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Household savings, capital investments and public policies: What drives the German current account?

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Non-technical summary

Research Question

What drives the high and persistent German current account surplus since the turn of the millennium? To many, the Agenda 2010 reforms (several structural labor market and tax reforms), population aging and pension reforms as well as a tight German fiscal stance are responsible for it. European and international institutions have repeatedly asked Germany to reduce their current account surplus. To do so, however, it is necessary to understand its driving forces.

Contribution

In this paper, we present a model that can account for a large part of the changes in the German current account balance since the 2000s. The model is a three-region New Keynesian model with a search-and-matching labor market, a fiscal block that includes a wide range of taxes and disaggregated government spending, and a life-cycle structure. The latter gives rise to a savings motive, which affects the German net foreign asset position.

Results

Our simulation results suggest that the structural tax and labor market reforms of the Agenda 2010, population aging and pension reforms led to an increase in the household savings rate in Germany until about 2010. As domestic investment opportunities could not absorb these additional savings, they were partly invested abroad. The German current account-to-GDP ratio rose. Thereafter, however, household savings stayed high but did not increase further, both in the model simulations and in the data. Nevertheless, the observed German current account surplus still kept on rising. According to our simulations, a tight fiscal stance in Germany (combined with an expansionary stance in the rest of the world), a reduction in investment in the corporate sector and productivity gains in emerging economies after 2010, which increased demand for German goods and investment opportunities there, contributed to this.

Nichttechnische Zusammenfassung

Fragestellung

Was treibt den deutschen Leitungsbilanzüberschuss seit der Jahrtausendwende? Viele machen dafür die Agenda 2010-Reformen (strukturelle Arbeitsmarkt- und Steuerreformen), Bevölkerungsalterung und Rentenreformen sowie die sparsame deutsche Fiskalpolitik verantwortlich. Mehrere europäische und internationale Organisationen haben Deutschland wiederholt aufgefordert, den Leistungsbilanzüberschuss zu reduzieren. Um dies tun zu können, muss man jedoch erst verstehen, woher dieser kommt.

Beitrag

Wir präsentieren in diesem Papier ein Modell, das in der Lage ist, einen Großteil der Entwicklungen des deutschen Leistungsbilanzsaldos seit der Jahrtausendwende zu erklären. Es handelt sich um ein drei Weltregionen umfassendes neukeynesianisches Modell mit Suchfriktionen auf dem Arbeitsmarkt, einem Fiskalsektor mit differenzierter Steuerstruktur und disaggregierten Ausgabenkomponenten sowie einem Haushaltssektor mit Lebenszyklusstruktur. Diese Lebenszyklusstruktur erzeugt ein Sparmotiv, welches die deutsche Nettoauslandsvermögensposition, und damit die Leistungsbilanz, beeinflusst.

Ergebnisse

Simulationsergebnisse legen nahe, dass sich die Ersparnisbildung in Deutschland bis ins Jahr 2010 wegen der Arbeitsmarkt- und Steuerreformen der Agenda 2010, Bevölkerungsalterung und Rentenreformen deutlich erhöht hat. Da diese zusätzlichen Ersparnisse nicht vollständig im Inland investiert werden konnten, wurden Teile im Ausland angelegt. Der Leistungsbilanzüberschuss stieg. Nach 2010 blieben die Ersparnisse gemäß den Simulationen und auch gemäß den Daten zwar auf einem hohen Niveau, stiegen aber nicht weiter an. Der Leistungsbilanzüberschuss hingegen stieg weiter. Wir identifizieren in unserer Analyse eine restriktive Fiskalpolitik in Deutschland (in Kombination mit einer vergleichsweise expansiven Politik im Rest der Welt), ein Rückgang der Investitionen im deutschen Unternehmenssektor und verbesserte ökonomische Bedingungen in Schwellenländern, die die dortige Nachfrage nach deutschen Gütern aber auch dortige Anlagemöglichkeiten ausbaute, als relevante Erklärungsfaktoren für die Entwicklung seit 2010.

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Household Savings, Capital Investments and Public Policies: What Drives the German Current Account?*

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Abstract

In this article, we present a model that can account for the changes in the German current account balance since the 2000s. Our results suggest that an array of structural tax and labor market reforms (*Agenda 2010*), population aging and pension reforms led to an increase in the household savings rate in Germany until about 2010. As domestic investment opportunities could not absorb these additional savings, they were partly invested abroad. The German current account-to-GDP ratio rose. After 2010, private savings remained rather stable, but opportunities to invest in Germany declined further. Our simulations suggest that a tight fiscal stance in Germany (combined with an expansionary stance in the rest of the world), underinvestment in the corporate sector and productivity gains in emerging economies after 2010 significantly contributed to this.

Keywords: Global Imbalances, Population Aging, Labor Market Reforms, Fiscal Policy, DSGE Modelling

JEL classification: H2, J1, E43, E62

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1 Introduction

What drives the high and persistent German current account surplus since the turn of the millennium? Popular answers given to that question are: (i.) the *Agenda 2010* (an array of structural tax and labor market reforms starting in 1999), (ii.) population aging and reforms of the German pension system as well as (iii.) the tight German fiscal stance.[1] The current account developments have repeatedly been criticized by several European and international institutions, asking the German government to deal with the issue (EC, 2016, 2019; IMF, 2018; The Economist, 2017; Felbermayr et al., 2017). To seriously do so, however, it is first of all necessary to understand its driving forces. In this paper, we therefore analyze to which extent the factors mentioned above have contributed to the German current account surplus. We find that all of them contributed to the current account developments during the first decade of the millennium. But since 2010, we identify under-investment in the corporate sector and productivity gains in emerging economies as two additional driving forces contributing to the current account developments.

We follow Gadatsch, Stähler, and Weigert (2016) and build a three-region New Keynesian DSGE model with a search and matching labor market and a comprehensive fiscal block that allows us to incorporate the German *Agenda 2010* reform measures in detail. We augment the model by a life-cycle structure in line with Gertler (1999), Carvalho, Ferrero, and Nechio (2016), Fujiwara and Teranishi (2008) and Kara and von Thadden (2016). The rational behind this is to determine the steady-state net foreign asset position endogenously. The life-cycle structure introduces a savings motive which determines individual savings over the life time. Thereby, it uniquely defines the amount of aggregate savings held in each region and, thus, the net foreign asset position endogenously. We do not need any further assumptions to obtain stationarity as is usually the case in conventional multi-region DSGE models (see Ghironi, 2008; Di Giorgio and Nistico, 2013; Oxborrow and Turnovsky, 2017, for a discussion). This gives us a superior tool, which we use to simulate current account effects of the suspected drivers.[2] Finally, we compare the simulated German current account surpluses to those observed in the data.

Our analysis combines several strands of the literature. First, by analyzing the *Agenda 2010* reforms, our paper relates to the literature discussing labor market reforms. In line

[1] During the 1990s, the German current account fluctuated around -1% of GDP. At the turn of the millennium, it started improving, reaching a level of around 6% of GDP by 2006 (after the implementation of major labor market reforms), further increased to almost 9% in 2015 and still remains high, currently standing at above 7% of GDP (see IMF, 2019). The *Agenda 2010* is made responsible for this by, among others, Chen, Milesi-Ferretti, and Tressel (2013); Hobza and Zeugner (2014); Kollmann, Ratto, Roeger, in 't Veld, and Vogel (2015), aging and pension reforms by BMF (2017); Busl, Jokisch, and Schleer (2012); Bundesbank (2018); Felbermayr, Fuest, and Wollmershäuser (2017); Priesmeier (2017); Schön and Stähler (2020) and the tight fiscal stance is mentioned in EC (2019). Gaysset, Lagoarde-Segot, and Neaime (2019) and the literature discussed therein suggest that a negative relationship between tight fiscal policy and the current account exists.

[2] In standard open-economy DSGE models (Obstfeld and Rogoff, 1995), the net foreign asset position is usually exogenous. Stationarity is reached by adding a friction to the financial market that kicks in whenever the exogenously fixed reference level is missed (see Schmitt-Grohe and Uribe, 2003, Hunt and Rebucci, 2005, Lubik, 2007 and Benigno, 2009). This very mechanism however makes the net foreign asset position independent of structural (policy) changes. Therefore, it is by construction not the right modelling device for our analysis.

with Krause and Uhlig (2012), Launov and Wälde (2013) and Gadatsch et al. (2016), among others, we find positive output, consumption and employment effects of a reduction in unemployment benefits, a component of the German Hartz IV reform. This also holds for improvements in the labor market matching efficiency, part of the Hartz III reforms (Busl and Seymen, 2013; Krebs and Scheffel, 2013; Launov and Wälde, 2016). The *Agenda 2010* additionally included labor and capital tax cuts as well as fiscal devaluations (a shift from labor to consumption taxation). Here, we find positive effects on domestic variables, too (in line with Bosca, Domenech, and Ferri, 2013; Burgert and Roeger, 2014; Gomes, Jacquinot, and Pisani, 2016; Langot, Patureau, and Sopraseuth, 2017; Lipinska and von Thadden, 2019; Picos-Sanchez and Thomas, 2015; Stähler and Thomas, 2012).

