gap between the actual and target levels of employment and investment. In addition, both employment and investment respond immediately to changes in production in the market sector and relative costs.

The demand for labour is matched with supply on a labour market characterized by wage negotiations.[16] Structural labour supply is exogenous to the model, depending on demographic and participation trends. The model contains a cyclical component of labour supply, which depends on deviations of the unemployment rate from its trend. Wage are determined in negotiations, which implies that the unemployment rate depends on policy variables like tax wedge and replacement rate. Finally, we distinguish between the labour costs of employees and self-employed.[17]

[14] The market sector thus covers all sectors, except for the government and the health care sector. The government sector includes all levels of government (including education) and government-controlled firms.

[15] More precisely, for policy simulations we take the volume of public expenditures and tax rates as given, but take public sector wages and prices and tax base endogenously.

[16] Note that for detailed analysis of the labour market, additional models are applied at CPB, like a demographic model and the microsimulation model for the tax-participation nexus.

[17] We model the share of self-employed in a rudimentary way. The actual share of self-employed converges to a specified target share. For a discussion on the determinants of the growing share of self-employed, see

Labour costs (per hour) of employees and self-employed in the market sector are based on the modelling of average labour cost in the market sector. The equation for the average target labour cost in the market sector follows from assuming that the labour income share is linear in the unemployment rate, the tax wedge and the replacement rate. We assume that that there is a constant target labour cost differential between employees and self-employed and that the average converges to the target. We find different dynamics of the labour costs of employees and self-employed. Labour costs in other sectors are based on the average labour cost in the market sector.

We allow for different output prices for each demand category, differentiated by cost shares, markup and productivity trends. Cost prices for consumption, investment and exports are a function of labour and capital costs, energy and import prices. Labour productivity is added to the equations for a potential Baumol effect (below or above average productivity growth per use category). A trend is added to the equation to capture the rise in the macroeconomic mark-up. Price dynamics are modelled as error-correction equations.

2.1.2 Market Demand

Private consumption results from the behaviour of optimizing and hand-to-mouth households. Target consumption of optimising households depends on permanent income and net wealth.[18] Permanent income equals the discounted sum of expected disposable income in the future. The level of permanent income varies with the type of expectations implemented. In the current version of the model we assume static expectations, implying that consumers expect that the ratio of permanent income to current income is constant. The deviation of actual consumption from the target level is one of the drivers in the dynamic equation describing the growth rate of consumption. Consumption growth also depends on current growth of disposable income.

Investment demand of the market sector strongly responds to current output of the market sector, besides the adjustment towards the target level. Target investment keeps the capital stock on the equilibrium growth path.

Total export demand consists of the exports of domestically produced goods and services, re-exports and energy exports. In view of the large import content, fluctuations in the latter two export categories have smaller effects on GDP than changes

Bosch et al. (2015).

[18] We apply the permanent income consumption function as derived by Aron et al. (2012), which is less restrictive than an Euler-type equation.

in the exports of domestic products.

The target level of exports of domestic products is determined by a combination of relevant world trade, output of the market sector and terms of trade. First, exogenous relevant world trade is included, such that a permanent shock in foreign demand has a permanent effect on the export to GDP ratio. Second, output of the market sector is included as a proxy of capacity restrictions. The increase in the export volume is limited by the available production capacity, which is captured by current output. Finally, a fall in the export price relative to the price of foreign competitors (or terms of trade) stimulates export demand. Since estimation did result in a low price elasticity, we decided to increase this elasticity from a low value (-1.5) in the short run to a large value (-4) in the long run to limit changes in the terms of trade. Volumes of re-exports and energy exports are specified similarly.

Analogously to the modelling of exports, we consider three types of imports: imports of goods and services, imports for re-exports and energy imports. The target import of goods and services is related to the volumes of the demand categories by using average import intensities. In addition, we include a weighted relative price effect. In the short run, imports respond to the weighted growth rate of the demand volumes and gradually adjusts to the target.

2.1.3 Government sector

The public sector is an important part of the model for use in both projections and scenario analysis. We have chosen the disaggregation of the government budget in accordance with the policy measures we want to analyse (see Table 1). Tax revenues are in general modelled by applying effective instead of statutory rates. These effective rates are calculated by dividing observed revenues by the respective tax bases. Government expenditures are generally modelled with rule-of-thumb relations, but can also be overruled by more detailed information. In applications, we use information from other CPB models to get a richer analysis of fiscal policy changes.[19]

"Direct taxes" in the model combine taxes and social security premiums levied on income. They are collected from three sources: (1) income taxes and social security premiums paid by households, (2) social security premiums paid by employers and (3) corporate income taxes. For (1) the tax base is the sum of labour income of employed and self-employed, social transfers and pension benefits, less interest payments on mortgages and pension premiums. For the income tax, we take tax progression into account. In the

[19] See `https://www.cpb.nl/en/models` for the suite of models used at CPB.

Table 1: Budget of the government (2018, in billion euros)

Revenues		Expenditures	
Indirect taxes (net of subsidies)	81	Consumption government	188
Direct taxes & social premiums	208	- Compensation civil servants	64
- Income taxes & social premiums households	138	- Expenditures on goods & services	45
- Social premiums paid by employers	41	- Transfers in kind (health care costs)	78
- Corporate income taxes	26		
- Other	4		
Depreciation	24	Investment government	24
Wealth income	8	Interest payments	7
		Social transfers	81
Income transfers received	4	Other income transfers paid	12
Capital transfers received	2	Capital transfers paid	5
		EMU surplus	11

short term, tax revenue grows harder than the tax base. In the long term, the tax schedule is corrected for income growth, so that the tax revenue is proportional with the tax base. The social security premiums include both national insurances (for old age pensions and long term care) and employees insurances (for unemployment, disability and health care). For (2) and (3), the tax bases are, respectively, the gross wage bill and corporate income approximated by the value of output minus labour costs, depreciation costs and interest payments on debt.

Indirect taxes (product related) are imposed on private and public consumption, health care expenditures, investment and domestically produced exports. These indirect taxes include both the value added tax and excise taxes, net of subsidies. Revenues are defined as an effective tax rate times the aggregate expenditures for each demand category. Tax rates differ between demand categories in the model.[20] In addition, we include other indirect taxes and subsidies. The remaining, minor revenues items (depreciation; wealth income; income and capital transfers) are linked to GDP.[21]

Transactions of the large second pillar pension funds affect the income tax revenues. Pension funds are not part of the government. Pension benefits and premiums

[20] Energy taxes or emission taxes are not separately modelled, given that this would require a richer consumption and production structure with energy and emissions separated out.

[21] Notice that we do not keep track of the accumulation of public capital and gross wealth (in contrast to debt).

have a substantial impact on household incomes. Premiums are paid by both employers and employees, as fractions of gross wages. Benefits in the model are indexed to consumer prices.[22] For the government budget, the only thing that matters is that pension benefits are taxed but premiums are tax-deductible for households.

We consider three types of government consumption. First, the government wage bill equals the number of civil servants times the average wage cost. In scenario analysis, the growth rate of the former is kept exogenous, whereas the government wage is linked to the wage cost in the market sector. Both the number of employees and the wage rate can be adjusted in policy simulations. Second, the volume of government consumption of goods and services grows at the exogenous rate, but it can be adjusted in particular policy simulations. The corresponding price depends on the producer price in the market sector. Third, public expenditure on health care is separately modelled. Its volume is similarly specified as the previous item, while its cost price is a weighted average of the wage cost in the health care sector and the cost price in the market sector.

Social security benefits constitute about a quarter of public expenditures and about 10% of GDP. They include both national insurances (for old age pensions and long term care) and employees insurances (for unemployment, disability and public health care). We distinguish three types of benefits: benefits linked to gross wages, benefits linked to consumer prices and unemployment benefits. Expenditures on the last benefits depend on the unemployment rate, the gross wage and the replacement rate. Again, the analysis can be enriched by including more detailed information on benefits from other models.

All changes in revenues and expenditures result in the change of the EMU balance. The basic version of the model includes rule-of-thumb equations for investments in the government and health care sector, each as exogenous shares of GDP. In both projections and scenario analysis these rules of thumb can be overruled by information from other CPB models.[23] We complete the modelling of the government budget with simple equations for income and capital transfers and interest payments. Table 1 shows that the budget shows a surplus in 2018. In most applications, in particular for baseline projections, the EMU balance is determined in close cooperation with other models. The change in government debt is equal to minus the EMU surplus. In simulations we normally

[22] In the CPB-model Gamma, 65% of the benefits are indexed to prices and 35% to wages (van Tilburg et al., 2019). The degree of the actual indexation is conditional on the financial position of the pension funds.

[23] Note, that we do not explicitly model public capital and therefore abstract from the productive nature of public investment. A model of endogenous growth is a possible extension (most likely in the form of a separate model) of the current modelling project.

do not apply some debt-stabilizing rule, which implies that the debt rate will only stabilise if the real interest rate is smaller than the growth rate in the long run. CPB-practice is to not suggest a standard stabilizing rule as this is an open option for policy.

2.1.4 Flow and wealth accounts

We have modelled consistent flow accounts. The net savings add up to zero over the four sectors (households, firms, government and the rest of the world), meaning that the national budget constraint holds in every period. This is an important feature to maintain consistency in the modelling. A next step is a detailed modelling of wealth accounts

We partly model the wealth accounts. We model that households save to accumulate wealth and that target consumption depends on total net wealth. We also keep track of the accumulation of government debt, which determines interest expenditures. In scenarios in which only debt financing is considered, these interest payments have no other feedback effects. For the remaining sectors, firms and rest of the world, wealth is calculated as an epilogue variable, as feedback effects are not incorporated at this stage. Observations show that a large part of wealth accumulations arises from re-valuations. Taking account of revaluation effects requires the specification of particular asset prices, like stock and bond prices and exchange rates. At this stage, we decided to abstain from modelling asset pricing and thus from modelling detailed wealth accounts for firms and rest-of-world.

2.2 Reaction, anticipation and equilibrium

The basic structure of the model consists of equilibrium equations and dynamic adjustment equations moving the economy towards equilibrium. These dynamic adjustment equations are a mixture of empirically estimated relations (like a strong short-run impact from production on investment), often theoretically founded (firm behaviour dictates investment decisions) and (near) accounting relations (like a strong and direct impact of indirect taxes on inflation). The dynamic equations contain an error-correction term, i.e. deviations between current variables and their target values define backward-looking (reactive) adjustment processes.

The model has a well-defined steady state (or more precisely a balanced growth path), where relations between main variables are based on economic theory. Structural supply of labour, exogenous technological progress and endogenous structural unemployment are the drivers of potential output of the market sector. In addition, production by the government and health care sectors are given fractions of GDP. Total demand adjust in the long run to this supply-determined growth path. Due to imperfections in export behaviour (limited price-setting power for domestic firms) and the labour market (bargaining power for employees), permanent changes in demand have permanent effect on the long-run level and composition of GDP (but not its growth rate). We elaborate on the long-run properties at the end of section 3.

For future use, the model includes the option of anticipating behaviour. Future changes in the target will be anticipated by the agents in this model version (households and firms). Anticipation is limited by a) the share of reactive (non-anticipating) households and firms (in their consumption and labour- and investment demand); b) the shortsightedness of agents, with a high discount rate of about 5% quarterly and limited horizon (12 quarters in consumption); and c) restrictions on the information set, where presumably hard-to-observe variables like labour productivity will not be anticipated.

2.3 Estimation and parameterization

We estimate the model on macroeconomic quarterly data (mainly national accounts data) for the Dutch economy in the period 1996-2019. We apply quarterly data for both simulations and estimations. The quarterly frequency is necessary for projection purposes, in particular for the first two years. For estimating the target equations, representing long-run relations in the Dutch economy, using a longer sample with annual data faces the higher risk of structural breaks. We focus on quarterly data to estimate the equilibrium and dynamics of the error-correction models. The basic data source for the model are the national accounts for the Netherlands[24], complemented with data for the key international statistics like world trade, interest rates and foreign prices.

For the dynamic equations, three parts can be distinguished:

- the target equation, representing the long-run relations between the key economic variables and their determinants. These target equations are estimated as a cointegration relation between a variable $\ln y$ and its structural determinants $\ln x_j$. The target levels $\ln y^*$ are given by the fitted values;
- the dynamic equation for the growth rate of the key economic variables as function of both an adjustment term (closing the gap between the variable and its target) and other variables. So, the growth rate of y ($d \ln y$) depends on an error-correction term (the deviation of the level of the variable from its target level: $(\ln y - \ln y^*)$), lagged dependent variables and ad-hoc variables. In the estimation procedure for six variables (labour and capital demand, the wage and three price indices) we

[24] https://www.cbs.nl/-/media/_pdf/2019/29/national-accounts-2018.pdf

added predicted values of target variables (growth rates of x_j^*). This enriches the model with forward-looking behaviour, but has little impact on the coefficients of the contemporaneous and backward-looking variables in these estimations;

- a small prediction model for computing the forward-looking components in the dynamic equations. For each of the six target variables in the forward-looking mode, we estimate a VAR-model in output gaps and inflation rates in the Netherlands and the EU, a European short-term interest rate and each target variable y^* (see Appendix A.1). The VAR-model is a condensed model of the economy, reflecting that expectations are based on a restricted information set and an imperfect understanding of the full dynamics. Therefore, outcomes of the VAR-model might differ from outcomes of the full model.

The equations are estimated with VAR-based expectations, whereas we simulate the model assuming static expectations. To be precise, we assume that agents expect that target variables grow at the trend rate. We leave the forward-looking mode of the model for future investigations.

These three parts are estimated separately for each variable. In view of the complexity of the model and the limited sample size, we chose to estimate the behavioural equations separately. Our focus in the estimations is on significant and economically plausible parameters. The estimates over a period of about 20 years are informative for the short-term (1-2 years) and medium-term (2-5 years) responses of the economy to shocks. Inference for longer horizons should be interpreted with care and are only made to contribute to a better understanding of the model (in the direction of its medium-run equilibrium) rather than predictions over more than 10 years.

We choose to fix a few elasticities based on a broad empirical literature. This holds in particular for a few parameters in target relations, most importantly the elasticity of substitution between labour and capital, price elasticities in export and import equations and the policy parameters in the wage equation. Estimation on our short, Dutch sample suffered from weak identification. Our priors for these parameters are based on a broad empirical literature, both for the Netherlands and for a panel of comparable economies. We fix the elasticity of substitution between labour and capital at 0.5 and estimate the remaining parameters in the labour and capital demand equations, see section 3.1. Similarly, we opt for more price-elastic target foreign trade than estimated (see section 3.3). Finally, the long-run elasticities of wages to the tax wedge and the replacement rate are fixed at 0.25 and 0.2, respectively (see section 3.4).

2.4 Key properties in terms of impulse responses

For both projections and scenario analysis, understanding the economic responses in the model to exogenous shocks is key. For scenario analysis this is straightforward: with the macro model we investigate how the economy responds to shocks in fiscal policy and in the external environment. But also for projections, these impulse responses provide insight into the properties of the model, as projections stem from an interplay of external factors (like world trade) and our model of the Dutch economy.