What is the international transmission of the reform agenda? Reform-induced reductions in effective labor and capital costs also improve German international competitiveness and exports. Higher income in Germany rises domestic demand and fosters imports. Thereby, the reform measures generate positive output spillovers to the foreign regions. In the literature using standard open-economy DSGE models, these effects even out in the new steady state, again implying a settled trade balanced. Even along the transition, movements in the current account are small (see Cacciatore, Duval, Fiori, and Ghironi, 2016; Dao, 2013; Felbermayr, Larch, and Lechthaler, 2013; Gadatsch et al., 2016; Gomes, Jacquinot, Mohr, and Pisani, 2013; Schwarzmüller and Stähler, 2013). In our framework, we can show that the German net foreign asset position increases permanently as a result of the *Agenda 2010* reforms due to the endogenous savings decision. The resulting impact on the current account balance is much larger in our model than it is in a standard open-economy DSGE framework (by more than a factor of 25 relative to Gadatsch et al., 2016). In addition, and contrary to the literature discussed so far, we find negative spillover effects of the reforms to foreign consumption, although foreign output is positively affected (due to a rise in import demand in Germany). The reason is that the German net foreign asset position rises permanently, which implies – in relative terms – a permanent transfer of income from foreign countries to Germany (in form of interest payments on international assets). This reduces foreign consumption.

Second, our paper is related to the literature dealing with population aging and the current account (Poterba, 2001; Börsch-Supan, Heiss, Ludwig, and Winter, 2003; Krueger and Ludwig, 2007; Börsch-Supan and Ludwig, 2009). As the society becomes older, fewer people need capital for production. In addition, aggregate savings tend to increase in an aging economy as people want to prepare for a longer life (Carvalho et al., 2016). Therefore, population stimulates supply and reduces demand for capital. In a closed economy, this reduces the interest rate accordingly (Carvalho et al., 2016; Papetti, 2019; Sudo and Takizuka, 2019). In an open-economy setting, it additionally leads to capital exports, driving up the net foreign assets and the current account. Using projected population dynamics as reported by OECD (2017), we find that Germany becomes a capital exporter in the first half of this century because it initially ages faster than the other countries/economies (in line with Brooks, 2003; Blanchard and Milesi-Ferretti, 2010; Ferrero, 2010; Marchiori, 2011; Backus, Cooley, and Henriksen, 2014; Börsch-Supan, Ludwig, and Winter, 2006; Börsch-Supan, Härtl, and Ludwig, 2014; Eugeni, 2015; Turnovsky, 2019; Schön and Stähler, 2020).

Moreover, we also include major pension reforms to our analysis, namely a gradual cut in the pension replacement rate by 3 percentage points and a gradual increase in the statutory retirement age from 65 to 67 years.[3] Here, we find that the cut in the replacement rates increases the positive impact on the current account slightly, as it fosters the incentive for German households to save. Opposite effects are obtained when increasing the retirement age. This measure shortens the retirement period and increases labor supply. However, the impact of the pension reforms on the current account are minor.

In the third step, we include public debt developments according to IMF (2019). From 1999 until 2008, the public debt-to-GDP ratios fluctuate around their initial steady state levels. In all regions, they increased significantly during the financial crisis. While debt levels around the world remained high, the German government started to consolidate and, in 2018, roughly reached the debt-to-GDP ratio of 1999 again. We use this as a proxy for describing the tight German fiscal stance and find that it indeed affected the German current account positively. As the German government reduced its debt, the supply of domestic assets as investment opportunities declined. In addition, the opportunities to invest in public debt in the other regions rose. This moved capital to the foreign regions. If we assume that agents believe that the differences in the debt-to-GDP ratios remain permanently, the effect is stronger relative to assuming the differences to be temporary.

Comparing the model-implied evolution of the German current account-to-GDP ratio to the data, we find that the *Agenda 2010*, population aging, pension reforms and a tight German fiscal stance (relative to the rest of the world) were significant drivers of the current account surplus until about 2010. Thereafter, however, household savings stayed high but did not increase further, both in the model simulations and in the data. Nevertheless, the observed German current account surplus still kept on rising. In an additional (admittedly somewhat stylized) simulation exercise, we identify two additional drivers that may be responsible for this. First, a corporate savings glut in Germany depressed physical capital investments after 2010 (see Chen, Karabarbounis, and Neiman, 2017; Klug, Mayer, and Schuler, 2019). Second, recent findings indicate an increasingly strong drift of German production towards exports (Dauth, Findeisen, and Suedekum, 2017) and emerging markets becoming more and more important internationally (Lane and Milesi-Ferretti, 2017, and Arezki and Liu, 2018). Therefore, we identify economic growth in emerging markets to foster both, the demand for German goods as well as the incentive to invest in these economies (see Danninger and Joutz, 2007, and Chen, Milesi-Ferretti, and Tressel, 2012, backed by data from OECD, 2019). Both developments made it less possible for Germans to invest their savings domestically and increased the German current-account after 2010. The increase in global trade and demand for German goods in the rest of the world as a driver for the German current account increases since 2010 is also identified by Albonico, Cales, Cardani, Croitorov, Ferroni, Giovannini, Hohberger, Pataracchia, Pericoli, Raciborski, Ratto, Roeger, and Vogel (2019) and Hoffmann, Kliem, Krause, Moyen, and Sauer (2020). Both papers estimate a multi-region New Keynesian DSGE model and perform a historical shock decomposition of the German trade balance.

The rest of the paper is structured as follows. Section 2 describes the model. Its calibration is explained in Section 3. The analysis is undertaken in Section 4. Section

[3] For details on the pension reforms we refer the interested reader to Bundesbank (2008, 2016, 2019) and Schön (2020). We further note that the literature on the impact of the German pension reforms on the developments of the current account is rather scarce. This is an attempt to shed some more light on this matter.

5 concludes. An appendix containing details on the reforms that we analyze and some supplementary analyses is added.

2 The model

In this section, we build a New Keynesian three-region life-cycle model. Regions are indexed by $i = a, b, c$. Two of the regions, a and b, form a monetary, while the third region, c, represents the rest of the world. Each region i produces differentiated goods that are tradeable across countries. They are purchased by households according to their preferences in their consumption and investment baskets. We also include a search and matching labor market with short and long-term unemployment as well as a fiscal block containing a wide range of taxes. Regions differ in size, their demographic developments and other structural parameters. The life-cycle structure implies that net foreign asset positions and the world interest rate are determined endogenously, also in the steady state.

2.1 Demographic structure

In the spirit of Gertler (1999), population in each region i consists of two distinct groups: workers, $N_t^{w,i}$, and retirees, $N_t^{r,i}$, where the superscripts w and r denote variables and parameters relevant for the corresponding group. New workers are born at rate $(1 - \omega_t^i + n_t^{w,i})$. Conditional on being a worker in the current period, an individual faces a probability ω_t^i of remaining a worker in the next period. At the same time, the working-age population in region i grows at rate $n_t^{w,i}$. Hence, $(1 - \omega_t^i + n_t^{w,i})$ can be interpreted as the "fertility rate". Retirees face a survival probability γ_t^i. In order to facilitate aggregation within each group, we assume that the probabilities of retirement and death are independent of individual age (Blanchard, 1985; Weil, 1989). Consequently, the laws of motion for workers and retirees in region i are

$$\begin{aligned} N_{t+1}^{w,i} &= \left(1 - \omega_t^i + n_t^{w,i}\right) N_t^{w,i} + \omega_t^i N_t^{w,i} = \left(1 + n_t^{w,i}\right) N_t^{w,i}, \\ N_{t+1}^{r,i} &= \left(1 - \omega_t^i\right) N_t^{w,i} + \gamma_t^i N_t^{r,i}. \end{aligned}$$

Defining the old-age dependency ratio as $\Psi_t^i = N_t^{r,i}/N_t^{w,i}$, its law of motion can be calculated as

$$\Psi_{t+1}^i = \frac{1 - \omega_t^i}{1 + n_t^{w,i}} + \frac{\gamma_t^i}{1 + n_t^{w,i}} \Psi_t^i. \tag{1}$$

The relative size of the labor force between region i and j, defined as $rs_t^{i,j} = N_t^{w,i}/N_t^{w,j}$, evolves according to $rs_{t+1}^{i,j} = (1 + n_t^{w,i})/(1 + n_t^{w,j})\, rs_t^{i,j}$. In steady state, it must thus hold that $n^{w,a} = n^{w,b} = n^{w,c}$, but ω^i and γ^i can be structurally different across regions. The growth rate of the retiree population satisfies $N_{t+1}^{r,i}/N_t^{r,i} = (1 + n_t^{r,i}) = (1 - \omega_t^i)/\Psi_t^i + \gamma_t^i$ which, along a balanced growth path, implies $n^{w,i} = n^{r,i}$.