After the model is put in place to generate our regular projections, we will assess the differences between out-of-sample projections and realisations.[25] The assessment requires prudence. We again stress that in practice projections of the model are supplemented in an iterative procedure by outcomes of other instruments and expert opinions. In the rest of this section and in section 4, we focus on the output of the model when used for scenario analysis.

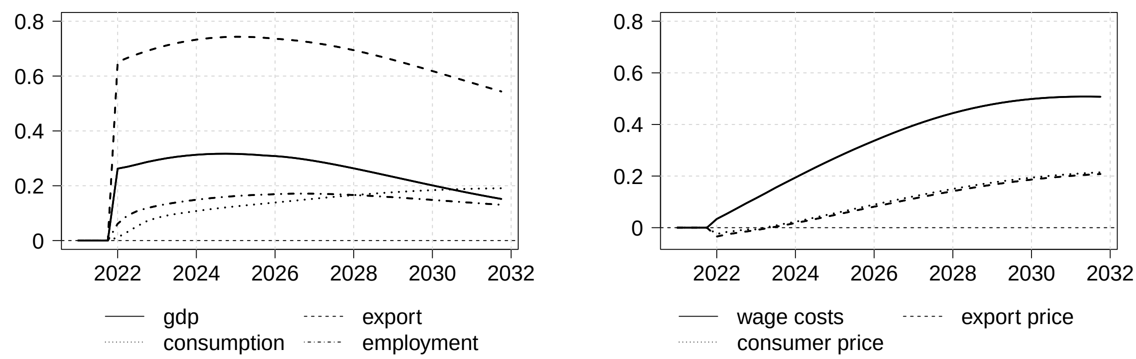
We briefly discuss the key properties of the impulse-responses, based on two main shocks. For practical applications, the responses on a one to five year horizon are most important: short-run projections are made for the next quarter until the end of next year, whereas medium-term projections and most policy analysis focus on the next five years. The short-term reaction parameters in combination with adjustment to a new target govern the dynamic responses of the economy to shocks. During the first quarters, the short-run parameters dominate the responses, as many error-correction parameters are quite low (a lot of them are in the range of 5%-10% quarterly).

Figure 1 illustrates the short- and medium-run responses of the economy to a permanent increase in relevant world trade by 1%. Exports respond immediately, leading to an increase in GDP. The required expansion of domestic production leads to higher employment and also (at least temporary) higher productivity. The reduction in unemployment triggers faster wage growth and initiates a wage-price spiral, which however in this model is quite moderate. In addition, exporting firms increase the cost-driven prices. Finally, consumption benefits from the expansion of employment and the increase in real wages.

Figure 2 illustrates the short- and medium-run responses of the economy to a permanent ex ante increase in personal income taxes by 1% of GDP. The reduction in disposable income leads to an immediate and strong reduction in private consumption. The wage rate initially increases as employees are able to shift a part

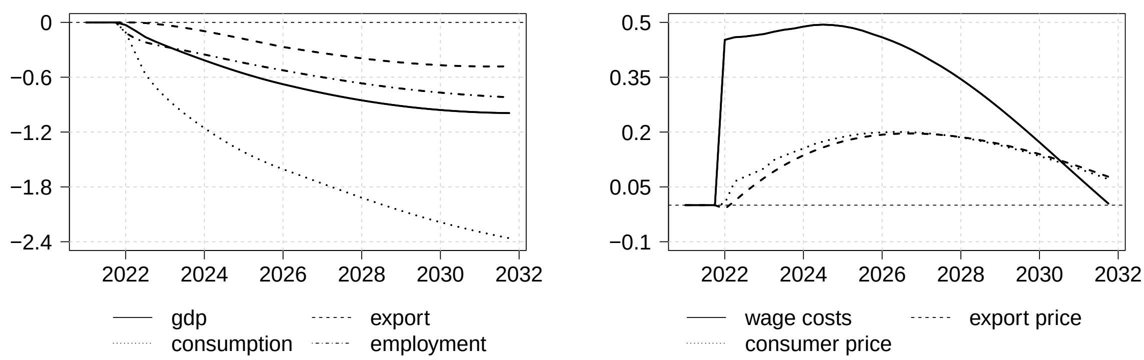
[25] In line with the approach in Verstegen (2021).

Figure 1: Response to permanent increase in world trade by 1% (%-changes relative to baseline)



of the incidence to employers. Over time, the reduction in output is followed by lower employment and a higher unemployment rate, which in turn causes nominal wages to fall again. Export prices follow the wage response: after about four years the export price starts to fall and exports start to recover. After ten years, only 0.6%-points remain from the initial improvement of the government budget of 1% GDP due to the decline in consumption and employment.

Figure 2: Response to permanent increase in personal income taxes by 1% (%-changes relative to baseline)



Most variables adjust to shocks within ten years. In a period of about ten years, the economy approximates the final steady state, with most variables close to their target level. However, not all adjustments have been completed after the first decade. For example, section 4 shows that in response to a labour supply shock, the gradual expansion of consumption as well as the gradual recovery of unemployment continue after the first decade. This rather lengthy adjustment process after some shocks is an unwelcome feature of the model, which we put on the agenda for future work.

The model will converge to the balanced growth path. Stability is an important feature of the model, even more so when used with model-consistent expectations. The long-term responses to shocks tell a lot about the economic properties of the model – and in section 4 we start the discussion of the impulse responses with the steady state changes. At the same time, we would like to stress that the steady state outcomes of the model should not be seen as long-run projections. For that, one would have to develop an endogenous growth model, rather than a business-cycle model.

2.5 What's new and what might come?

Saffier 3.0 replaces Saffier 2.1 after more than 15 years of loyal service in both projections and scenario analysis. This section briefly summarizes the key differences between the new model and its predecessor (see CPB, 2010):

- Whereas the parameterisation of Saffier 2.1 is mainly based on an annual dataset[26], we use recent quarterly data. The dataset starts in 1996, being the first year after a data revision. The advantage of using a dataset on a recent period is that the parameters estimated are likely to better capture the current economic structure. In particular, estimation on recent data suggests a weakening of wage-price dynamics compared to Saffier 2.1.[27]
- As in Saffier 2.1, the current version starts with agents with static expectations. The new model gives the option to develop versions allowing for (forward-looking) model consistent and (backward-looking) VAR-based expectations, as in the FRB/US model.
- The model converges to a steady state (or more precisely, a balanced growth path), which is needed for solving the model with forward-looking expectations.
- The model is more compact and transparent than Saffier 2.1. In particular, we have considerably reduced the number of revenue and expenditure items on the government budget by dropping disaggregation without meaningfully different macroeconomic responses. Furthermore, demand categories are reduced from 15 to 11 (see

[26] The sample differs over the equations but it starts in general in the beginning of the 70's and ends before 2008.

[27] Bobeica et al. (2019) find that the link between labour cost inflation and price inflation remained rather stable in the four biggest euro area countries. However, the link is weaker when inflation is low and when the economy is hit more by supply shocks than by demand shocks.

Table 4.3 in CPB, 2010). We have combined goods and services into a single composite for both exports and imports. Next, we cut back the number of cost factors of demand prices from 7 in Saffier 2.1 to the main 4 (labour, capital, imports and energy). In view of its diminished share, we no longer separate the mineral extraction sector. Finally, we do not apply the less transparent lag structures of Saffier 2.1.

- Saffier 2.1 is solved with software that was developed at the CPB. We switched to the public **R** software. By applying an open source software package in all steps of the process (data collection; construction of the dataset; estimation of the equations; solving the model and generating the output), we improve the transferability for internal users and external experts.

A model is never finished, there is more to come. First, the model is developed to include expectations for the main behavioural equations (see section 2.2). In the current use of the model, we use static expectations meaning that expected growth rates do not respond to changes in economic or policy shocks. In future use, we will study a version with forward-looking behaviour. In any case, we model less than perfect foresight by specifying a high discount rate (5% per quarter) and limiting the forecasting horizon (to 12 quarters). Second, the basic version of the model is designed for the analysis of fiscal policy and does, for example, not include a financial sector. In future applications of the model, extensions like the financial sector, but also a more elaborate housing market might be added. The third element of ongoing research is the re-estimation of key relations in the model, which might also ask for a re-specification of the behavioural equations. Finally, where the current model takes technological progress as given, modelling endogenous growth is high on our agenda.

3 Model description

We describe the main behavioural equations for production, consumption, foreign trade, wages and price setting. Several equations are estimated with a PAC specification, including VAR-expectations about future changes of the target (see the explanation in Appendix A.1).[28] All equations are estimated on the sample 1996q1-2019q4.[29]

3.1 Firms: production, labour demand and investment

We start with a normalised CES production function. We normalise variables with the value in the base period, denoted by $\tilde{x} = x/x_0$.[30] The normalised production function in labour l and capital k is written as:[31]

$$\tilde{y}_t^{ms} = \left[(1-\pi_0)(\tilde{l}_t^{ms}\hat{\Gamma}_t^l)^{-\rho} + \pi_0(\tilde{k}_t^{ms}\hat{\Gamma}_t^k)^{-\rho}\right]^{-1/\rho} \tag{1}$$

where $\hat{\Gamma}^i$ is the technical progress index from factor i, π_0 is the capital share in value added in the base year and $\sigma = 1/(1+\rho)$ is the elasticity of substitution.

We have imposed two restrictions on the production function: we fix the substitution elasticity ($\sigma = 0.5$) and we exclude capital-augmenting technical progress ($\hat{\Gamma}_t^k = 1$). First, we have applied the Klump et al. approach. In this approach, each technical progress index is modelled using a Box-Cox transformation with two free parameters. This specification is restrictive as it only describes monotonous (non-linear) developments. We estimated the system consisting of the production function and the factor demand equations but we got no robust results. We choose to fix the substitution elasticity σ at 0.5.[32] Second, we solved the system for the residual series $\hat{\Gamma}^l$ and $\hat{\Gamma}^k$ conditional on this substitution elasticity. However, the resulting decomposition of TFP in labour and capital augmenting progress resulted in negative trend growth rates in the middle of the sample and quite high growth rates in the last years of capital-augmenting

[28] Since we use static expectations in the current version, we might instead estimate error correction models without forward looking terms. However, estimation results do not differ much between the PAC and ECM approach. We find in general that the order of the PAC equation equals one ($m = 1$), implying that it does not include lagged values of the dependent variable. The labour demand equation is the only exception with $m = 2$.

[29] Memos with detailed estimation results will be available on our website.

[30] The base period in estimations is the quarter at the middle of the sample.

[31] The advantages of using a normalised production function are well discussed in Klump et al. (2007).

[32] Estimation in CPB (2010) results in $\sigma = 0.5$. Chirinko (2008) concludes "the weight of the evidence suggests a value of σ in the range of 0.4–0.6.". Chirinko and Mallick (2017) focus on the long-run value and prefer the estimate of 0.4. In a recent meta study, Gechert et al. (2021) find a mean elasticity of 0.3. The Cobb-Douglas specification (with $\sigma = 1$) is rejected in these papers.

progress. Therefore, we decided to exclude capital-augmenting technical progress by setting $\hat{\Gamma}^k = 1$. The series $\hat{\Gamma}^l$ is now obtained by solving the production function (1). In the target factor demands we use structural productivity Γ^l, calculated by HP-filtering $\hat{\Gamma}^l$.[33]

Labour demand of market sector

The first order condition for labour demand implies restrictions on the coefficient of output, relative factor price and structural technical progress in the target equation (4). The target equation is derived from minimizing total costs, subject to the CES production function. The relative price equals the ratio of the effective wage cost and the total cost price of value added. The latter variable is calculated from the identity:[34]

$$p_t^{va,ms} y_t^{ms} = p_t^{l,ms} l_t^{ms} + p_t^{ku,ms} k_t^{ms} \tag{2}$$

The user cost of capital $p^{ku,ms}$ is defined as:

$$p_t^{ku,ms} = \frac{1}{1-\tau_v} \left(\bar{r}_t + \delta - \pi_t^k - \tau_v r_v \rho_v - \tau_v \beta \delta \right) p_t^k \tag{3}$$

The cost of capital is determined by the average $\bar{r}$ of the nominal return on equity and the interest rate on debt (including risk premia); a fixed depreciation rate δ; the expected inflation π^k of the price of the capital good p^k[35]; tax gains from deducting nominal interest payments on debt and depreciation allowances, where τ_v denotes the statutory tax rate on corporate income. Total interest payments on debt equal $r_v \rho_v p^k k^{ms}$, where r_v denotes the nominal interest rate on debt and ρ_v is the fixed ratio of debt and the value of the capital stock. Depreciation allowances are modelled as a fixed fraction β of total economic depreciation (the value of β is chosen to reproduce observed corporate tax revenues). As a single constant for the whole period results in systematically positive residuals towards the end of the sample (which prove to be without explanatory value in the short run), we allow for one additive structural break in 2014q2.[36]

Dynamic labour demand is explained by the adjustment to the target, one autoregressive term, contemporaneous variables and an anticipation term. It is estimated as an extended PAC equation (of order $m = 2$); the anticipation term is denoted by $\Delta \ln l_t^{z,ms}$. The error term of the target equation is used as the error correction

[33]The TFP-index is given by $(1 - \pi_0)\Gamma^l$.

[34]The target level of the total cost price can be alternatively calculated as as the normalised CES-composite of the effective wage cost and the user cost of capital.

[35]This is currently modelled as an AR-process.

[36]The breakpoint has been determined by running a loop over candidate breakpoints between 2010 and 2017 and selecting the point that results in the best fit of the short-run equation.

term in the dynamic equation. As ad-hoc short-run variables, we extend the equation with current growth rates of output, wage cost, total cost price and technical progress. Table 2 shows that employment is persistent with a low, insignificant pace to the target level. The coefficients of all ad-hoc variables are significant and have the same sign as in the long run, except for technical progress.

$$\ln l_t^{ms,*} = \beta_0 + \ln y_t^{ms} - \sigma \ln \frac{p_t^{l.ms}/\Gamma_t^l}{p_t^{va,ms}} - \ln \Gamma_t^l + \beta_1 dum_{14-19,t} \qquad \text{with } \sigma = 0.5 \tag{4}$$

$$\begin{aligned} \Delta \ln l_t^{ms} =& \alpha_0 \ln(l_{t-1}^{ms}/l_{t-1}^{ms,*}) + \alpha_1 \Delta \ln l_{t-1}^{ms} \\ &+ \gamma_1 \Delta \ln y_t^{ms} + \gamma_2 \Delta \ln p_t^{l,ms} + \gamma_3 \Delta \ln p_t^{va,ms} + \gamma_4 \Delta \ln \Gamma_t^l + \Delta \ln l_t^{z,ms} + \epsilon_t \end{aligned} \tag{5}$$

Table 2: Estimation of dynamic labour demand of market sector (1996q1-2019q4)

$\ln(l^{ms}/l^{ms,*})_{-1}$	-0.047
	(0.035)
$\Delta \ln l_{-1}^{ms}$	0.385^{***}
	(0.083)
$\Delta \ln y^{ms}$	0.309^{***}
	(0.066)
$\Delta \ln p^{l,ms}$	-0.317^{***}
	(0.060)
$\Delta \ln p^{va,ms}$	0.131^{***}
	(0.032)
$\Delta \ln \Gamma^l$	0.316^{**}
	(0.134)
Adj. R^2	0.688
Num. obs.	93

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Notes: the dynamic equation for labour demand is estimated including the forward term of the PAC, see Appendix A.1.

Investment of market sector

The target equation of capital is analogously derived from cost minimization at given production function. It is transformed into a target equation of investment using $i^{ms,*} = (g + \delta)k^{ms,*}$, where g denotes the trend growth rate of output and δ is the depreciation rate. In each period, the relationship between capital and investment is given by the standard accumulation law: $k^{ms}_{t+1} = (1-\delta)k^{ms}_t + i^{ms}_t$. It implies that we assume that it takes one quarter before new capital goods can be effectively used in production. The PAC equation is extended with the current growth rate of output. This variable might be interpreted as capturing decisions by cash flow constrained firms.

$$\ln i^{ms,*}_t = \beta_0 + \ln y^{ms}_t - \sigma \ln \frac{p^{ku,ms}_t}{p^{va,ms}_t} \qquad \text{with } \sigma = 0.5 \tag{6}$$

$$\Delta \ln i^{ms}_t = \alpha_0 \ln(i^{ms}_{t-1}/i^{ms,*}_{t-1}) + \gamma_1 \Delta \ln y^{ms}_t + \Delta \ln i^{z,ms}_t + \epsilon_t \tag{7}$$

The dynamic investment equation involves both a development towards target investment and a strong response to current output growth. The results in Table 3 (with $m = 1$) show a significant error correction coefficient and a strong (accelerator) effect of the current change of output.[37]

Table 3: Estimation dynamic investment of market sector (1996q1-2019q4)

$\ln(i^{ms}/i^{ms,*})_{-1}$	-0.126^{***}
	(0.045)
$\Delta \ln y^{ms}$	1.847^{***}
	(0.407)
Adj. R^2	0.218
Num. obs.	94

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Notes: the dynamic equation for investment is estimated including the forward term of the PAC, see Appendix A.1. Outliers in the investment series are smoothed for estimation.

3.2 Households: consumption and labour supply

The specification of the consumption equation is inspired by the work of Muellbauer and co-authors.[38] Muellbauer starts with a basic aggregate life-cycle/permanent income target consumption function, that is less restrictive than an Euler-type equation:

$$c^*_t = \omega y^p_t + \phi W^h_{t-1} \tag{8}$$

[37] We specify an ECM for the changes in inventories, ensuring that inventories fall when the ratio to GDP exceeds the target level. The GDP identity including the change in inventories holds.

[38] See Hendry and Muellbauer (2018) and Aron et al. (2012).

where c denote real consumption (including imputed rents), y^p real permanent income and W^h real net wealth (measured at the end of the period). Some simplifications and log-approximating give

$$\ln c_t^* = \beta_0 + \ln y_t^{dnp} + \beta_1 \ln \frac{y_t^p}{y_t^{dnp}} + \beta_2 \frac{W_{t-1}^h}{y_t^{dnp}} \tag{9}$$

where real disposable non-property income y^{dnp} is defined as the sum of labour earnings, transfers, pensions, minus income taxes and social premiums paid by households (real disposable property income y^{dp} is defined as after-tax income from wealth). The (ln) ratio of permanent to current income reflects expected income growth and is approximated by:

$$\ln \frac{y_t^p}{y_t^{dnp}} = \frac{\sum_{s=1}^{S} \eta^s E_t \ln y_{t+s}^{dnp}}{\sum_{s=1}^{S} \eta^s} - \ln y_t^{dnp} \tag{10}$$

where η is the discount factor and S is the forecasting horizon. To account for the uncertainty of forecasting income, and in line with FRB/US and ECB-BASE[39], we fix a low discount factor: $\eta = 0.95$. In addition, we restrict the forecasting horizon S to 12 quarters.[40] Which series of future income is used, depends on the considered type of expectations. In the basic version with static expectations, we assume $E_t \ln y_{t+s}^{dnp} = \ln \left[y_t^{dnp} (1+g)^s \right]$, where g denotes the growth rate on the balanced growth path.

We need to account for two developments in the data. First, the ratio c/y^{dnp} initially falls before getting rather stable. This development corresponds to an increasing share of non-property income in total income during the first years. We account for this by extending the long-run equation with the ratio $y^{dnp}/(y^{dnp} + y^{dp})$. Second, we find in several housing-related series a turning point around 2014q1 (relative housing price; housing wealth, loan-to-value ratio). In particular, we observe a strong recovery of the (housing) wealth ratio, while the consumption ratio remained stable during this period. The best option to deal with this break seems to be including a dummy for the period 2014q1-2019q4. We estimate the following long-run specification:

$$\ln c_t^* = \beta_0 + \ln y_t^{dnp} + \beta_1 \ln \frac{y_t^p}{y_t^{dnp}} + \beta_2 \frac{W_{t-1}^h}{y_t^{dnp}} + \beta_3 \frac{y_t^{dnp}}{y_t^{dnp} + y_t^{dp}} + \beta_4 d\_per2_t \tag{11}$$

Table 4 presents the estimation results.

[39]See Brayton et al. (2014) and Angelini et al. (2019).

[40]Increasing the forecasting horizon to 16 quarters does not make much difference, in view of the high discount rate.

- The coefficient of permanent income is $\beta_1 = 0.82$. Muellbauer-type studies report estimates of 0.96 for the US, 0.75 for France and 0.11 for Australia.[41]

- The coefficient of net wealth $\beta_2 = 0.05$ equals the marginal long-run propensity to consume out of net wealth when $c/y^{dnp} = 1$.[42] Muellbauer-type studies find estimates ranging from 0.03 in the UK to 0.08 in Canada.[43]

- The initial rise in the non-property income share has a depressing effect on consumption ($\beta_3 = -0.77$).

Dynamics are modeled within an ECM-framework. Unrestricted estimation of equation (12) gives an implausibly large effect of changes in the relative housing prices (γ_4). Therefore, we decided to fix this coefficient at 0.15 (inspired by Berben et al. 2018). As a result, the error correction coefficient (ρ) dropped to an insignificant, small value. Hence, we imposed $\rho = -0.1$.

$$\begin{aligned}\Delta \ln c_t =& \rho \ln(c_{t-1}/c^*_{t-1}) + \gamma_1 \sum_{j=0}^{2} \gamma_{1j} \Delta \ln y^{dnp}_{t-j} + \gamma_2 \Delta \ln y^{dp}_t + \\ & \gamma_3 d\_per1_t \Delta \ln r^h_t (W^{hd}_{t-1}/y^{dnp}_{t-1}) + \gamma_4 \Delta(p^h_t/p^c_t) + \gamma_5(\ln l^{ms}_t - \ln l^{ms}_{t-4})/4 + \epsilon_t \qquad (12)\end{aligned}$$

- We include the weighted average growth rate of non-property real income. The weights are estimated, under the restriction that the sum of the three weights equals 1. These variables capture consumption responses by credit-constrained (or hand-to-mouth) households. The effect of the average growth of non-property income (γ_1) is significant and small. The current growth rate gets the largest weight (γ_{10}). We only include the current growth of property income (γ_2), since lagged growth rates were insignificant.

- Growth of non-property income has a larger effect on consumption growth than growth of property income. An average increase of non-property income of 1 euro increases real consumption by 0.12 euro in the same quarter, compared to 0.03 euro for an 1 euro increase in property income.[44]

[41] This equation is estimated after predicting future incomes using a separate forecasting equation. Results differ not much when income expectations are based on actual realizations of future values.

[42] $dc_t/dW_t = c_t/y^{dnp}_t \beta_2$.

[43] See also the overview for the 4 large euro area countries in de Bondt et al. (2020).

[44] Based on $\Delta c = 0.129 c/y^{dnp} \Delta y^{dnp}$ and $\Delta c = 0.002 c/y^{dp} \Delta y^{dp}$; evaluated at 2019q4-values and neglecting the error correction adjustment.

Table 4: Estimation consumption equation (1996q1-2019q4)

Long run		*Short run*	
Constant	0.559^{***}	$\ln(c/c^*)_{-1}$	-0.1
	(0.084)		
$\ln y^p/y^{dnp}$	0.816^{***}	$\sum_j \gamma_{1j} \Delta \ln y^{dnp}_{-j}$	0.129^{**}
	(0.170)		(0.054)
$W^h_{-1]}/y^{dnp}$	0.045^{***}	$\Delta \ln y^{dnp}$	0.401^{**}
	(0.006)		(0.160)
$y^{dnp}/(y^{dnp} + y^{dp})$	-0.767^{***}	$\Delta \ln y^{dnp}_{-1}$	0.292^{**}
	(0.073)		(0.141)
Dummy 2014q1-2019q4	-0.020^{***}	$\Delta \ln y^{np}$	0.002^{**}
	(0.005)		(0.001)
		$d\_per1 \Delta \ln r^h (W^{hd}/y^{dnp})_{-1}$	-0.073^{***}
			(0.025)
		$\Delta(p^h/p^c)$	0.15
		$(\ln l^{ms}_t - \ln l^{ms}_{t-4})/4$	0.482^{***}
			(0.109)
		Dummy crisis	-0.017^{***}
			(0.005)
		Dummy 2006q1	-0.010^{***}
			(0.004)
R^2	0.943		0.495
Num. obs.	95		92

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

- An increase in the interest rate on new mortgages r^h (weighted with the ratio of the mortgages to non-property income) has a negative effect on consumption growth before 2014q1 (γ_3). The effect is not significant after 2014q1.
- We include the average change (over the last 4 quarters) in the employment (in hours) of the market sector as confidence indicator (γ_5). We find that an increase of the average employment growth with 1% point increases the growth of consumption with 0.5% in the same quarter.[45]
- We include the crisis-dummy to capture the quarters 2009q1/q2 (γ_6) and the 2006q1-dummy to capture a change in the measurement of the consumption of health care (γ_7).

In the future more research is needed on the interactions between the housing market and macro consumption.[46]

Total labour supply is specified as the sum of exogenous structural labour supply and endogenous cyclical labour supply ($a_t^t = a_t^s + a_t^c$). Cyclical labour supply, due to e.g. discouraged workers, is zero in the long run by definition. Besides a lagged term, cyclical supply depends on the unemployment gap:

$$\Delta\left(\frac{a_t^c}{a_t^t}\right) = \beta_1(u_t - u_t^*) + \beta_2\left(\frac{a_{t-1}^c}{a_{t-1}^t}\right) + \epsilon_t \qquad (13)$$

where the variables are expressed as a fraction of total labour supply (u_t is the unemployment rate). Estimation results are presented in Table 5.

3.3 Foreign trade

3.3.1 Exports

We distinguish three types of exports: export of domestically produced goods and services, re-export and export of energy. We distinguish re-exports from other exports in view of its large share in total exports and its low share of value added compared to exported goods and services that are domestically produced. Therefore, increasing re-exports has a much smaller impact on gdp and a larger impact on imports than increasing

[45] We experimented to include instead the change in the unemployment rate as an indicator of uncertainty. However, the large estimated coefficient (-1.1) resulted in implausibly large changes of consumption growth in model simulations.

[46] Several CPB studies have estimated the relationship between debt and consumption using micro data; e.g. Ji et al. (2019) find that consumption of households with high mortgage debt has decreased much more during the financial crisis than that of other households.

Table 5: Estimation cyclical labour supply (1996q1-2019q4)

$u - u^*$	-0.121^{***}
	(0.036)
a^c_{-1}/a^t_{-1}	-0.168^{***}
	(0.051)
Adj. R^2	0.095
Num. obs.	96

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

domestically produced exports. We treat energy exports separately to account for the strongly fluctuating energy prices. The remaining exports, i.e. of domestically produced non-energy goods and services, make up the largest fraction of total exports.

Domestically produced exports of goods and services

Domestically produced non-energy exports (b^d) are determined by world trade (m^w), output of the market sector (y^{ms}) and the relative price:(p^{bd}/p^w):

$$\ln b_t^{d*} = \beta_0 + \beta_1 \ln m_t^w + (1 - \beta_1) \ln y_t^{ms} + \beta_2 \ln(p_t^{bd}/p_t^w) \tag{14}$$

$$\Delta \ln b_t^d = \rho \ln(b_{t-1}^d/b_{t-1}^{d*}) + \gamma_1 \Delta \ln m_t^w + \gamma_2 \Delta \ln(p_t^{bd}/p_t^w) + \epsilon_t \tag{15}$$

First, target exports depend on the exogenous relevant world trade. An increase in the foreign demand for domestically produced goods and services will have a positive effect on exports. Second, the expansion of exports is subject to capacity restrictions. Capacity is proxied by the current output of the market sector. Effects of a positive demand shock are limited by supply factors as labour supply and structural productivity growth. In addition, supply shocks that increase (decrease) potential output will permanently increase (decrease) the export volume. Exports, world trade and output need to have a common growth rate on the balanced growth path. In our short sample we observe that the ratio of exports to output increases while the ratio of exports to relevant world trade falls (and output falls relative to world trade). Therefore, we impose long-run homogeneity by restricting that the coefficients of y^{ms} and m^w add up to one. Third, the relative price, or the terms of trade, equals the ratio between the export price and the exogenous world market price of goods and services. The modelling of the export price is discussed in section 3.4.2. An increase in the relative price reflects a deterioration of external competitiveness, which depresses exports.

The growth rate of domestically produced exports in (15) depends on the lagged deviation from the target level, the growth trade of world trade and the growth rate of the relative price.

We increase in simulations the price elasticity of exports over time starting at the lower end and finishing close to the upper end of the range of empirically plausible values. After a sharp decline, the ratio of exports to relevant world trade develops more stable in the last years. A breakpoint analysis identifies a break in 2005q3. We decided to deal with this break by restricting the sample to 2006q1-2019q4. Free estimation of the long-run equation results in a price elasticity (-0.16), that we consider too small.[47] Imbs and Mejean (2010) report an overview of trade elasticity estimations of a broad range of countries (but without the Netherlands).[48] The estimated price elasticities of exports of European countries range from -1.5 in Germany to -4 in Spain. In view of short-run inertia, we start simulations with an elasticity from the lower bound (-1.5). In the long run, we consider a high price elasticity of export more plausible and choose a value (-4) from the upper end of the empirical range. In models of differentiated product varieties in international trade, the elasticity increases if the number of varieties per country can adjust. This is more likely in the long than in the short run. Furthermore, a high long-run export elasticity limits the long-run employment and GDP effects of domestic and foreign demand shocks. We increase elasticity values gradually in the period 2020-2070 to avoid large oscillations.

The estimation results are presented in the first column of Table 6. When we fix the long-run price elasticity at .1.5, we find a dominating effect of world trade (0.73) compared to output (0.27).[49] Finally, estimating the ECM gives a significant world trade effect but an insignificant error correction coefficient and price effect.[50]

[47]The target elasticity in the Delfi-model of DNB equals -1.77, estimated on the larger sample 1980q1-2016q4 (Berben et al., 2018).