2.2 Decision problem of retirees and workers

Workers inelastically offer one unit of labor on the labor market each period. They can be employed or unemployed. Retirees do not work. Preferences for an individual of group $z = \{w, r\}$ follow a restricted version of recursive utility that assumes risk neutrality (Epstein and Zin, 1989):

$$V_t^{z,i} = \left\{ \left(c_t^{z,i}\right)^\rho + \beta_{t+1}^{z,i} \left[E_t \left(V_{t+1}^i | z\right)\right]^\rho \right\}^{\frac{1}{\rho}}, \tag{2}$$

where $c_t^{z,i}$ denotes consumption and $V_t^{z,i}$ the value of utility in period t. Workers and retirees have different discount factors to account for the probability of death. It holds that $\beta_{t+1}^{r,i} = \beta \cdot \gamma_{t+1}^i$ and $\beta^{w,i} = \beta$. Furthermore, the expected continuation value in equation (2) differs because of the transition probabilities between groups. It holds that $E_t \left(V_{t+1}^i | r\right) = V_{t+1}^{r,i}$ and $E_t \left(V_{t+1}^i | w\right) = \omega_{t+1}^i \cdot V_{t+1}^{w,i} + (1 - \omega_{t+1}^i) \cdot V_{t+1}^{r,i}$. As is extensively discussed in the literature (Gertler, 1999; Ferrero, 2010; Carvalho et al., 2016), this life-cycle model is analytically tractable because the transition probabilities to retirement and death are independent of age. Separating the elasticity of intertemporal substitution, $\sigma \equiv (1 - \rho)^{-1}$, from risk aversion in (2) allows for a reasonable response of consumption and savings to changes in interest rates (Farmer, 1990; Heiberger and Ruf, 2019).

Households are assumed to allocate their financial wealth, a_t^i, among investments in physical capital, k_t^i, nominal government bonds, $B_t^i = P_t^i \cdot b_t^i$, and internationally traded nominal private bonds, $D_t^i = P_t^i \cdot d_t^i$, where P_t^i is the consumer price index in region i, which we will derive in detail below. It hence holds that $a_t^i = k_t^i + b_t^i + d_t^i$. Households rent the capital stock to firms at a real rate $r_t^{k,i}$ and bear costs of depreciation $\delta^{k,i} \in (0, 1)$. Returns on capital gains are taxed at rate $\tau_t^{k,i}$, which is used as a proxy for corporate taxation. Depreciation is assumed to be tax exempt. Government bonds pay a gross return $R_t^{G,i}$ and international bonds pay $R_t^{D,i}$. The return on last period's financial wealth in region i is given by $R_{t-1}^i \cdot a_{t-1}^i = \left[(1 - \tau_t^{k,i}) \cdot r_t^{k,i} + \tau_t^{k,i} \cdot \delta^{k,i}\right] \cdot k_{t-1}^i + R_{t-1}^{G,i} \cdot \frac{b_{t-1}^i}{\pi_t^{cpi,i}} + R_{t-1}^{D,i} \cdot \frac{d_{t-1}^i}{\pi_t^{cpi,i}}$, where $\pi_t^{cpi,i} = P_t^i / P_{t-1}^i$ denotes CPI inflation of region i (to be derived below). As in Christiano, Eichenbaum, and Evans (2005), physical capital is associated with capital adjustment costs, implying that the capital stock evolves according to

$$k_t^i = (1 - \delta^{k,i})\, k_{t-1}^i + \left[1 - \underbrace{\frac{\kappa_{inv}^i}{2} \left(\frac{inv_t^i}{inv_{t-1}^i} - 1 \right)^2}_{\equiv S_t^i(\cdot)} \right] \cdot inv_t^i, \tag{3}$$

where inv_t^i denotes (real CPI-deflated) capital investment. The no-arbitrage condition thus implies

$$R_t^i = R_t^{D,i} / \pi_{t+1}^{cpi,i} = R_t^{G,i} / \pi_{t+1}^{cpi,i} = \frac{(1 - \tau_{t+1}^{k,i})\, r_{t+1}^{k,i} + \tau_{t+1}^{k,i}\, \delta^{k,i} + Q_{t+1}^i\, (1 - \delta^{k,i})}{Q_t^i} \equiv R_t, \tag{4}$$

where R_t is the world asset market-clearing real interest rate and the shadow value of capital (i.e. Tobin's q) is given by

$$1 = Q_t^i \cdot \left[1 - S_t^i(\cdot) - S_t^{i,'}(\cdot) \cdot \frac{inv_t^i}{inv_{t-1}^i}\right] + \frac{Q_{t+1}^i}{1+r_{t+1}} \cdot S_{t+1}^{i,'}(\cdot) \left(\frac{inv_{t+1}^i}{inv_t^i}\right)^2. \tag{5}$$

Retirees: An individual born in period j and retired in period τ chooses consumption $c_t^{r,i}(j,\tau)$ and assets $a_t^{r,i}(j,\tau)$ for $t \geq \tau$ to solve equation (2) for $z = r$ subject to

$$c_t^{r,i}(j,\tau) + a_t^{r,i}(j,\tau) = pen_t^{r,i}(j,\tau) - T_t^{r,i}(j,\tau) + \frac{R_{t-1} \cdot a_{t-1}^{r,i}(j,\tau)}{\gamma_t^i}. \tag{6}$$

$pen_t^{r,i}(j,\tau)$ denotes real pension benefits and $T_t^{r,i}(j,\tau)$ are lump-sum taxes. For retirees, a perfectly competitive mutual fund industry invests the proceeds and pays back a premium over the market return to compensate for the probability of death (see Yaari, 1965; Blanchard, 1985). This explains the term $1/\gamma_t^i$ in the equation above.[4] Retirees thus use their income to finance consumption and financial investments. Additionally, the optimization problem is subject to the consistency requirement that the retiree's initial asset holdings upon retirement correspond to the assets held in the last period as a worker, i.e. $a_{\tau-1}^{r,i}(j,\tau) = a_{\tau-1}^{w,i}(j)$. After some algebra (which is very well described in the technical appendix of Carvalho et al., 2016), we find that the level of consumption of each retiree is a fraction of total wealth:

$$c_t^{r,i}(j,\tau) = \xi_t^{r,i} \cdot \left(h_t^{r,i}(j,\tau) + \frac{R_{t-1} \cdot a_{t-1}^{r,i}(j,\tau)}{\gamma_t^i}\right), \tag{7}$$

where $h_t^{r,i}(j,\tau) = pen_t^{r,i}(j,\tau) - T_t^{r,i}(j,\tau) + \gamma_t^i / R_t \cdot h_{t+1}^{r,i}(j,\tau)$ is the recursive law of motion of the retiree's human capital (i.e. life-time income from pension benefits). The marginal propensity to consume satisfies the following first-order non-linear difference equation

$$\xi_t^{r,i} = 1 - \gamma_{t+1}^i \cdot \beta^\sigma \cdot (R_t)^{\sigma-1} \cdot \frac{\xi_t^{r,i}}{\xi_{t+1}^{r,i}}. \tag{8}$$

Workers: Workers start their lives with zero assets. A worker cohort born in j chooses consumption $c_t^{w,i}(j)$ and assets $a_t^{w,i}(j)$ for $t \geq j$ to maximize equation (2) for $z = w$ subject to

$$\begin{aligned} c_t^{w,i}(j) + a_t^{w,i}(j) = R_{t-1} \cdot a_{t-1}^{w,i}(j) - T_t^{w,i}(j) + \Pi_t^i(j) + (1 - \tau_t^{l,i})\, \tilde{e}_t^i(j)\, w_t^i \\ + u_t^i(j) \left(\varrho_t^i\, \kappa_t^{B,s,i} + (1 - \varrho_t^i)\, \kappa_t^{B,l,i}\right), \end{aligned} \tag{9}$$

and $a_j^{w,i}(j) = 0$. The worker's budget constraint differs from the one of retirees. First, in addition to the interest received from asset accumulation, the worker receives firm profits, $\Pi_t^i(j)$. When employed, she receives a wage payment, w_t^i, which is taxed at rate

[4] In our model, national funds of region i only operate in their home region. This prevents equalization of returns in the insurance market, which would otherwise dampen the effects of life expectancy differences across regions significantly (see Ferrero, 2010).