[48]Imbs and Mejean (2017) document that trade elasticity estimates fall with the level of aggregation. They show that estimation on aggregate data, as we do, results in lower elasticities than estimation on bilateral sectoral trade data, due to a heterogeneity bias.

[49]When freely estimated, the restriction that the coefficients of m^w (1.066 (0.057)) and y^{ms} (-0.112 (0.139)) add up to one is not rejected. The restriction is rejected with the full sample.

[50]We dealt with the endogeneity of the relative price by instrumenting the growth rate of the domestic export price by the growth rate of effective labour costs and the growth rate of the energy price. IV-estimation decreases the short-run price elasticity, without affecting much the value of the other coefficients.

Table 6: Estimation results for exports (1996q1-2019q4)

	goods & services[a]	re-exports[b]	energy
Long run			
constant	4.173***	4.960***	2.117***
	(0.473)	(0.023)	(0.388)
$\ln m^w$	0.727***	1.000	0.704***
	(0.075)		(0.060)
$\ln y^{ms}$	0.273	0.000	0.296
$\ln rp$	−1.500	−0.469***	
		(0.069)	
R^2	0.882	0.997	0.828
Short run			
$\ln(b_{-1}/b^*_{-1})$	−0.071	−0.338***	−0.128***
	(0.052)	(0.085)	(0.039)
$\Delta \ln m^w$	0.648***	1.408***	0.832***
	(0.118)	(0.112)	(0.234)
$\Delta \ln rp$	−0.132	−0.178*	−0.115**
	(0.082)	(0.097)	(0.057)
R^2	0.267	0.583	0.173
Observations	55	95	95

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

[a] Restricted sample 2006q1-2019q4.

[b] Two period dummies and three period-specific time trends are included in long-run equation.

Re-exports

The specification of re-exports is the same as the one of domestically produced exports:

$$\ln b_t^{r*} = \beta_0 + \beta_1 \ln m_t^w + (1 - \beta_1) \ln y_t^{ms} + \beta_2 \ln(p_t^{br}/p_t^w) \tag{16}$$

$$\Delta \ln b_t^r = \rho \ln(b_{t-1}^r/b_{t-1}^{r*}) + \gamma_1 \Delta \ln m_t^w + \gamma_2 \Delta \ln(p_t^{br}/p_t^w) + \epsilon_t \tag{17}$$

When looking at the ratio of the volume of re-exports to relevant world trade, we observe three sub-periods. After a strong increase during the first years, the ratio stabilises in a second sub-period, followed by a continuation of a rising trend during the last years. A breakpoint analysis confirms breaks in 2006q1 and 2013q2. We extend the long-run equation with two period dummies and three period-specific time trends (coefficients are not reported). The freely estimated β_1 exceeds one but we cannot reject the hypothesis that $\beta_1 = 1$. Therefore, we report in Table 6 the restricted estimation. In the short run, we find a large, significant error correction coefficient and a strong response to changes in world trade but an insignificant, inelastic response to price changes.

Exports of energy

Since the export price hardly deviates from the world market price of energy, the energy price is expressed relative to the world price of goods and services to keep the equation homogenous in prices:

$$\ln b_t^{e*} = \beta_0 + \beta_1 \ln m_t^w + (1 - \beta_1) \ln y_t^{ms} + \beta_2 \ln(p_t^{be}/p_t^w) \tag{18}$$

$$\Delta \ln b_t^e = \rho \ln(b_{t-1}^e/b_{t-1}^{e*}) + \gamma_1 \Delta \ln m_t^w + \gamma_2 \Delta \ln(p_t^{be}/p_t^w) + \epsilon_t \tag{19}$$

The relative price is not significant in the long-run equation and is therefore dropped ($\beta_2 = 0$). The price elasticity is small and significant in the short run (see last column of Table 6). The effect of world trade is large both in the long run and short run.

3.3.2 Imports

Imports are divided into the same categories as exports: imports of (non-energy) goods and services, imports used in re-exports and imports of energy.

Imports of goods and services

Imports depend on a measure of effective import demand (mv^d) and the relative import price. Effective import demand is defined as a weighted sum of consumption, investment (of market and non-market sectors), government spending (on goods & services and transfers in kind) and exports of domestically produced goods and services, where the weights are average import intensities of the demand categories:

$$mv_t^d = 0.43c_t + 0.58i_t^{ms} + 0.18(i_t^{pl} + i_t^{kw} + i_t^{wo}) + 0.19(g_t^{sn} + g_t^m) + 0.41b_t^d \quad (20)$$

The relative price is a weighted average of the relative import price of the demand categories:

$$rp_t^{md} = \frac{p_t^{md}}{mv_t^d}\left(\frac{0.43c_t}{p_t^c} + \frac{0.58i_t^{ms}}{p_t^{ims}} + \frac{0.18i_t^{pl}}{p_t^{ipl}} + \frac{0.18i_t^{kw}}{p_t^{ikw}} + \frac{0.18i_t^{wo}}{p_t^{iwo}} + \frac{0.19(g_t^{sn} + g_t^m)}{p_t^g} + \frac{0.41b_t^d}{p_t^{bd}}\right) \quad (21)$$

We impose the homogeneity restriction that the coefficient of mv^d equals one in the target equation.[51] When we perform a breakpoint analysis of the equation:

$$\ln m_t^{d*} = \beta_0 + \ln mv_t^d + \beta_2 \ln rp_t^{md} \quad (22)$$

we find a break in 2010q4. Therefore, we allow that both the constant term and price elasticity in the target equation differ in quarters before and after 2010q4.

The import equations are now specified as:

$$\ln m_t^{d*} = \beta_0 + \ln mv_t^d + (\beta_2 + \beta_3 per2_t)\ln rp_t^{md} + \beta_4 per2_t \quad (23)$$

$$\Delta \ln m_t^d = \rho \ln(m_{t-1}^d / m_{t-1}^{d*}) + \gamma_1 \Delta \ln mv_t^d + \gamma_2 \Delta \ln rp_t^{md} + \epsilon_t \quad (24)$$

Table 7 shows that the price elasticity is significantly larger in the second period (-1.6 versus -0.6) Estimation of the short-run part gives a high adjustment coefficient, an elastic response to effective demand and an insignificant price elasticity.

[51] This restriction is rejected.

Table 7: Estimation results imports goods & services (1996q1-2019q4)

Long run		Short run	
constant	-0.402^{***}	$\ln(m^d_{-1}/m^{d*}_{-1})$	-0.157^{***}
	(0.005)		(0.049)
$\ln rp^{md}$	-0.550^{***}	$\Delta \ln mv$	1.426^{***}
	(0.073)		(0.101)
$\ln rp^{md} per2$	-1.079^{***}	$\Delta \ln rp^{md}$	-0.089
	(0.315)		(0.095)
per2	0.115^{***}		
	(0.007)		
Observations	96	Observations	95
R^2	0.981	R^2	0.639

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

Imports for re-exports

Target imports (excluding energy) are linked to re-exports using the average import intensity: $m^{r*}_t = 0.9b^r_t$. In view of missing quarterly data on imports, we fix the error coefficient ad-hoc at 0.3 and the short-run elasticity of b^r at its long-run value:

$$\Delta \ln m^r_t = -0.3 \ln(m^r_{t-1}/m^{r*}_{t-1}) + 0.9\Delta \ln b^r_t + \epsilon_t \quad (25)$$

Imports of energy

Target energy import is the sum of the energy use in the production of six categories (mainly energy export), using fixed intensities:

$$m^{e*}_t = 0.027c_t + 0.012i^{ms}_t + 0.004(g^{sn}_t + g^m_t) + 0.038b^d_t + 0.725b^e_t \quad (26)$$

The short-run equation is specified as:

$$\Delta \ln m^e_t = \rho \ln(m^e_{t-1}/m^{e*}_{t-1}) + \gamma_1 \Delta \ln b^e_t + \epsilon_t \quad (27)$$

The estimation results in Table 8 show a high adjustment speed and a positive response to the growth in energy exports.

Table 8: Short-run import equation energy (1996Q1-2019Q4)

$\ln(m^e_{-1}/m^{e*}_{-1})$	-0.304^{***}
	(0.066)
$\Delta \ln b^e$	0.366^{***}
	(0.072)
Adj. R^2	0.338
Num. obs.	95

$^{***}p < 0.01, ^{**}p < 0.05, ^{*}p < 0.1$

3.4 Wage and price setting

3.4.1 Wages

We model the nominal labour costs per hour in the market sector differently for employees and self-employed. We find that these costs respond very differently to, in particular, unemployment, productivity growth and consumer price inflation. We model total labour costs, without distinguishing between contract wages and incidental wages.[52] Wages paid in the public sector are linked to wages paid in the market sector. Labour costs of employees and self-employed start from the same target equation but have different dynamic equations.

Target wages

The target labour income share depends linearly on unemployment and policy variables. We have experimented with non-linear versions of the wage equation, including non-linearity at the zero lower bound of the unemployment rate and an interaction term between social security benefits (the replacement rate) and unemployment. The resulting estimates either prove almost linear (like it is in Saffier 2.1) or implausible. We have also experimented with a Phillips-type wage equation, but this did not result in a better explanation. Therefore, we estimate a target equation, where the (ln) wage rate linearly depends on unemployment and policy variables:

$$\ln p_t^{l*,ms} = \beta_0 + \ln h_t^l + \ln p_t^y + \beta_1 u_t + \beta_2 \ln t_t^w + \beta_3 \ln rr_t + \beta_4 D_{09q2} + \beta_5 S_{05q4-11q3} \quad (28)$$

The values of the coefficients are presented in Table 9:

[52] In the epilogue of simulations, we can split between contract and incidental wages.

- We assume that target labour costs grow one-to-one with labour productivity (h^l) and producer prices (p^y). As a consequence, the equation can be alternatively written in the (ln) labour income share in the market sector ($\ln(p^{l,ms}l^{ms})/(p^y y^{ms})$). When freely estimated, we cannot reject the restriction on the producer price coefficient, but the productivity coefficient is significantly smaller than one.

- The coefficient of the unemployment rate (u) is significantly estimated at -1.1. The effect is smaller than in Saffier 2.1, which is supported by recent findings on a decreasing impact of unemployment on wages and on wages falling behind with economic growth.[53]

- The coefficients of the tax wedge (t^w) and the replacement rate (rr) cannot be robustly estimated. [54] Increasing the tax wedge or the replacement rate will increase the real wage, and this effect will be larger the larger the corresponding coefficient. In our sample, the replacement rate falls almost linearly. Free estimation results in an implausible value of the effect of the replacement rate, because it picks up all other possible explanations for the declining labour income share. In times of low unemployment, it is harder to find a significant coefficient for the (relatively low) replacement rate. Estimation of policy effects in the literature exploits the variation over countries. Following the meta-study of Folmer (2009), we fix the effects at 0.25 and 0.2, respectively.[55]

- We control for the credit crisis by including a dummy for the second quarter of 2009. In addition, we observe that the labour income share is temporarily lower in the middle of the sample period, which is not explained by other variables. To account for this fall, we include a dummy for the period between 2005q4 and 2011q3.

We take into account that wages per hour of employees are structurally higher

[53] We estimate the effect of the unemployment rate on the wage level, whereas the effect on the wage inflation is assessed in studies on the Phillips curve. An example of the last approach for the Netherlands is Bonam et al. (2018). They find that the link between wage inflation and the unemployment gap flattened. However, when using an alternative indicator of labour shortage, the wage Phillips curve remained stable. Related studies like Blanchard et al. (2015) find evidence that the effect of unemployment on *price* inflation decreased in most advanced countries until the early 1990s. Hindrayanto et al. (2019) conclude that this Phillips curve slope has not changed significantly since the Global Financial Crisis in the Euro area and the Netherlands. In contrast, Vlekke et al. (2020) report for the Netherlands that the median slope of the curve with headline inflation is stable until it declines around 2015.

[54] The tax wedge is defined as the ratio between the nominal labour cost and the nominal net wage. The replacement rate equals the ratio between the net unemployment benefit and the net wage.

[55] Melguizo and Gonzalez-Paramo (2013) report a meta-analysis for other countries.

than the hourly income of self employed. We specify that the target wage of employees exceeds the uniform target wage in the market sector by 9%, where the ratio is given by the sample average: $p_t^{le*,ms} = 1.09 p_t^{l*,ms}$. Similarly, the target for the self-employed equals: $p_t^{ls*,ms} = 0.68 p_t^{l*,ms}$. The wage of employees will thus converge to a permanently higher level than the hourly income of self-employed (note that this includes capital income of self-employed).

Table 9: Target wage equation (1996q1-2019q4)

constant	-0.569^{***}
	(0.007)
u	-1.075^{***}
	(0.137)
D_{09q2}	0.051^{***}
	(0.016)
$S_{05q4-11q3}$	-0.051^{***}
	(0.004)
$\ln t^w$	0.25
$\ln rr$	0.2
Adj. R^2	0.992
Num. obs.	96

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Dynamic equation wage employees in market sector

The growth rate of wage costs depends on the adjustment to target, inflation, productivity growth and changes in labour tax rates. We find that the growth rate of the nominal labour cost of employees is best explained by a PAC equation of order $m = 1$. In Table 10 we report a significant, moderate error correction coefficient (α_0). Wages are adjusted significantly to current changes in the tax wedge of employers. We could not find a plausible estimate of the effect of changes in the tax wedge of employees. To allow that the incidence of tax rates on employees is shifted already in the short run, we fix the coefficient at the same value as in the long run. The last term of equation (29) denotes the effect of expected growth in target wages, including coefficients that are a non-linear function of a fixed discount factor and α_0.

$$\Delta \ln p_t^{le,ms} = \alpha_0 \ln \frac{p_{t-1}^{le,ms}}{1.09 p_{t-1}^{l*,ms}} + \gamma_1 \Delta \ln p_t^c + \gamma_2 \Delta \ln h_t^l + \gamma_3 \Delta t_t^{ww} + \gamma_4 \Delta t_t^{wl} + \Delta \ln p_t^{le,ms,z} + \epsilon_t \tag{29}$$

Table 10: Dynamic equation wages employees (1996q1-2019q4)

$\ln(p_{-1}^{le,ms}/p_{-1}^{le*,ms})$	-0.109^{***}
	(0.038)
$\Delta \ln p^c$	0.207^{*}
	(0.121)
$\Delta \ln h^l$	0.153^{*}
	(0.086)
$\Delta \ln t^{ww}$	0.611^{**}
	(0.270)
$\Delta \ln t^{wl}$	0.25
Adj. R^2	0.595
Num. obs.	93

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Dynamic equation hourly labour income self-employed in market sector

The growth rate of labour income of self-employed is simply fitted by an error correction term and an auto-regressive term. We did not find strong evidence in favour of effects of expectations and tax rate changes. Deviations from the target level are slowly removed, while the growth rate is strongly correlated with the rate in the previous quarter (see Table 11).

$$\Delta \ln p_t^{ls,ms} = \rho \ln \frac{p_{t-1}^{ls,ms}}{0.68 p_{t-1}^{l*,ms}} + \gamma_1 \Delta \ln p_{t-1}^{ls,ms} \tag{30}$$

3.4.2 Prices of consumption, exports and investment

We apply a uniform modelling approach to the prices of private consumption, exports of domestically produced goods & services, and investment ($j \in$

Table 11: Dynamic equation hourly labour income of self-employed (1996q1-2019q4)

$\ln(p_{-1}^{ls,ms}/p_{-1}^{ls*,ms})$	-0.014
	(0.010)
$\Delta \ln p_{-1}^{ls,ms}$	0.918^{***}
	(0.047)
Adj. R^2	0.808
Num. obs.	94

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

$\{c, b, i\}$).[56] The target price is based on the cost price, extended with a specific productivity effect and a time trend. Estimation results are presented in Table 12.

$$\ln p_t^{j*} = \beta_0 + \sum_{k \in \{m,l,k,e\}} \omega_k^j \ln p_t^k + \beta_h^j \ln h_t + \beta_{tr}^j \mathit{trend} + \ln(1 + \tau_t^j) \tag{31}$$

$$\Delta \ln p_t^j = \alpha_0^j \ln(p_{t-1}^j / p_{t-1}^{j*}) + \sum_{k \in \{m,l,k,e\}} \gamma_k^j \Delta \ln p_t^k + \gamma_{tfp}^j \Delta \ln \mathit{tfp}_t + \Delta \ln(1 + \tau_t^j) + \Delta \ln p_t^{j,z} + \epsilon_t^j \tag{32}$$

- The cost price is a weighted sum of prices of four inputs (imports, labour, capital and energy).[57] Free estimation of the effects of the input prices gave outcomes that are hard to interpret. Therefore, we use fixed cost shares (see upper panel of the Table). Average cost shares, calculated from Input-Output tables, are similar across the demand categories.

- We include aggregate productivity in the input price developments. However, following the Baumol-hypothesis, the productivity in producing consumer products (including labour-intensive services and other non-tradables) grows slower than the productivity in producing export products. As a consequence, the trend in consumer prices exceeds the trend in export prices, as is clearly supported by observations. To account for Baumol-effects, we include the trend labour productivity (h) in the target equations. As we model the Baumol effects as developments relative to an aggregate

[56] Price targets for re-export and energy export are simply set equal to the import price for the same category.

[57] Labour costs are expressed per unit by dividing the wage rate by the index of labour-augmenting technical progress.

trend, we impose in the estimation that the weighted sum of Baumol coefficients equals zero. We indeed find that the consumption price increases significantly more than the export price due to a different productivity growth.

- We calculated a strong increase in the fraction of markup or factorless income (to around 30% in 2019)[58] However, we cannot calculate how this markup income is divided over the different demand categories. Furthermore, including the macro markup as an explanatory variable in the price regressions causes endogeneity and aggregation problems. However, dropping it might result in a missing variable bias. Therefore, we decided to capture the markup trend by a time trend (the trend increase is 0.001 per quarter). We find a significant, positive trend for the export price and insignificant trends for the other prices.[59] Correcting for the markup trend remains an issue for further research.

In the dynamic price equations, we include the growth rate of all input prices, the growth rate of TFP and dummies for the quarters in the crisis year 2009. The last term in equation (32) denotes the sum over the effects of expected changes in target prices, which are non-linear functions of the fixed discount factor and the estimated α_0. The preferred dynamic PAC equations in Table 13 have order $m = 1$. Free estimation yielded negative effects of some input prices on output prices. Since this does not make sense economically, we restrict the respective short-run price coefficients to be zero. As these coefficients were only slightly and insignificantly negative, the effect of the restriction on the other parameters is small.[60]

- We selected a consumption price equation with a sufficiently strong wage-price spiral. The contemporaneous wage effect is not significant but the lagged wage growth has a significant effect of 0.14. The growth rate depends significantly on the current growth rate of the energy price. Extending the regression with lagged growth rates of the other input prices does not improve the results. The coefficient of the error correction term is small. To be precise, the PAC equation is estimated for the price of consumption goods and services, excluding housing rents. The growth rate of

[58] This is the income that remains after subtracting from gross value added total labour costs and the ex ante compensation of capital (the latter equals $p^{k,ms}k^{ms}$ in the market sector). A decline in the labour income share and a rise in the share of factorless income are observed in many countries. Karabarbounis and Neiman (2018) provide three explanations: increasing economic profits (or higher markups); mismeasurement of capital and the change in the rental rate of capital. They are sceptical about the first two causes and consider the last cause the most promising one.

[59] Notice that this is in addition to the general inflation in cost prices.

[60] We have included the output gap in the dynamic price equations but its coefficient was never significant.

the full consumption price is a weighted average of the growth rate of housing rents (with weight 0.2) and the growth rate of the price of other consumption (0.8).

- For the export price we find a significant, moderate adjustment speed. As expected, the change in the export price is strongly driven by the change in the import price. The productivity effect is, as the wage effect, insignificant. Adding lagged growth rates of input prices hardly affects the estimates.
- The adjustment speed is the highest for the investment price, implying that most of the previous gap to the target price is closed within one quarter. None of the ad-hoc terms is significantly estimated. The finding that the error correction term is the only significant determinant is robust to other specifications.

Table 12: Estimation of target prices of consumption, exports and investment (1997q1-2019q4)

	p^c	p^b	p^i
ω_m	0.432	0.405	0.493
ω_l	0.380	0.343	0.398
ω_k	0.158	0.194	0.097
ω_e	0.030	0.058	0.012
β_0	-0.0873^{***}	-0.746^{***}	-1.147^{***}
	(0.011)	(0.012)	(0.018)
β_h	0.392^{***}	-0.334^{***}	-0.221^a
	(0.046)	(0.048)	
β_{tr}	-0.195	0.847^{***}	0.355
	(0.147)	(0.159)	(0.228)
Adj. R^2	0.969	0.912	0.883
Num. obs.	96	96	96

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

^{a}: calculated from the restriction that the weighted sum of β_h's = 0.

Table 13: Estimation of dynamic prices of consumption, exports and investment (1997q1-2019q4)

	p^c	p^b	p^i
ϵ_{t-1}	-0.070^{*}	-0.124^{**}	-0.693^{***}
	(0.035)	(0.052)	(0.106)
constant	0.001	-0.000	-0.001
	(0.001)	(0.001)	(0.003)
$\Delta \ln p^l$	0.032		0.265
	(0.061)		(0.258)
$\Delta \ln p^l_{t-1}$	0.137^{**}		
	(0.060)		
$\Delta \ln p^k$	0.027		0.020
	(0.019)		(0.073)
$\Delta \ln p^m$		0.603^{***}	0.133
		(0.058)	(0.133)
$\Delta \ln p^e$	0.022^{***}	0.018	0.005
	(0.007)	(0.011)	(0.028)
$\Delta \ln tfp$	-0.107	-0.117	-0.196
	(0.078)	(0.125)	(0.269)
d_2009q1	-0.008	-0.031^{**}	
	(0.007)	(0.012)	
d_2009q2	-0.018^{**}	-0.003	
	(0.005)	(0.010)	
d_2009q3	0.000	0.017^{*}	
	(0.006)	(0.010)	
d_2009q4	-0.001	-0.007	
	(0.006)	(0.009)	
Adj. R^2	0.490	0.667	0.378
Num. obs.	94	94	94

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

3.5 Long-run properties

In the model actual output converges to potential output; i.e. the output gap converges to zero. Potential output has exogenous and endogenous determinants. The exogenous determinants are structural labour supply and structural total factor productivity (TFP, the productivity with which labour and capital are used). The endogenous ones are the unemployment rate and the capital/labour ratio. As a consequence, the long-run growth of the economy (at real terms) is determined by the trend growth in labour supply and in TFP. Growth in nominal terms is further determined exogenously by the growth in foreign prices.

From the target wage equation (28) follows a linear relationship between the (ln) labour income share (of the market sector) and the unemployment rate, for given exogenous policy parameters. Our model includes a CES production function (with a substitution elasticity between labour and capital less than one). Furthermore, we specify a large but finite price elasticity of export and import demand to allow for (small) terms of trade effects.[61] As a result, the long-run labour income share and unemployment rate are not fixed in the model. As a consequence, permanent demand shocks affect the long-run output through terms of trade effects.

[61] In contrast, in a stylised small open economy setting (with perfect substitutability between domestic and foreign goods), the long-run labour income share is fixed by exogenous foreign prices. The labour income share is also fixed with a Cobb-Douglas production function.

4 Impulse responses

The simulation properties of the model are presented as the economic and budgetary responses to economic and policy changes. We discuss impulse responses to a selected set of four economic shocks and four policy shocks. The permanent shocks are given in 2022. In all the variants the government budget is closed by changing the debt. Outcomes are expressed in deviation from the base path. The value in 2200 is given by a dot in each figure. We end this section with a description of the convergence properties of the model.

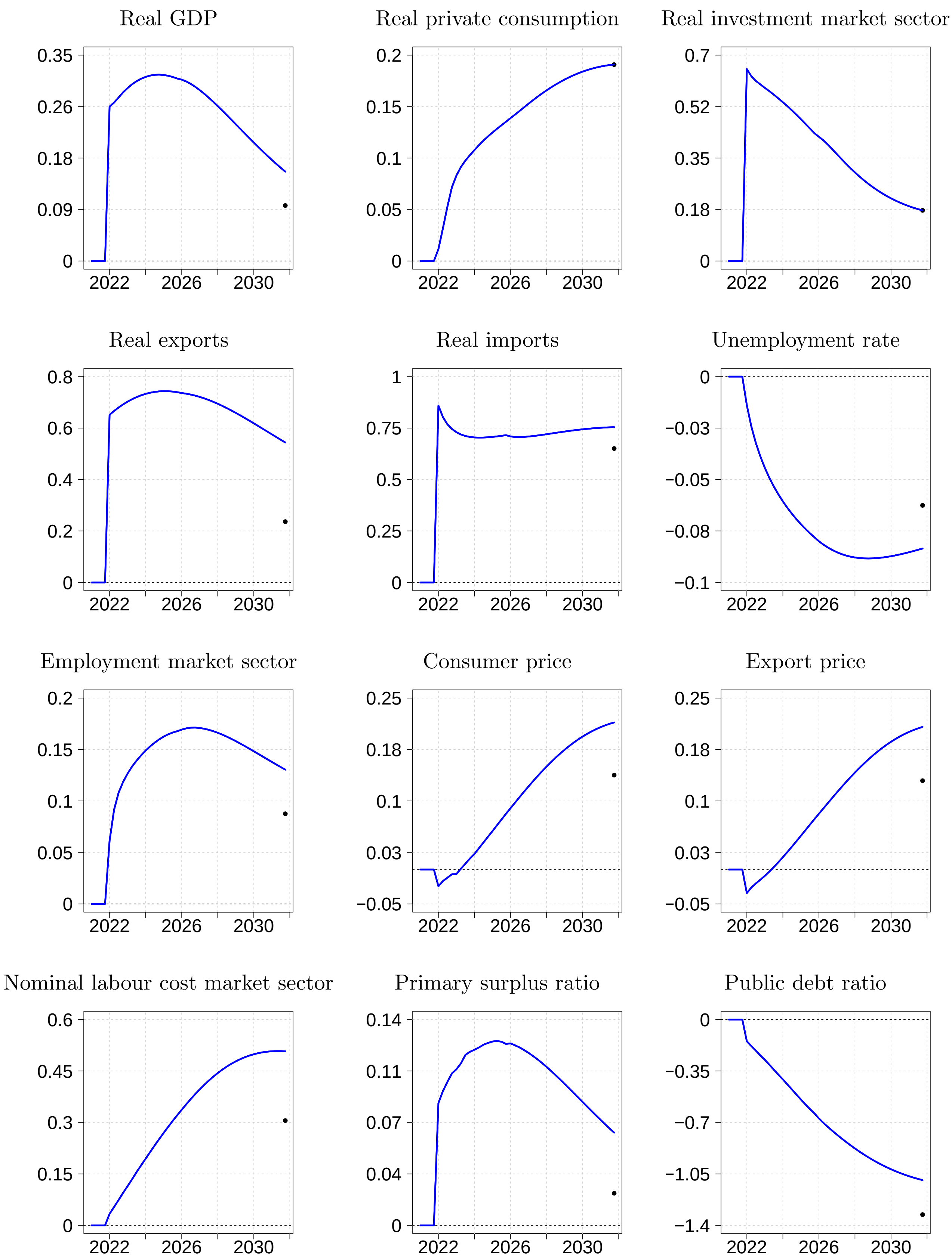
4.1 World trade

We consider a permanent increase in world trade (1%), exogenous to the Dutch economy. The target export (i.e. the equilibrium value in a frictionless economy) is determined by a convex combination of world trade and output of the market sector (as a measure of capacity restrictions), where the former variable has the largest weight. Therefore, the shock in foreign demand results in higher exports at a higher price in the long run (see the dots).

In the short run, the higher foreign demand increases both production and output prices. Induced by an increase in exports, output and labour demand of the market sector expand, which reduces the unemployment rate. This increases nominal labour costs and initiates a wage-price spiral.[62] The increased real labour income, which also results from higher labour productivity, allows for higher private consumption. The higher export prices (with a fixed import price) deteriorate competitiveness of the firms which in the end reduces the expansion of exports and GDP. The stimulus of the economy improves the government budget and reduces public debt.

[62] Consumption and export prices respond similarly because input shares are not that different, after controlling for the Baumol productivity effect.