$\tau_t^{l,i}$. When unemployed, she receives unemployment benefits. These are differentiated according to the unemployment spell. Short-term unemployed workers receive $\kappa_t^{B,s,i}$, while long-term unemployed workers get $\kappa_t^{B,l,i} < \kappa_t^{B,s,i}$. $\tilde{e}_t^i$ denotes the employment rate, u_t^i the unemployment rate and ϱ_t^i the share of workers being short-term unemployed relative to total unemployment. We will derive these shares as well as wages in detail below. Again, $T_t^{w,i}(j)$ are lump-sum taxes.

The second difference with respect to retirees is that workers do not turn to the mutual funds industry and, hence, do not receive the additional return that compensates for the probability of death. Allowing them to do so would provide complete insurance against the probability of retirement and, thus, shut down most of the life-cycle dimension of the model. Also, the expected continuation value of workers in equation (2) is different to the one of retirees. Solving the worker's optimization problem shows that workers' consumption is a fraction of total wealth, defined as the sum of financial and non-financial (human) wealth,

$$c_t^{w,i}(j) = \xi_t^{w,i} \cdot \left(R_{t-1} \cdot a_{t-1}^{w,i}(j) + h_t^{w,i}(j)\right), \tag{10}$$

where

$$\begin{aligned} h_t^{w,i}(j) = {} & (1-\tau_t^{l,i})\, \tilde{e}_t^i(j)\, w_t^i + u_t^i(j) \left(\varrho_t^i\, \kappa_t^{B,s,i} + (1-\varrho_t^i)\, \kappa_t^{B,l,i}\right) - T_t^{w,i}(j) + \Pi_t^i(j) \\ & + \frac{\omega_t^i}{R_t\, \Omega_{t+1}^i}\, h_{t+1}^{w,i}(j) + \left(1 - \frac{\omega_t^i}{\Omega_{t+1}^i}\right) \frac{h_{t+1}^{r,i}(j)}{R_t} \end{aligned}$$

represents the discounted value of current and future wage income net of taxation, unemployment benefits and profits, expressed recursively (again, the interested reader is refereed to the technical appendix of Carvalho et al., 2016, for a detailed formal derivation). It is independent from individual characteristics. As for retirees, the workers' marginal propensity to consume out of wealth evolves according to

$$\xi_t^{w,i} = 1 - \beta^\sigma \cdot \left(\Omega_{t+1}^i \cdot R_t\right)^{\sigma-1} \cdot \frac{\xi_t^{w,i}}{\xi_{t+1}^{w,i}}. \tag{11}$$

The adjustment term $\Omega_t^i \equiv \omega_t^i + (1-\omega_t^i) \cdot \left(\xi_t^{r,i}/\xi_t^{w,i}\right)^{1/(1-\sigma)}$ depends on the ratio of the marginal propensities to consume between retirees and workers. It can be shown that $\xi_t^{r,i}/\xi_t^{w,i} > 1 \forall t$. This indicates that retirees discount future income streams at an effectively higher rate than retirees, reflecting the expected finiteness of their life. Relative to a conventional DSGE model, the (far) future "less valuable" to households in our model.

2.3 Aggregation of households' decisions

Any aggregate variable $S_t^{z,i}$ for group $z = \{w, r\}$ in region i takes the form $S_t^{z,i} \equiv \int_0^{N_t^{z,i}} S_z^{z,i}(j)dj$. As we have seen in the previous subsection, the marginal propensities to consume out of wealth are independent from individual characteristics. Hence, given the linearity of the consumption functions discussed above, they are given by

$$c_t^{z,i} = \xi_t^{z,i} \cdot \left(R_{t-1} \cdot a_{t-1}^{z,i} + h_t^{z,i}\right), \tag{12}$$

and aggregate economy-wide consumption is defined as

$$c_t^i = c_t^{w,i} + c_t^{r,i}. \tag{13}$$

$a_{t-1}^{z,i}$ is total financial wealth that members of group $z = \{w, r\}$ carry from period $t-1$ to t. It must hold that $a_t^i = a_t^{w,i} + a_t^{r,i}$. To determine the aggregate stocks of human capital, $h_t^{r,i} = N_t^{r,i} \cdot h_t^{r,i}(j,\tau)$ and $h_t^{w,i} = N_t^{w,i} \cdot h_t^{w,i}(j)$, we have to take into account population dynamics described in section 2.1. This yields

$$h_t^{r,i} = pen_t^i + \frac{\gamma_t^i}{(1+n_t^{r,i})\, R_t}\, h_{t+1}^{r,i}, \tag{14}$$

$$h_t^{w,i} = (1-\tau_t^{l,i})\, \tilde{e}_t^i\, w_t^i + u_t^i \left(\varrho_t^i\, \kappa_t^{B,s,i} + (1-\varrho_t^i)\, \kappa_t^{B,l,i}\right) - T_t^{w,i} + \Pi_t^i$$
$$+ \frac{\omega_t^i}{(1+n_t^{w,i})\, R_t\, \Omega_{t+1}^i}\, h_{t+1}^{w,i} + \left(1 - \frac{\omega_t^i}{\Omega_{t+1}^i}\right) \frac{h_{t+1}^{r,i}}{(1+n_t^{w,i})\, R_t\, \Psi_t^i}. \tag{15}$$

These equations take into account the respective population growth rates $n_t^{r,i}$ and $n_t^{w_i}$. The absence of γ_t^i in equation (12) for $z = r$ relative to individual consumption for retirees reflects the competitive insurance/annuity market.[5] Analogously, we have to take into account working-age population growth for the aggregate value of human wealth.

If we let $\lambda_t^i \equiv a_t^{r,i}/a_t^i$ denote the share of total financial assets held by retirees in region i, it remains to determine how it evolves. Aggregate assets of retirees depend on the savings of those who are retired plus the assets of the fraction of workers that will retire:

$$\lambda_t^i\, a_t^i = \lambda_{t-1}^i (R_{t-1})\, a_{t-1}^i + pen_t^i - c_t^{r,i} + (1-\omega_t^i) \Big[(1-\lambda_{t-1}^i)(R_{t-1})\, a_{t-1}^i + (1-\tau_t^{l,i})\, \tilde{e}_t^i\, w_t^i$$
$$+ u_t^i \left(\varrho_t^i\, \kappa_t^{B,s,i} + (1-\varrho_t^i)\, \kappa_t^{B,l,i}\right) - T_t^{w,i} + \Pi_t^i - c_t^{w,i}\Big].$$

Aggregate savings of workers, $(1-\lambda_{t-1}^i) \cdot a_t^i$, depend only on the savings of the fraction of workers who remain in the labor force. This is given by the term in square brackets multiplied by $(1-\omega_t^i)$ in the previous equation. Using this as well as equation (12) for $z = w, r$ yields

$$\lambda_t^i\, a_t^i = \omega_{t+1}^i \left\{\left(1-\xi_t^{r,i}\right)\left[R_{t-1}\, \lambda_{t-1}^i\, a_{t-1}^i + h_t^{r,i}\right] - \left(h_t^{r,i} - pen_t^i\right)\right\} + (1-\omega_{t+1}^i)\, a_t^i. \tag{16}$$

The aggregate amount of domestic savings in region i, a_t^i, and who holds them, λ_t^i, are additional state variables in our model (when compared to a conventional DSGE model).

2.4 Production

The production side follows the conventional structure of New Keynesian models in the literature (see, for example, Gertler, Gali, and Clarida, 1999, Christiano et al., 2005, or Smets and Wouters, 2003, 2007). This implies that the production sector is partitioned

[5] As discussed in Blanchard (1985), the probability of death is relevant for the individual household j, but it does not affect the aggregate consumption of retirees as a group. This is because the assets "left over" from those who pass away are transferred to the other retirees and remain in the same group.

in a final and an intermediate goods sector. The search labor market is described in the next subsection.

Final goods: We assume that, in each country i, there is a measure-one continuum of firms in the final goods sector. Firms are owned by the working-age population as in Fujiwara and Teranishi (2008). Each final goods producer purchases a variety of differentiated intermediate goods, bundles these and sells them to the final consumer under perfect competition. The producer price index (henceforth, PPI) of goods produced in country i and sold in j is defined as $P_t^{i,j}$. We assume that the law of one price holds across regions, so firms in country i set their price $P_t^{i,i}$ for all markets (Di Giorgio and Nistico, 2013; Di Giorgio, Nistico, and Traficante, 2018; Di Giorgio and Traficante, 2018). Multiplying with the nominal exchange rate $S_t^{i,j}$ then determines the price of country-i goods charged in j: $P_t^{j,i} = S_t^{j,i} P_t^{i,i}$, where $S_t^{j,i}$ is defined as country-j currency per unit of country-i currency. Within the monetary union, it holds by definition that $S_t^{b,a} = S_t^{a,b} = 1 \forall t$. It must then hold that $S_t^{c,a} = S_t^{c,b} \equiv S_t$, where S_t is the nominal exchange rate between the monetary union and the rest of the world (expressed in country-c currency per unit of the monetary union currency).

Assuming a Dixit and Stiglitz (1977)-aggregator on the interval $\tilde{j} \in [0,1]$, the final good in region i is, as usual, given by $y_t^i = \left[\int_0^1 y_t^i(\tilde{j})^{(\theta_p^i-1)/\theta_p^i} d\tilde{j}\right]^{\theta_p/(\theta_p-1)}$. $\theta_p^i > 1$ is the elasticity of substitution between differentiated intermediate goods. Demand for an intermediate good $\tilde{j}$ is given by $y_t^i(\tilde{j}) = \left[P_t^{i,i}(\tilde{j})/P_t^{i,i}\right]^{-\theta_p^i} y_t^i$. The PPI of region i is given by $P_t^{i,i} = \left[\int_0^1 P_t^{i,i}(\tilde{j})^{1-\theta_p^i} d\tilde{j}\right]^{1/(1-\theta_p^i)}$.

Intermediate goods: The representative intermediate good producer $\tilde{j}$ operates with production technology $y_t^i(\tilde{j}) = \epsilon^{a,i} \cdot \left[l_t^i(\tilde{j})\right]^{\alpha^i} \cdot \left[k_{t-1}^i(\tilde{j})\right]^{1-\alpha^i}$. Here, $\epsilon^{a,i}$ is an exogenously given parameter scaling production across regions and α^i is the Cobb-Douglas share of labor in production. $l_t^i(\tilde{j})$ and $k_{t-1}^i(\tilde{j})$ are the inputs of labor and capital in production by producer $\tilde{j}$. Taking prices for labor (CPI-deflated real labor costs x_t^i) and capital (CPI-deflated real capital interest $r_t^{k,i}$) as given, firm $\tilde{j}$'s cost minimization problem yields the following capital-to-labor ratio

$$\frac{l_t^i}{k_{t-1}^i} = \frac{\alpha^i}{1-\alpha^i} \cdot \frac{r_t^{k,i}}{x_t^i} \tag{17}$$

which must be equal across all intermediate goods producing firms for given wages and capital interest rates (as symmetry applies, we dropped the index $\tilde{j}$ for convenience). Hence, CPI-deflated real marginal costs are given by

$$mc_t^i = \left(\frac{x_t^i}{\alpha^i}\right)^{\alpha^i} \cdot \left(\frac{r_t^{k,i}}{1-\alpha^i}\right)^{1-\alpha^i} / \epsilon^{a,i}. \tag{18}$$

Following the convention in the New Keynesian literature, we assume that each period, a randomly chosen fraction of firms $\kappa_p^i \in [0,1)$ cannot re-optimize their price (Calvo, 1983). In a symmetric equilibrium, the price of those firms $\tilde{j}$ who can set their price in period t

is equal across firms, i.e. $P_t^{i,i,*}(\tilde{j}) = P_t^{i,i,*}$. This profit maximizing price is given by

$$\frac{P_t^{i,i,*}}{P_t^i} = \frac{\kappa_p^i}{\kappa_p^i - 1} \cdot \frac{\sum_{z=0}^{\infty} \left(\kappa_p^i \beta\right)^z \cdot DF_{t,t+z}^i \cdot y_{t+z}^i \cdot mc_{t+z}^i \cdot \left(\frac{P_{t+z}^{i,i}}{P_t^{i,i}}\right)^{\kappa_p^i}}{\sum_{z=0}^{\infty} \left(\kappa_p^i \beta\right)^z \cdot DF_{t,t+z}^i \cdot y_{t+z}^i \cdot \frac{P_{t+z}^{i,i}}{P_{t+z}^i} \cdot \left(\frac{P_{t+z}^{i,i}}{P_t^{i,i}}\right)^{\kappa_p^i - 1}}. \tag{19}$$

As shown by Fujiwara and Teranishi (2008), the discount factor of firms is given by $DF_{t,t+1}^i = \partial V_{t+1}^{w,i} / \partial c_{t+1}^{w,i}$, which is a result of the fact that we assume workers to be the owners of firms. Producer prices in region i hence evolve according to

$$P_t^{i,i} = \left[\kappa_p^i \cdot \left(P_{t-1}^{i,i}\right)^{1-\theta_p^i} + (1-\kappa_p^i) \cdot \left(P_t^{i,i,*}\right)^{1-\theta_p^i}\right]^{1/(1-\theta_p^i)}, \tag{20}$$

while price dispersion is expressed recursively as $D_t^i = \kappa_p^i \cdot \left(P_t^{i,i}/P_{t-1}^{i,i}\right)^{\theta_p^i} \cdot D_{t-1}^i + (1-\kappa_p^i) \cdot \left(P_t^i/P_t^{i,i,*}\right)^{\theta_p^i}$. Aggregate profits of intermediate firms are $\Pi_t^{int,i} = (P_t^{i,i}/P_t^i - mc_t^i)\, y_t^i$.

2.5 The labor market

Following Christoffel, Kuester, and Linzert (2009) and Gadatsch et al. (2016), we assume that a labor firm bundles the labor input by each employed worker and sells this to the intermediate goods firm at price x_t^i. With $N_t^{w,i}$ being the number of workers in the economy and $\tilde{e}_t^i$ being the employment rate, the total supply of labor is given by $l_t^i = N_t^{w,i} \cdot \tilde{e}_t^i$. Equilibrium in the market for labor services requires that $l_t^i = \int_0^1 l_t^i(\tilde{j}) d\tilde{j}$. Using the demand function for intermediate inputs, the production function for intermediate goods and the fact that the capital-to-labor ratio is equal across all intermediate goods producing firms, this yields $D_t^i \cdot y_t^i = \epsilon^{a,i} \cdot [l_t^i]^{\alpha^i} \cdot \left[k_{t-1}^i\right]^{1-\alpha^i}$. Below, we will describe the matching process, flows in the labor market, vacancy creation and the wage determination.

Matching process and labor market flows: A household member in the working-age population can be in one of three states: employed, short-term unemployed or long-term unemployed. Long-term unemployment is the residual state in the sense that a worker whose employment relationship ends and who does not find a job while being short-term unemployed ends up here eventually. All unemployed workers look for a job. There is no on-the-job search. Given employment and unemployment rates $\tilde{e}_t^i$ and u_t^i, the number of employed and unemployed workers in region i is given by $\tilde{e}_t^i \cdot N_t^{w,i}$ and $u_t^i \cdot N_t^{w,i}$, respectively. Taking population growth into account and assuming that all new-born workers enter the economy as (long-term) unemployed workers, implies that the employment and unemployment rates evolve according to

$$(1 + n_t^{w,i})\tilde{e}_t^i = (\omega_t^i - s^i) \cdot \tilde{e}_{t-1}^i + f_t^i \cdot \left(u_{t-1}^i + s^i \cdot \tilde{e}_{t-1}^i\right) \tag{21}$$

and

$$(1 + n_t^{w,i})u_t^i = (\omega_t^i - f_t^i) \cdot u_{t-1}^i + (1 - f_t^i) \cdot s^i \cdot \tilde{e}_{t-1}^i + (1 - \omega_t^i + n_t^{w,i}), \tag{22}$$

where s^i represents the constant job-separation rate and f_t^i is the probability for an unemployed worker to find a job. It holds that $u_t^i + \tilde{e}_t^i = 1$. These are standard labor market flow equations with two exceptions. First, we have to take into account that employed and unemployed workers retire with probability $(1 - \omega_t^i)$ and that all new-born workers are (long-term) unemployed. Second, given that we will work with an annual calibration (see Section 3), we assume that employed workers who are dismissed in period $t-1$ start searching for and may find a job in $t-1$ already. Hence, the number of searchers in each period is higher than the number of unemployed workers, indicated by $s^i \cdot \tilde{e}_t^i$ (see also Blanchard and Gali, 2010, for a discussion).