Figure 3: Shock in world trade



Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

4.2 Labour supply

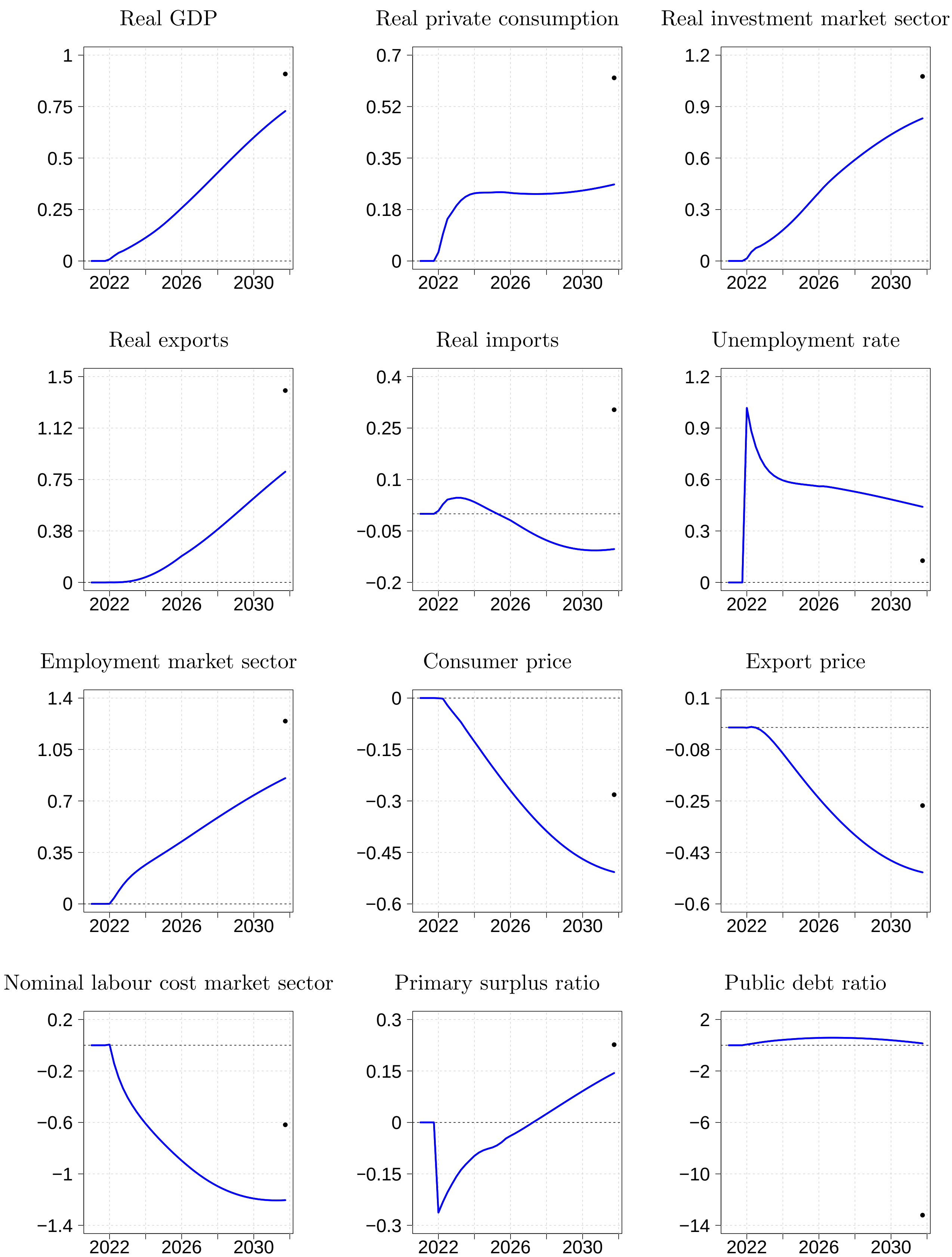
We simulate a permanent increase of labour supply (1%). An expansion of the (non-reproducible) input increases potential output and decreases wage costs. As a consequence, the export price also falls and GDP will expand by less than 1% in the long run.

The higher labour supply is only gradually absorbed since the employment and capital stock of the market sector slowly expand due to adjustment costs.[63] The resulting immediate increase in unemployment depresses labour costs and output prices. The fall in the export price leads to a strong increase in exports. The rise in disposable income increases private consumption. Real disposable income improves as the effect of reduced nominal wages is dominated by the effect of higher employment, lower consumer prices and higher unemployment benefits. After a small deterioration following an increase in unemployment benefits[64], the primary surplus benefits from the larger size of the economy.

[63] Broersma et al. (2000) show impulse responses to a shock in labour supply using a small VAR model estimated for the Netherlands. They conclude that the unemployment rate returns to its starting value in around seven years.

[64] This holds under the assumption that the new inflow of workers is immediately entitled to unemployment benefits.

Figure 4: Shock in labour supply



Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

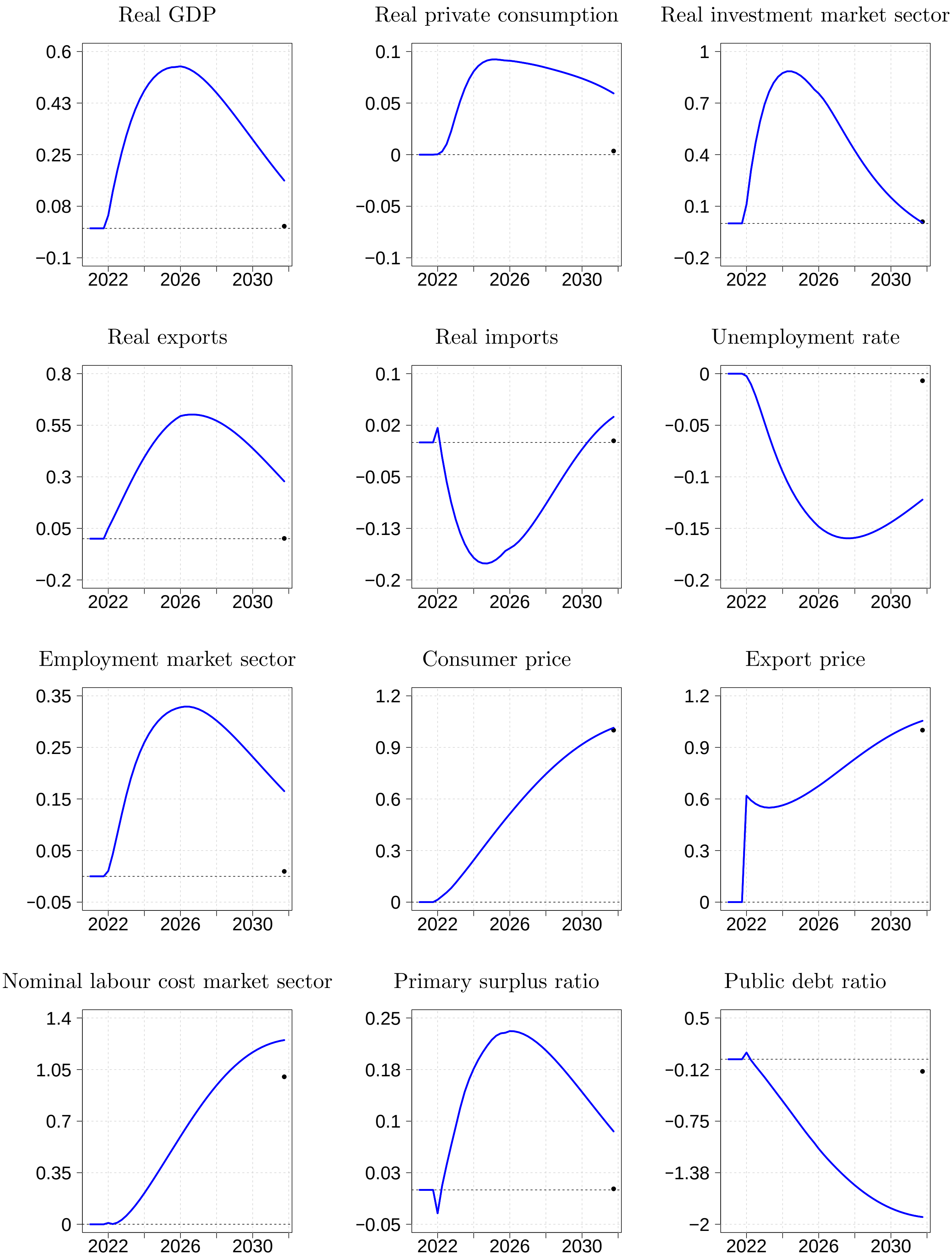
4.3 International price

A permanent increase of world market prices (of 1%) has two opposing effects on the economy.[65] First, the price of domestic output is initially lower than world market prices, which stimulates the demand for the domestic good. Second, a higher price of imported inputs increases the costs of producing the domestic good. International prices fix all long-run prices as domestic inflation is equalised to the foreign inflation. Therefore, an uniform increase in international prices has homogeneous effects in the long run, meaning that all volumes will return to their initial levels, while all nominal variables will be 1% higher.

A higher import price temporarily stimulates the economy. During the first quarters, the first channel through a lower relative output price dominates, which improves exports, consumption and GDP. The temporary expansion of output requires a higher labour demand (or lower unemployment) and investment demand. After some quarters, the second channel of higher input prices (including wages) kicks in and export and GDP start to converge back to the initial base path. The temporary expansion of the economy leads to a small improvement of the primary surplus of the government.

[65] The international price that is considered as the competing price differs between imports and exports.

Figure 5: Shock in import price



Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

4.4 Cost of capital

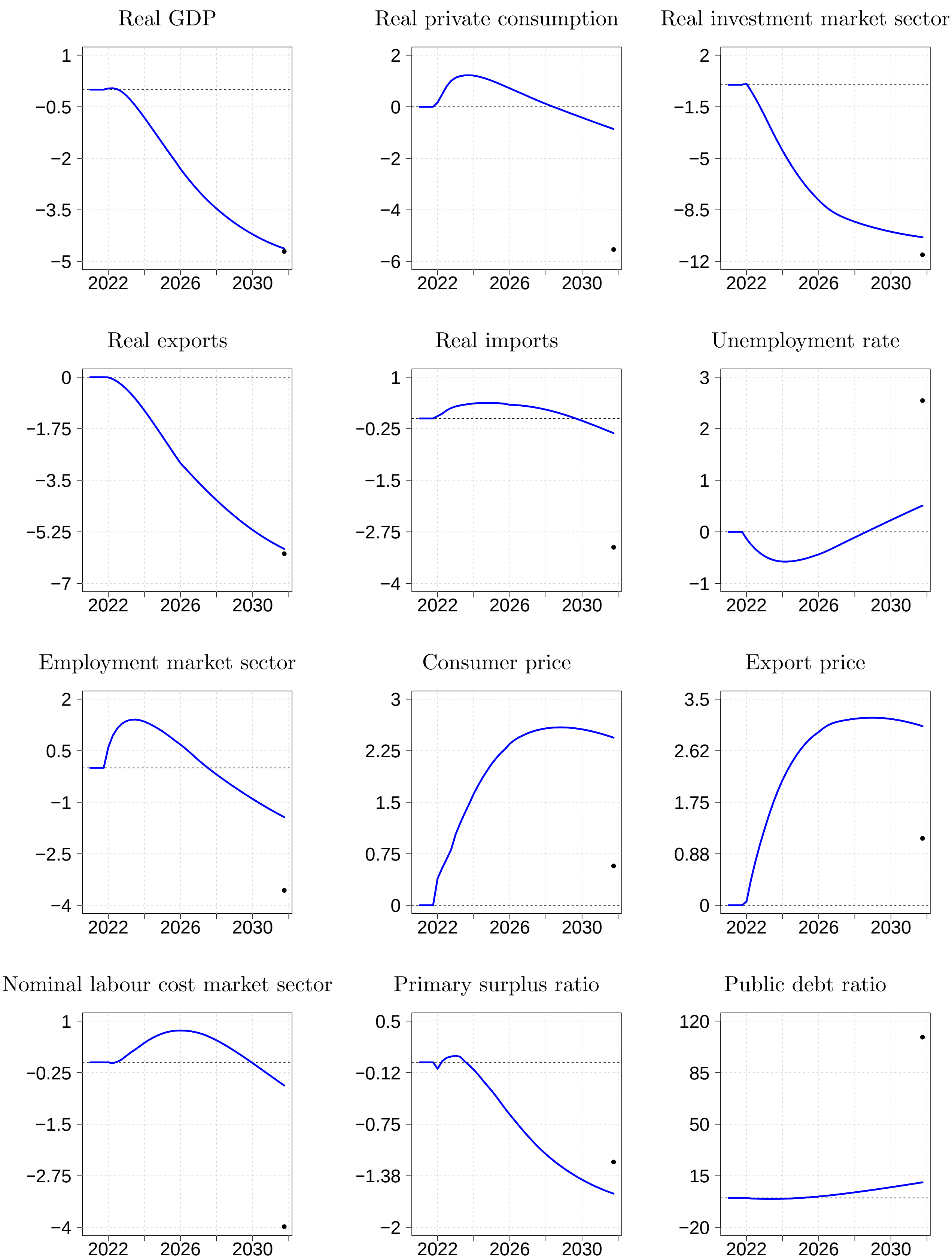
We increase the interest rates permanently by 1%-point. This increase should not be interpreted as being triggered by an increase in the policy rate in the monetary union. We do not change foreign interest rates and hence do not adjust foreign prices. In addition, we abstract from changes in the valuation of financial assets. Therefore, the higher interest rates mainly affect the economy by increasing the capital cost for firms, the mortgage rate for households and the borrowing cost for the government. This variant is therefore better interpreted as a capital cost variant than a interest rate variant.

The higher cost of capital increases the cost price of firms and depresses the investment demand. During the first quarters the substitution towards relatively cheaper labour temporarily increases employment and nominal labour costs. The initial increase in wage costs contributes to the increase of output prices. The effects on (un)employment and wages soon get dominated by the depressing effects on real activity. When wages start falling, the increase in output prices is weakening. The fall in real disposable income leads to lower consumption by households.[66] The higher mortgage rate depresses housing investment. House prices increase with consumer prices, reflecting higher cost prices. The loss in international competitiveness (with constant foreign prices), combined with a reduced capacity of the market sector, causes a fall in exports. In total, higher capital costs depress GDP. The government budget balance worsens due to higher interest payments, lower tax revenues and eventual higher unemployment benefits.[67]

[66] Permanent income is mainly reduced by lower real labour income. As we apply a high discount rate, extra discounting only has a minor effect on the change in permanent income.

[67] Berben et al. (2018) report an equivalent scenario. They consider additional channels of interest rate changes by modelling the financial sector and housing market.