Following Moyen and Stähler (2014), we additionally assume that workers who are dismissed first fall into the pool of short-term unemployment, while new-borns fall into long-term unemployment (i.e. they are not eligible for the higher short-term unemployment benefits as they have not worked before). With exogenous probability ϑ^i, which will be calibrated to reflect the average duration of being eligible for short-term unemployment benefits, those who are in the pool of short-term unemployment become long-term unemployed. If we let ϱ_t^i be the share of short-term unemployed workers over total unemployment, given by equation (22), it can be shown that ϱ_t^i evolves according to (see Moyen and Stähler, 2014)

$$(1 + n_t^{w,i}) \cdot \varrho_t^i \cdot u_t^i = (\omega_t^i - f_t^i - \vartheta^i) \cdot \varrho_{t-1}^i \cdot u_{t-1}^i + s^i \cdot \tilde{e}_{t-1}^i. \tag{23}$$

Matches in the economy are formed according to a standard Cobb-Douglas aggregate matching function, $M_t^i = \kappa^{m,i} \left(u_t^i + s^i \cdot \tilde{e}_t^i\right)^{\eta^{m,i}} \cdot \left(vac_t^i\right)^{1-\eta^{m,i}}$, where $u_t^i + s^i \cdot \tilde{e}_t^i$ describes the number of searchers and vac_t^i the number of open vacancies (to be determined below). $\kappa^{m,i} > 0$ is a matching efficiency parameter and $\eta^{m,i} \in (0,1)$ the matching elasticity. The probability for an unemployed worker to find a job is given by $j_t^i = M_t^i / \left(u_t^i + s^i \cdot \tilde{e}_t^i\right)$ and the probability for firms to fill a vacancy is given by $vf_t^i = M_t^i / vac_t^i$.

Wage bargaining, asset values of jobs and job creation: Workers and firms bargain about their share of the overall match surplus to determine wages. As in Bosca, Domenech, and Ferri (2011), a union undertakes wage bargaining and sets one economy-wide wage that is independent of whether the firm bargains with an employed, short-term unemployed or long-term unemployed worker. Hence, the firm bargains with "an average worker". Letting $\mathcal{J}_t^i$ be the value function of employing one marginal worker and $\mathcal{W}_t^i$ be the marginal value if the representative households of having one additional member employed, the Nash bargaining problem is given by

$$\max_{w_t^i} \left(\mathcal{W}_t^i\right)^{\zeta^i} \left(\mathcal{J}_t^i\right)^{1-\zeta^i},$$

where $\zeta^i \in (0,1)$ is the workers' bargaining power. The value function of the firm is given by

$$\mathcal{J}_t^i = x_t^i - \left(1 + \tau_t^{sc,i}\right) \cdot w_t^i - \frac{\kappa^{w,i}}{2} \cdot \left(\frac{w_t^i}{w_{t-1}^i} - 1\right)^2 + \beta \cdot DF_{t,t+1}^i \cdot \left(\omega_t^i - s^i\right) \cdot \mathcal{J}_{t+1}^i. \tag{24}$$

A labor firm earns x_t^i for each employed worker, which is what intermediate goods producing firms pay for labor, and has to pay a wage w_t^i, which is subject to payroll taxes at rate $\tau_t^{sc,i}$ each period. We follow Arseneau and Chugh (2008) and assume that wage adjustments are costly, given by the quadratic (real) wage adjustment cost function $\kappa^{w,i}/2 \cdot \left(w_t^i/w_{t-1}^i - 1\right)^2$. If the match continues, i.e. if the employed worker is not dismissed nor retires, the firm earns the continuation value. For the average worker, an analogous function is given by

$$\begin{aligned} \mathcal{W}_t^i = & \left(1 - \tau_t^{l,i}\right) \cdot w_t^i - \varrho_t^i \cdot \kappa_t^{B,s,i} - (1 - \varrho_t^i) \cdot \kappa_t^{B,l,i} \\ & + \beta \cdot DF_{t,t+1}^i \cdot \left\{ \left(\omega_t^i - s^i - f_{t+1}^i\right) \cdot \mathcal{W}_{t+1}^i + \left(\vartheta^i \cdot \varrho_{t+1}^i + s^i (1 - \varrho_{t+1}^i)\right) \cdot \mathcal{V}_{t+1}^i \right\}. \end{aligned} \tag{25}$$

The employed worker earns a wage w_t^i that is taxed at rate $\tau_t^{l,i}$ each period. If the match continues next period, i.e. the worker is not dismissed and does not retire, the worker earns the continuation value $\mathcal{W}_{t+1}^i$. The fall back utility is given by the (foregone) average unemployment benefits $\varrho_t^i \cdot \kappa_t^{B,s,i} + (1 - \varrho_t^i) \cdot \kappa_t^{B,l,i}$, the expected utility gain $\mathcal{W}_{t+1}^i$ of finding a job tomorrow, which happens with expected probability f_{t+1}^i (and zero when employed as there is no on-the-job search), plus the expected utility difference of those being in the short over those in the long-term unemployment pool (see Moyen and Stähler, 2014, and Gadatsch et al., 2016, for a more elaborate discussion),

$$\mathcal{V}_t^i = \kappa_t^{B,s,i} - \kappa_t^{B,l,i} + \beta \cdot DF_{t,t+1}^i \cdot \left(\omega_t^i - j f_{t+1}^i - \vartheta^i\right) \cdot \mathcal{V}_{t+1}^i. \tag{26}$$

Using the value functions (24), (25) and (26) to solve for the Nash bargaining problem, we get the sharing rule

$$\begin{aligned} \left(1 + \tau_t^{sc,i}\right) \cdot \mathcal{W}_t^i = & \frac{\zeta^i}{1 - \zeta^i} \cdot \left(1 - \tau_t^{l,i}\right) \cdot \mathcal{J}_t^i - \kappa^{w,i} \cdot \frac{\left(w_t^i/w_{t-1}^i - 1\right)}{w_{t-1}^i} \\ & + \beta \cdot DF_{t,t+1}^i \cdot \kappa^{w,i} \cdot \frac{\left(w_{t+1}^i/w_t^i - 1\right) \cdot w_{t+1}^i}{\left(w_t^i\right)^2}. \end{aligned} \tag{27}$$

The workers' share of a match surplus increases with the bargaining power, ζ^i, and falls with higher labor tax and social security contribution rates. Wage adjustment costs have ambiguous effects. Current wage adjustments reduce the share workers can claim from the joint surplus. However, if future wage adjustments are expected, workers can demand a higher share today (as that reduces tomorrow's adjustment costs). Again using equations (24), (25) and (26) allows us to extract a wage equation from (27).

It remains to determine how jobs are created. We assume that opening a vacancy is costly. It is associated with a (CPI-deflated) flow cost $\kappa^{v,i}$. Free entry into the vacancy posting market drives the expected value of a vacancy to zero. Under the assumption of instantaneous hiring, average real vacancy costs, $\kappa^{v,i}/vf_t^i$, must equal the expected value of a firm:

$$\frac{\kappa^{v,i}}{vf_t^i} = \mathcal{J}_t^i, \tag{28}$$

where $1/vf_t^i$ is the average duration a vacancy stays on the market before it is filled.

2.6 Fiscal policy

The government's budget constraint in region i in CPI-deflated real terms is given by

$$b_t^i = R_{t-1}\, b_{t-1}^i + PD_t^i, \tag{29}$$

where use has been made of the no-arbitrage condition (4), with

$$\begin{aligned} PD_t^i = & \frac{P_t^{i,i}}{P_t^i} \cdot g_t^i + pen_t^i + u_t^i \cdot N_t^{w,i} \cdot \left(\varrho_t^i \cdot \kappa_t^{B,s,i} + (1-\varrho_t^i) \cdot \kappa_t^{B,l,i}\right) \\ & -\tau_t^{k,i} \cdot \left(r_t^{k,i} - \delta^{k,i}\right) \cdot k_{t-1}^i - \left(\tau_t^{l,i} + \tau_t^{sc,i}\right) \cdot w_t^i \cdot l_t^i - \tau_t^{c,i} \cdot c_t^i - T_t^i, \end{aligned} \tag{30}$$

as the primary deficit, where $T_t^i = T_t^{w,i} + T_t^{r,i}$. Hence, the government must finance real government expenditures, g_t^i, aggregate real pension benefits, pen_t^i, aggregate real unemployment benefits, $u_t^i \cdot N_t^{w,i} \cdot \left(\varrho_t^i \cdot \kappa_t^{B,s,i} + (1-\varrho_t^i) \cdot \kappa_t^{B,l,i}\right)$, and interest payments on outstanding debt, $R_{t-1} \cdot b_{t-1}^i$, by taxing labor income, capital returns and consumption, the issuance of new debt, b_t^i, and lump-sum taxes. Following Stähler and Thomas (2012) and Gadatsch et al. (2016), we assume full home bias in government consumption, which requires the PPI/CPI correction for public consumption expenditures. The assumption is based on the observation that the import share in government consumption is, in general, significantly lower than in private consumption or investment (Brülhart and Trionfetti, 2001, 2004, and Trionfetti, 2000).