Figure 6: Shock in capital costs



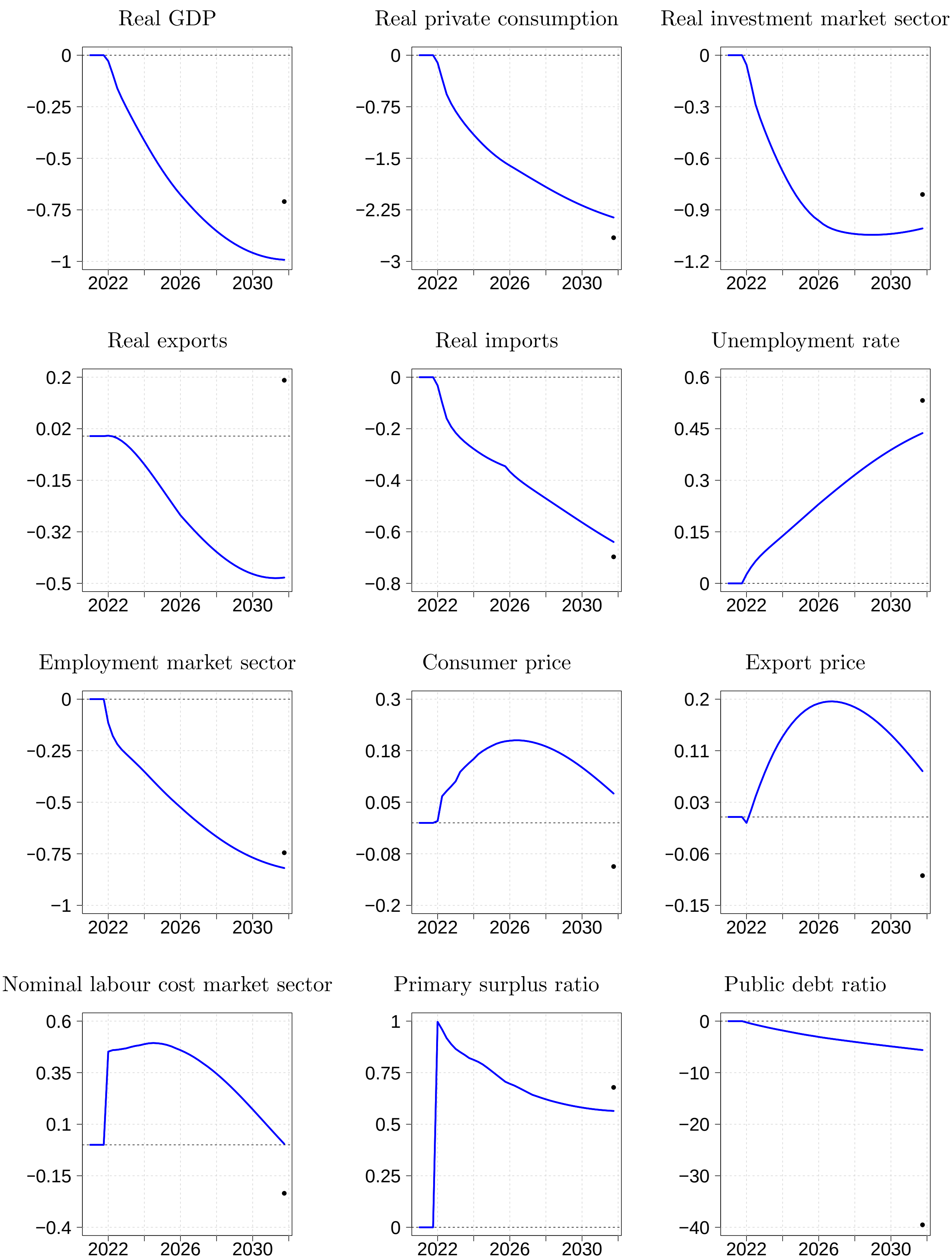
Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

4.5 Personal income taxation

The rate of the personal income tax is permanently increased, such that the ex ante revenues are raised by 1% of GDP. A higher income tax affects the economy through two main channels. First, the fall in after-tax income reduces private consumption. Second, employees are initially able to shift part of the incidence of the higher taxes to employers, but the increase in unemployment eventually results in lower wages. The increase in the distortionary tax raises the unemployment rate structurally and depresses long-run GDP.

The drop in after-tax income immediately decreases private consumption, which dominates the short-run effects on GDP and imports. During the first years, the higher tax wedge is shifted to higher gross wages. After the depressing effects on output start to dominate, wages converge to a permanent lower level. The pattern of labour costs is reflected in output prices. On the one hand, the resulting fall in real incomes enforces the reduction of consumption. On the other hand, the lower relative export price leads to a higher export, which limits the loss in GDP. After an increase on impact, the primary surplus improves less due to the shrinking of tax bases and the increase of unemployment benefits.

Figure 7: Shock in personal income taxation



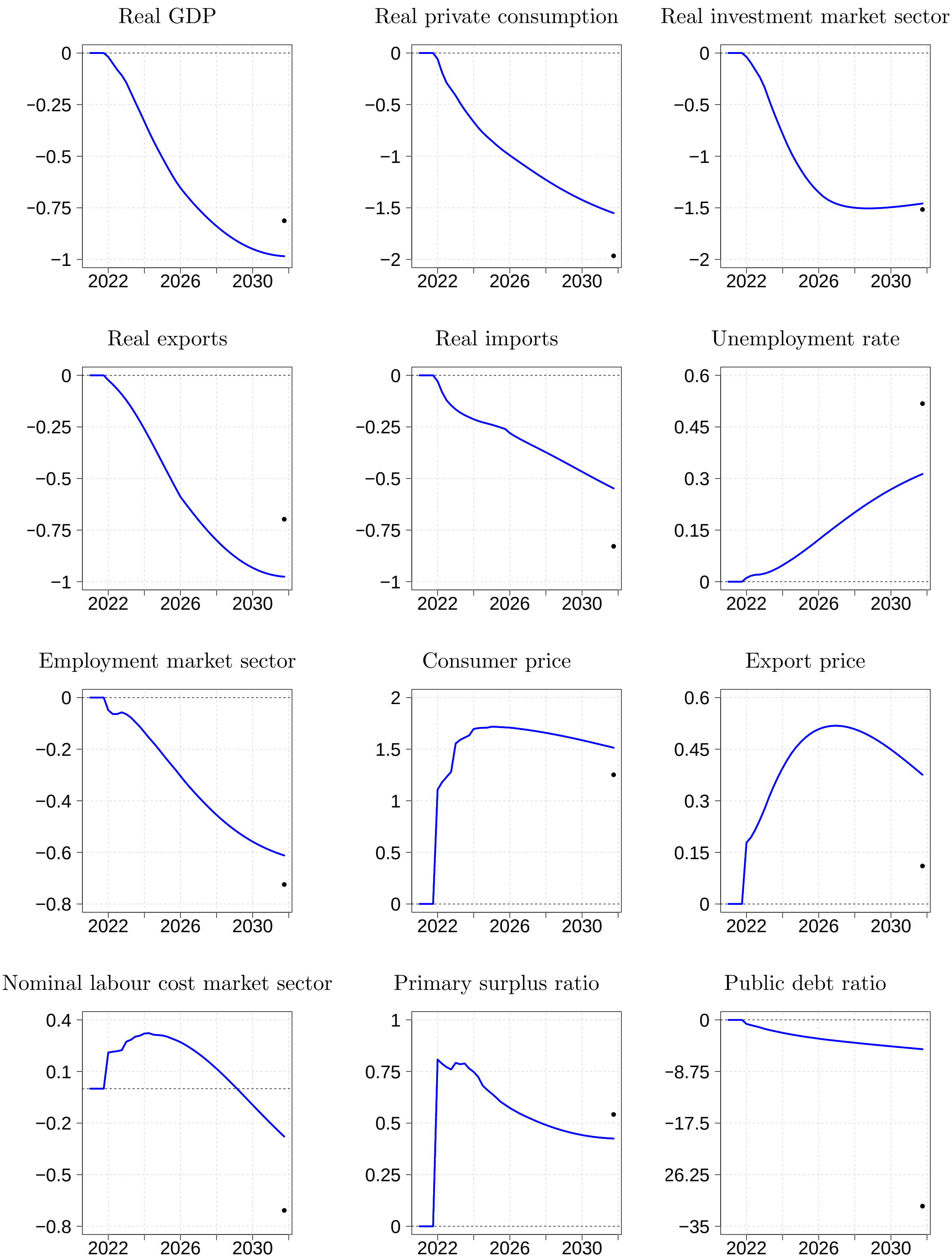
Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

4.6 Indirect taxation

We simulate a permanent increase of the indirect tax rate, generating extra ex ante revenues of 1% GDP. Indirect taxes (VAT and excise taxes) are mainly imposed on private consumption (50%), less on investment, government consumption and exports. The higher tax-inclusive prices reduce the demand for goods. As the fall in domestic demand is only partially compensated by a higher export (since the ultimate increase in the consumer price is larger than the drop in the export price), a permanent GDP loss results.

The pattern of the transition paths is similar to the one following the shock in direct taxation. Private consumption falls less than in the previous scenario since higher taxes are only partly imposed on households. The incidence shift to gross wages is short-lived, and the effect on labour costs gets negative following the fall in labour demand. The consumer price is permanently increased as the higher tax outweighs its decreased cost price. In contrast, the export price eventually drops below the base path level, which explains the eventual recovery of foreign demand. The primary surplus initially improves less than the ex ante shock in revenues (and less than in the direct tax scenario), due to a higher price of government consumption, reduction of tax bases and the increase of unemployment benefits. The surplus again follows the drop in economic activity.

Figure 8: Shock in indirect taxation



Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

4.7 Government consumption

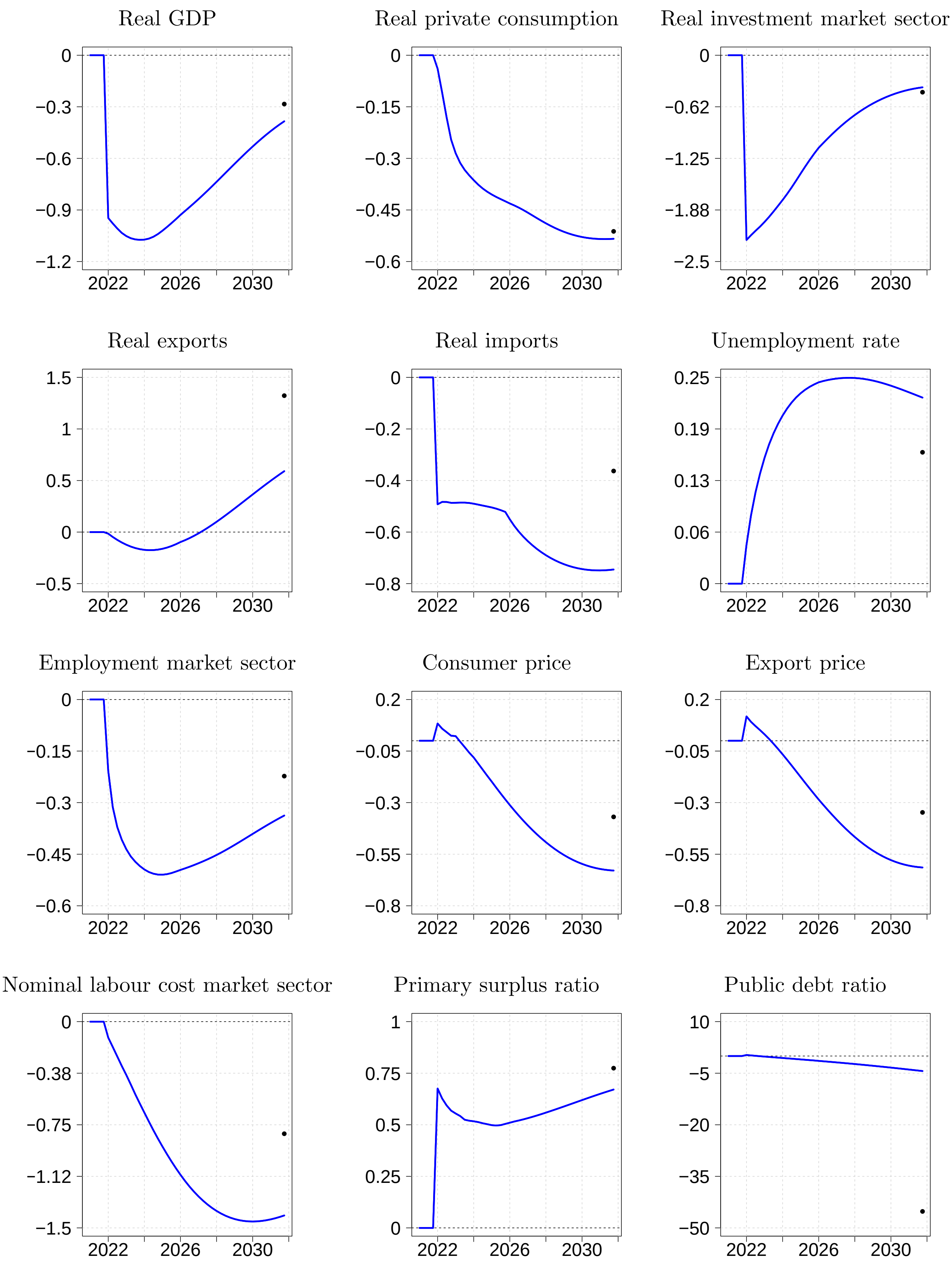
A permanent reduction of government consumption of goods and services (1% GDP), in combination with lower public debt, leads to a permanent GDP reduction. A *negative* shock in government spending on mainly domestic products depresses output of the market sector and increases unemployment. The resulting fall in labour costs improves the competitive position but the increase in exports is not sufficient to compensate for the drop in government consumption.[68] Note that a balanced budget reduction of government consumption, where for example labour income taxes are being reduced as well, would result in a negligible long-run effect on GDP.

In the short run, the fall in government consumption causes a reduction of GDP and employment. With the exception of exports, all demand components decline.[69] The fall in output of the market sector decreases the demand for labour and investment and increases unemployment. The lower wages start a deflation of output prices. The lower real disposable income causes a drop in private consumption. The increase in exports, following the fall in the export price, allows for a partial recovery of GDP. The initial savings on government spending improves the primary surplus. The surplus continues improving following the partial recovery of GDP.

[68] Another, minor explanation of the permanent effects is the shift to a less import intensive composition of GDP and a change in the relative price structure.

[69] During the first years exports fall because the effect of lower domestic output on target exports dominates the effect of lower export prices.

Figure 9: Shock in government consumption



Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

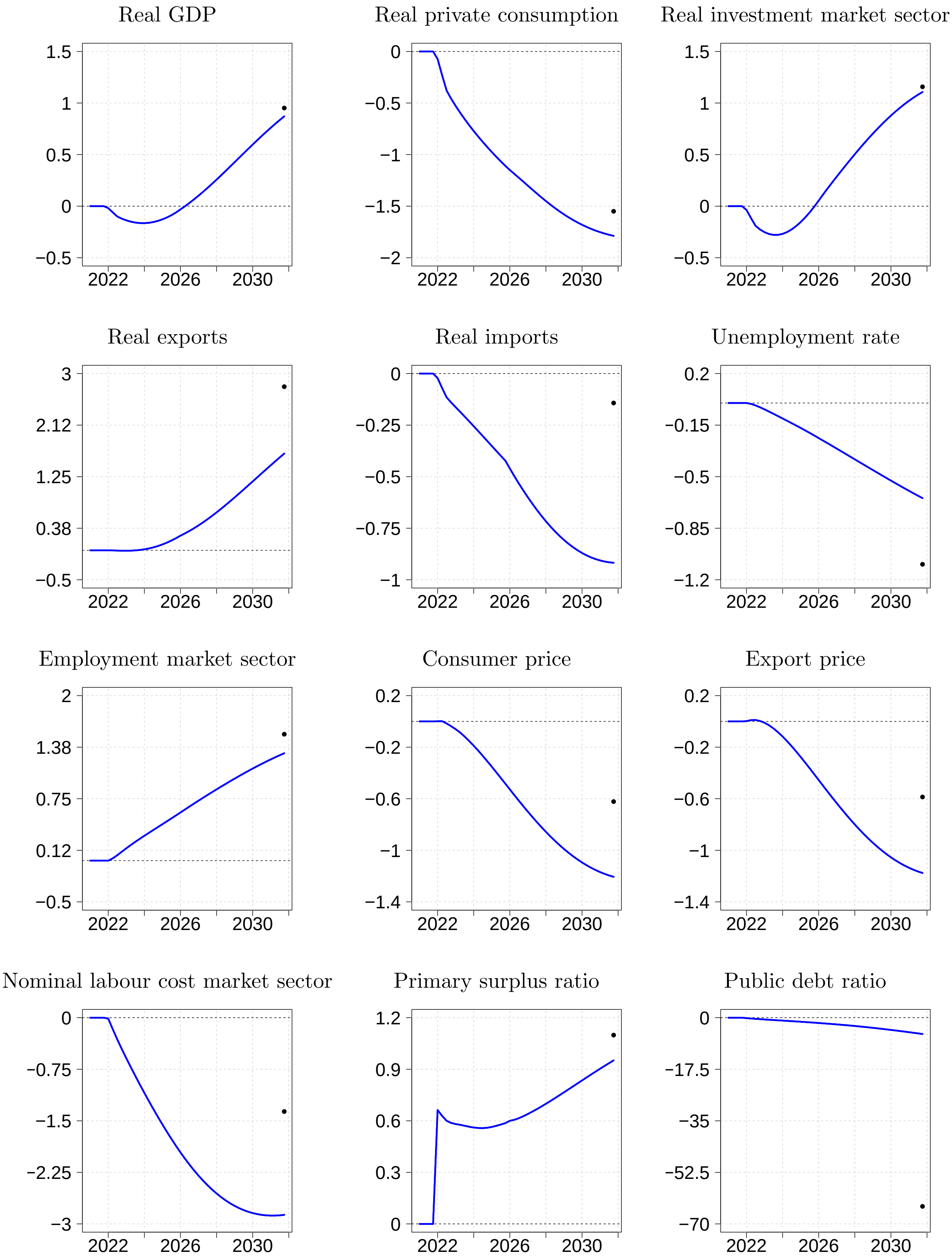
4.8 Social transfers

We consider a permanent reduction of the gross social transfers (incl. unemployment benefits) to households; giving ex ante public savings (with constant premiums) equal to 1% GDP. Results are explained by two main channels. First, the fall in transfer and labour incomes lowers private consumption and GDP (and reduces exports through the capacity effect). Second, unemployment benefits are reduced as a fraction of the average wage (i.e. the replacement rate is decreased). A worse fall-back position of employees in wage negotiations results in lower labour costs and more competitive firms.[70] The channel through lower labour costs dominates in the end, resulting in higher long-run exports and GDP.

During the first years the depressing effects of the first – disposable income – channel dominates. The reduction of transfer income immediately decreases private consumption (less than gross transfers since they have to pay less taxes on lower incomes). The pressure on wages enforces the drop in consumption spending. At the same time, the effect of the lower replacement rate on the target wage kicks in. This contributes to the reduction of labour costs and output prices and the expansion of exports and GDP. The combination of a lower structural unemployment rate and worsening of the terms of trade explains the GDP gain in the long run. The primary surplus rate improves less than 1% on impact, since transfers after taxes decrease less than gross transfers. Following the expansion of the economy, the budget balance improves.

[70] We do not account for permanent effects on labour supply.

Figure 10: Shock in social transfers



Notes: Relative changes in %. Absolute differences in %-points are given for the unemployment rate, the ratio primary surplus/GDP and the ratio government debt/GDP.

4.9 Long-run convergence

In this subsection we illustrate that the model convergences to a balanced growth path (BGP), following the approach used for the ECB-model and the Banque of France-model.[71] The aim is not to provide an appropriate projection of a basepath but to show how fast the model converges to a well-defined balanced growth path.

Slow convergence is reported for this type of models in the literature. The output and inflation gaps in the Banque of France-model converge to zero in around 40 years. Convergence in the ECB-model seems to take more than 100 years for some variables.[72] This result is explained by two main features of these models (Lemoine et al., 2019). First, with constant interest rates and without a monetary policy rule, closing the gaps runs through price adjustments that affect dynamics only slowly. Second, when the last observed values of the stock variables differ much from their long-run levels, convergence requires more years.

In our exercise, we distinguish between the medium run (2020-2025) and the post-2025 period. In the medium run, the model is fit to a reduced set of "quasi data" generated by specialised forecast tools and expert opinion. These data cover crucial macroeconomic aggregates and core income and expenditure data of the public budget. The rest of the model data adjusts endogenously in this period.[73] After 2025, the model converges to a BGP shaped by the following assumptions:

- Interest rates grow linearly with one percentage point in a transition period (50 years) and remain constant thereafter.
- Trend growth rates start at their 2025 value and approach their long-term target linearly during the transition period. These long-term targets are 0.2% for labour supply, 0.8% for inflation and 1.0% for labour productivity (annual).
- The target value of the following variables in the public sector is set equal to the fitted value in the last quarter of the medium run: share of public sectors in GDP, ratio public production to public expenditure, and the labour intensity of public production. This reflects the assumption that the development of the public sector

[71] In this exercise, Angelini et al. (2019, section 4.1) and Lemoine et al. (2019, section 5.1) set all residuals to zero and the growth rate of each exogenous variable at its BGP rate after the last observation.

[72] The Banque of France uses a model version with expectations based on projections from a VAR-model. The ECB model combines model-consistent expectations and VAR-based expectations. We expect that convergence in these models is faster than in a model with static expectations.

[73] Fitting the key variables in the medium run is still work in progress. We clearly need to correct the output gap in 2025 of around 3%.

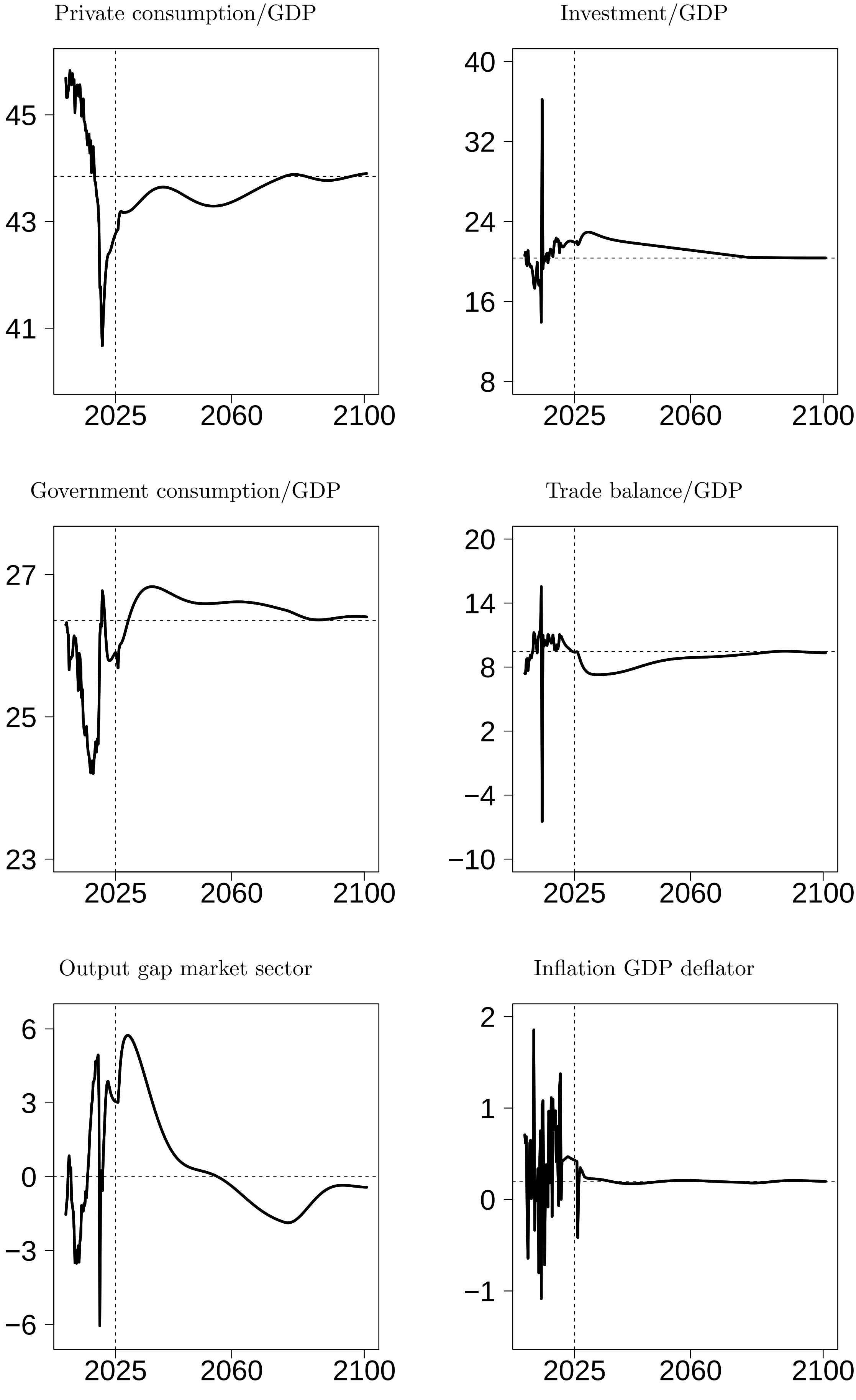
follows policy decisions that should not be overridden by model equations as long as model-external information is available. After 2025, the public sector follows the target equations of the model (mostly constant shares of GDP).

- All other exogenous variables (most prominently tax rates) are held constant.
- All other gaps are closed according to the ECM parameters of the model.

Main variables converge slowly to its long-run values, in particular the output gap. The first two rows of Figure 11 show the transition path of the shares of the demand components in GDP from the last ‘observation’ (2025q4) to 2100. The shares of consumption, government consumption and investment fall from an early maximum to the lower steady state values in 2100 (the first two with small oscillations). This pattern is mirrored by the improvement of the trade surplus ratio. The last row presents the output gap and price inflation.[74] The output gap of the market sector is large during the first years, followed by a sharp drop. The negative output gap is closed rather slowly. The main factor that explains the negative output gap is the continuous fall of the desired capital intensity, which arises from the gradual increase of the interest rate. Firms want to produce the output given by demand with more labour and less capital than the actual stocks. Since upward adjustment of labour input is faster than downward adjustment of the capital stock, firms produce with more inputs than necessary for the given output. This is by definition a negative output gap and might be interpreted as excess capacity. The inflation of the GDP price converges to its long-run value of 0.2%.

[74] Potential output is calculated with structural unemployment, structural productivity and the actual capital stock

Figure 11: Convergence properties of the model



Notes: vertical line: last fitted value in 2025q4; horizontal line: steady state value.

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Appendix

A.1 Introduction to the PAC approach

The Polynomial Adjustment Cost (PAC) approach is developed by Tinsley (2002) and is applied by the FRB (2014) to model dynamic macroeconomic equations. We apply the PAC approach to the equations of investment, employment, prices and wages. We first explain in general the derivation and interpretation of PAC equations, then we discuss how these equations are estimated.

Explanation

This approach assumes that the economic agents minimise an adjustment cost function of the following general form:

$$Cost_t = \sum_{i=0}^{\infty} \beta^i \left[\left(y_{t+i} - y^*_{t+i} \right)^2 + \sum_{k=1}^{m} b_k \left(\Delta^k y_{t+i} \right)^2 \right] \tag{33}$$

where

- y_t is the variable (in logs) under study
- y^*_t is its target (or frictionless) level
- β is a discount factor (fixed at 0.943),
- m is the degree of the cost polynomial
- b_k are the m parameters of relative adjustment costs

The first squared term is the cost of diverging from the target level y^*. The other terms are (relative) costs of adjustment of degree k (changes, changes in changes, etc.). From the first-order condition of minimising (33), the following "decision rule" can be derived:

$$\Delta y_t = -a_0 \left(y_{t-i} - y^*_{t-i} \right) + \sum_{j=1}^{m-1} a_j \Delta y_{t-j} + \sum_{i=0}^{\infty} f_i \Delta y^*_{t+i} \tag{34}$$

i.e. the current change of y is a function of three types of terms:

- a conventional error correction term in the lagged deviation from the target
- $m - 1$ autoregressive terms in the lagged changes
- an infinite sum of future changes in the target

The coefficients a_i are nonlinear functions of the cost parameters b_k and the discount rate β. In turn, the forward weights f_i can be expressed as functions of the a_i parameters and the discount rate. For example, in the simple case $m = 1$ it holds that $f_i = a_0 \left[(1 - a_0)\, \beta\right]^i$.

To improve the fit, it is common to add auxiliary variables w to the PAC equation:

$$\Delta y_t = -a_0 \left(y_{t-i} - y^*_{t-i}\right) + \sum_{j=1}^{m-1} a_j \Delta y_{t-j} + \sum_{i=0}^{\infty} f_i \Delta y^*_{t+i} + \gamma \Delta w_t \tag{35}$$

Their interpretation is difficult in an adjustment cost context. A common loose interpretation is that there are two groups of agents: maximising agents whose behaviour is described by the original PAC terms, and rule-following agents who correlate their behaviour to other variables.

Estimation

Estimating PAC equations consists of three main steps:

1. In the first step, the target level y^* is determined, as the fitted value of a cointegrating relationship between the variable y and its long-run determinants x:

   $$y^*_t = \sum_j c_j x_{j,t} \tag{36}$$

   Restrictions are imposed to ensure that the equation generates a balanced growth path.

2. Next, we need expected values of future changes of the target variable. These series are generated by estimating a VAR system.[75] For each target variable, we estimate a VAR system that consists of two sets of variables: (1) the determinants of the target variable x_j and (2) five basic variables: the output gap and CPI inflation in both the Netherlands and the euro area, and the short-run interest rate in the euro area, denoted by z_j. We impose that the basic variables converge to a final value (i.e. the output gap to 0%; annual inflation to a value based on a consensus forecast (ECB) and the interest rate to a value based on 5-year future prices of the Euribor). We specify that the x_j variables depend on their own lagged values and the lagged values of the basic variables, while the basic variables z_j only depend on their own

[75] Notice that in simulations other types of expectations might be specified, like model consistent or static expectations. In estimations VAR-type expectations are used to identify the forward weights f_i in PAC equations.

lagged values (thus not of the x_j variables). This is expressed in matrix notation as:

$$\begin{bmatrix} x_t \\ z_t \end{bmatrix} = \begin{bmatrix} \Gamma_{yy} & \Gamma_{yz} \\ 0 & \Gamma_{zz} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ z_{t-1} \end{bmatrix} \quad (37)$$

After estimating the Γ-matrices , forecasts of the determining variables, using forecasts of the basic variables, are simply computed from (37). Finally, forecasts of the target variables are obtained from evaluating the target equation (36):

$$E_t y^*_{t+k} = \sum_j c_j E_t x_{j,t+k} \quad (38)$$

Since both the forward weights and the VAR expectations are geometrically declining, there exists an explicit expression for the infinite sum in (35) that can be used in estimation.

3. In a third step, the PAC equation (35) is estimated by iterative OLS. Initial values of the PAC coefficients a's are used to calculate the sum of expectations terms. Given the series of this term, the PAC coefficients a's and γ's are estimated and the sum of expectations terms is re-evaluated. Iterations on the coefficients are performed until convergence.