The path of aggregate real pension benefits is determined by the replacement rate μ_t^i between individual benefits and real wages, that is

$$\mu_t^i = \frac{pen_t^{r,i}}{w_t^i} \quad \Rightarrow \quad pen_t^i = pen_t^{r,i} \cdot N_t^{r,i} = \mu_t^i \cdot w_t^i \cdot N_t^{r,i}. \tag{31}$$

Real unemployment benefits are given by

$$\kappa_t^{B,\tilde{z},i} = \rho^{B,\tilde{z},i} \cdot (1-\tau_{t-1}^{l,i}) \cdot w_{t-1}^i, \tag{32}$$

where $\tilde{z} \in \{s, l\}$ differentiates short and long-term benefits, and $\rho^{B,s,i} > \rho^{B,l,i}$, with $\rho^{B,\tilde{z},i} \in [0,1)$. Hence, real unemployment benefits are a fraction of the previous period's net wage income, and short-term benefits are larger than long-term benefits.

To close the system, we assume that the government follows a (modified) balanced budget rule by setting $b_t^i = \omega^{b,i} \cdot y_t^i \cdot P_t^{i,i}/P_t^i$, where $\omega^{b,i}$ is a parameter determining the debt-to-GDP ratio, and letting T_t^i adjust to meet this target.[6]

[6] The balanced-budget rule is primarily assumed for being able to easily conduct the simulation in which we let the debt-to-GDP ratios of each region follow a predetermined path (see Section 4.3). It is straightforward to include fiscal rules along the lines of Schmitt-Grohe and Uribe (2007) and Kirsanova and Wren-Lewis (2012) in our model (see, for example, Mitchell, Sault, and Wallis, 2000, for a discussion). Were we to assume such a rule, the general results would not be affected much.

2.7 International linkages, monetary policy and market clearing

International trade in goods and assets implies that the three regions $i = a, b, c$ are linked together, which not only affects the net foreign asset position but also the market clearing conditions. Furthermore, we have to bear in mind that there is a common monetary policy for regions a and b, while the one for region c is solely undertaken for that region. We will describe these linkages in more detail in this subsection.

International trade, prices and net foreign assets: We assume that households in region i consume goods produced in any of the three regions. The corresponding consumption bundle is given by

$$c_t^i = \left[\left(\vartheta_a^i\right)^{1-\eta^i} \left(c_{a,t}^i\right)^{\eta^i} + \left(\vartheta_b^i\right)^{1-\eta^i} \left(c_{b,t}^i\right)^{\eta^i} + \left(\vartheta_c^i\right)^{1-\eta^i} \left(c_{c,t}^i\right)^{\eta^i} \right]^{\frac{1}{\eta^i}} .$$

Here, $c_{j,t}^i$ denotes goods produced in j and consumed in i and $\eta^i \in (-\infty, 1)$ governs the elasticity of substitution between these goods, which equals $1/(1-\eta^i)$. As $\eta^i \to 0$, the function boils down to a Cobb Douglas aggregator. ϑ_j^i denotes the consumption bias of region i-households towards goods produced in j. Hence, ϑ_i^i can be interpreted as the home bias of region i. We assume that $\vartheta_a^i + \vartheta_b^i + \vartheta_c^i = 1$. Cost minimization of nominal consumption expenditures, $P_t^i c_t^i = P_t^{i,a} c_{a,t}^i + P_t^{i,b} c_{b,t}^i + P_t^{i,c} c_{c,t}^i$, implies

$$c_{j,t}^i = \vartheta_j^i \left(\frac{P_t^{i,j}}{P_t^i} \right)^{-\frac{1}{1-\eta^i}} \cdot c_t^i, \tag{33}$$

and consumer price index (CPI) is

$$P_t^i = \left[\vartheta_a^i \cdot \left(P_t^{a,i}\right)^{-\eta^i/(1-\eta^i)} + \vartheta_b^i \cdot \left(P_t^{b,i}\right)^{-\eta^i/(1-\eta^i)} + \vartheta_c^i \cdot \left(P_t^{c,i}\right)^{-\eta^i/(1-\eta^i)} \right]^{-\frac{1-\eta^i}{\eta^i}} . \tag{34}$$

We assume that an analogous aggregator holds for investment goods such that we can derive analogous equations for inv_t^i and $inv_{j,t}^i$. CPI-deflated net exports in region i, nx_t^i, are given by

$$\begin{aligned} nx_t^i = & \frac{P_t^{j,i}}{P_t^i} \cdot \left(c_{i,t}^j + inv_{i,t}^j\right) + \frac{P_t^{\tilde{j},i}}{P_t^i} \cdot \left(c_{i,t}^{\tilde{j}} + inv_{i,t}^{\tilde{j}}\right) - \frac{P_t^{i,j}}{P_t^i} \cdot \left(c_{j,t}^i + inv_{j,t}^i\right) \\ & - \frac{P_t^{i,\tilde{j}}}{P_t^i} \cdot \left(c_{\tilde{j},t}^i + inv_{\tilde{j},t}^i\right), \end{aligned} \tag{35}$$

where $i, j, \tilde{j} = a, b, c$, and $i \neq j \neq \tilde{j}$. Alternatively, net exports can also be written as domestic production minus domestic demand: $nx_t^i = P_t^{i,i}/P_t^i\,(y_t^i - g_t^i) - c_{i,t}^i - inv_{i,t}^i$. We note that $P_t^{j,i} = P_t^{j,j}$ whenever the regions belong to the monetary union (ie $i, j = a, b$); see Section 2.4. Whenever a monetary union-country imports from the rest of the world, $P^{i,c} = P^{c,c}/S_t$, and when the rest of the world imports from the monetary union, $P_t^{c,i} = S_t \cdot P_t^{i,i}$, with $i = a, b$.

Given net exports and using the no-arbitrage conditions (4), we get that net foreign assets in region i evolve according to

$$d_t^i = (1 + r_{t-1})\, d_{t-1}^i + nx_t^i. \tag{36}$$

Because international assets traded between regions are in zero net supply, it must hold that $P_t^a \cdot d_t^a + P_t^b \cdot d_t^b + P_t^c \cdot d_t^c = 0$. The current account-to-GDP ratio is given by $ca_t^{rat,i} = P_t^i \left(d_t^i - P_{t-1}^i / P_t^i \cdot d_{t-1}^i\right) / \left(P_t^{i,i} \cdot y_t^i\right)$.

Monetary policy: Following Ghironi (2008), Di Giorgio and Nistico (2013) and Kara and von Thadden (2016), monetary policy is modelled through a Taylor-type feedback rule (Taylor, 1993). We assume monetary policy targets a gross output price inflation of one. According to the Taylor rule, the nominal interest rate set by the central bank, i_t^i, is a function of consumer price inflation deviations from target, $\log\left(\pi_t^{cpi,i}\right)$, and the previous value of the nominal interest rate. Given that regions a and b form a monetary union with a common monetary policy, we assume that the monetary policy rate in the union, denoted by $i_t^u = i_t^a = i_t^b$, reacts to a population-weighted average of inflation deviations (following, among others, Stähler and Thomas, 2012, and Gadatsch, Hauzenberger, and Stähler, 2016). Denoting union-wide aggregates by the superscript u, these are given by $inf_t^u = rs_t^{a,b} \cdot \pi_t^{cpi,a} + (1 - rs_t^{a,b}) \cdot \pi_t^{cpi,b}$. Hence, monetary policy in $i = u, c$ is described by

$$\log\left(\frac{i_t^i}{i^i}\right) = \rho^{mp,i} \cdot \log\left(\frac{i_{t-1}^i}{i^i}\right) + \zeta^{\pi,i} \cdot \log\left(\pi_t^{ppi,i}\right), \tag{37}$$

where $\rho^{mp,i}$ is an autocorrelation parameter, $\zeta^{\pi,i} > 0$ is a direct feedback parameter to counteract deviations of inflation from target and the omission of the time-subscript denotes steady-state values.

Product market clearing: Product market clearing implies that whatever is produced in region i must be purchased somewhere around the world. Formally, we get

$$D_t^i \cdot y_t^i = \left(c_{i,t}^i + inv_{i,t}^i\right) + \left(c_{i,t}^j + inv_{i,t}^j\right) + \left(c_{i,t}^{\tilde{j}} + inv_{i,t}^{\tilde{j}}\right) + g_t^i. \tag{38}$$

This completes the model description. At equilibrium, government actions and optimizing decisions of workers, retirees, labor bundlers and firms must be mutually consistent at the aggregate level. As we allow for exogenously given, time-varying population dynamics, the economy may be subject to ongoing exogenous growth. A detrended version of the model is therefore given by considering a version of the model in which any potentially unbounded variable is expressed in region-i per-worker terms (see also Kara and von Thadden, 2016, and Schön and Stähler, 2020).

3 Calibration

We calibrate our model to an annual frequency. Population data is from OECD (2017) and the related data appendices. The model encompasses three regions which are Germany (region a), the rest of the Euro area (excluding Germany, region b) and the rest of the world (remaining OECD economies, region c).

Table 1 summarizes our assumptions determining the demographic situation in the initial steady state. In each region, individuals are born at the age of 20, stay on average $1/(1-\omega^i)$ years in the labor force and live on average $1/(1-\gamma^i)$ years after retirement. We choose ω^i such that individuals retire at the age of 65, in steady state. For simplicity, we further assume $n^{w,i} = 0$ to be the steady-state growth rate of the working-age population. It varies over time when conducting the aging simulations (see Section 4.2), however.[7] Given ω^i and population growth $n^{w,i}$, the survival probabilities γ^i are used to match all region-i old-age dependency ratios of the year 1999 – the base year for our analysis. Calculations based on OECD (2017) suggest these ratios to be $\Psi^a = 0.2591$, $\Psi^b = 0.2639$ and $\Psi^c = 0.1989$ for the individual regions. Similarly, we set the relative size of the working-age population in the initial steady state to $rs^{a,b} = 0.3455$, $rs^{a,c} = 0.093$ and $rs^{b,c} = 0.2693$ in accordance with the data.

Table 1: Initial steady-state population dynamics

Variable/Parameter	Symbol	Value		
		Germany	Rest of EA	Rest of world
WAP growth rate	n^w	0.0	0.0	0.0
Retirement probabilities	$1-\omega$	0.0222	0.0222	0.0222
Old age dependency ratio^T	Ψ	0.2591	0.2639	0.1989
Survival probabilities^e	γ	0.9232	0.9248	0.9085
Relative size Germany/RoEA^T	$rs^{a,b}$		0.3455	
Relative size Germany/RoW^T	$rs^{a,c}$		0.0930	
Relative size RoEA/RoW^T	$rs^{b,c}$		0.2693	

Source: OECD (2017). The superscript T marks targets, e endogenously derived values to meet these targets. Parameters without a mark are set exogenously as described in the text. We omit the country index i for convenience.

We assume the structural parameters of the model as indicated in Table 2. Following Ferrero (2010), we set standard values from the business cycle literature in gerneral (see also Cooley and Prescott, 1995). In particular, we target a world asset market-clearing real interest rate of 4%. Together with the demographic structure described above, this implies a discount factor of $\beta \approx 0.95$ in each region. We calibrate the elasticity of intertemporal substitution to $\sigma = 0.5$, which has become standard in this class of models since Auerbach and Kotlikoff (1987). With respect to international trade, we follow Schön and Stähler (2020) and assume a substitution elasticity between home and foreign goods of 1.5. According to Balta and Delgado (2009), home bias for goods in a typical EU country

[7] As discussed above, working-age population growth has to be equal across regions in steady state (see Section 2.1). According to OECD (2017)-data, this is not the case in our simulation period. Therefore, we have to make a simplifying assumption here. We opt for assuming that a steady state is characterized by constant variables, including a constant population. Assuming positive steady-state population growth would not change our results qualitatively if population growth rates are equal across regions, in the initial and the final steady state.

is a bit above 60%, and the import content from other European economies amounts to about 10%. In line with Schön and Stähler (2020), we hence set a home bias parameter of 0.6 for domestic goods in both European economies (implying a domestic consumption share of about two thirds when including public consumption) and a bias towards the goods produced in the other European region of 0.1. When setting the relative prices between all regions equal to one in the initial steady state, this allows us to derive the biases towards the different regional consumption/investment goods in the rest of the world (see Table 2 for the values and Schön and Stähler, 2020, for a detailed description how to derive them formally).

In intermediate goods production, we choose a labor share of $\alpha = 2/3$, and assume that capital depreciates at an annual rate of $\delta = 10\%$. To capture the relationship of per-capita consumption discussed in Gadatsch et al. (2016), we assume different TFP scaling parameters, $\epsilon^{a,a} = 1, \epsilon^{a,b} = 0.97$ and $\epsilon^{a,b} = 0.925$. The investment adjustment cost parameter is set to 4.5, which is a standard value in the DSGE literature (see also Schön and Stähler, 2020). We follow Kara and von Thadden (2016) and set $\theta_p^i = 10$, which determines the price markup. We set a Calvo parameter of 0.3. This value reflects an average price duration of almost one and a half years, which falls in the range of standard calibrations.

Table 2: Structural parameters

Variable/Parameter	Symbol	Value		
		Germany	Rest of EA	Rest of world
Preferences:				
Discount rate^e	β	0.9507	0.9507	0.9507
Elasticity of intertemporal substitution	σ	0.5	0.5	0.5
Substitution elasticity home/foreign	$1/(1-\eta)$	1.5	1.5	1.5
Bias for goods produced in Germany	ϑ_a	0.6^T	0.1^T	0.0144^e
Bias for goods produced in rest of EA	ϑ_b	0.1^T	0.6^T	0.1001^e
Bias for goods produced in rest of world	ϑ_c	0.3^e	0.3^e	0.8855^e
Production:				
Cobb-Douglas share of labor	α	2/3	2/3	2/3
Capital depreciation	δ	0.1	0.1	0.1
Total factor productivity	ϵ^a	1.0	0.97	0.925
Investment adjustment costs	κ_{inv}	4.5	4.5	4.5
Demand elasticity for intermed. goods	θ_p	10	10	10
Calvo survival probability	κ_p	0.3	0.3	0.3
Labor Market:				
Unemployment rate^T	$\bar{u}$	0.0818	0.0946	0.0753
Matching elasticity	η^m	0.5	0.5	0.5
Workers' bargaining power	ζ	0.5	0.5	0.5
Wage adjustment costs	κ_w	50	50	50

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Variable/Parameter	Symbol	Value		
		Germany	Rest of EA	Rest of world
Separation rate[e]	s	0.0888	0.0888	0.0888
Matching efficiency[e]	κ^m	0.7066	0.6779	0.7224
Vacancy filling probability[T]	$\bar{vf}$	0.8	0.8	0.8
Job finding probability	$\bar{j}$			
Vacancy positing costs[e]	κ^v	0.3403	0.3640	0.3196

Source: The superscript T marks targets, e endogenously derived values to meet these targets. Parameters without a mark are set exogenously as described in the main text. We omit the country index i for convenience.

The labor market is characterized in Germany by a steady state unemployment rate of 8.18%. In the rest of Europe and in the remaining OECD economies the unemployment rate is, respectively, 9.46% and 7.53% (see also Moyen, Stähler, and Winkler, 2019). The elasticity of the matching function $\eta^{m,i}$ is set to 0.5 in line with DSGE model estimates based on European data of Christoffel et al. (2009). In addition, we calculate the separation rate to be 0.0888, based on their estimates and taking into account the retirement probability. This translates into an quarterly job termination rate of 0.03. With an assumed vacancy filling probability of 0.8, we are able to calculate the matching efficiency and vacancy posting cost parameters as well as the shares of short-term unemployed workers. The wage adjustment cost parameter is set to 50, which is in the range of values often assumed for the Euro area (see Moyen et al., 2019, for a discussion).

Policy parameters are summarized in Table 3. The replacement rate for pension benefits is set to $\mu^a = 0.51$ in Germany and $\mu^i = 0.48$, with $i = b, c$ for the remaining economies. The government spending-to-GDP ratio is set to 0.18 in all regions, which is a standard value in the literature. The debt-to-GDP ratios in the year 2000 are 60%, 70.7% and 69.8% for Germany, the rest of the Eurozone and the rest of the world in line with IMF (2019). For setting the consumption, capital and the labor income tax as well as the social contribution rates, we follow Gadatsch et al. (2016). All these policy values may be debatable, inter alia depending on data sources and/or definitions (as we are working with implicit average tax and replacements rates, for example). However, changing their exact values within a plausible range (say, tax rates not exceeding 60%) does not change our results qualitatively. Quantitative changes are also minor. We finally set the lump-sum tax to close the governments' budgets. As they are negative in all regions, it is a per-capita transfer, not a tax, in our model.

The social security policies in our model, namely short- and long-term unemployment benefits, are calibrated in line with Moyen and Stähler (2014). In particular, the short-term unemployment benefit replacement rate amounts to 60% in all regions, while the long-term benefit replacement rate is 53%, 46% and 40% in Germany, the rest of the Euro area and the remaining OECD economies. We set the average duration of being eligible for short-term unemployment benefits to $\vartheta^i = 1/3$, for all regions $i = a, b, c$. Finally, in the Taylor rule, we opt for an autocorrelation parameter of 0.7 and an inflation coefficient of 2. The inflation target is zero.[8]

Table 3: Policy parameters

Variable/Parameter	Symbol	Value		
		Germany	Rest of EA	Rest of world
Fiscal Policy:				
Replacement rate for pension benefits^T	μ	0.51	0.48	0.48
Government spending share^T	$\bar{g}y$	0.18	0.18	0.18
Debt-to-GDP ratio^T	ω^b	0.6	0.707	0.698
Consumption tax rate^T	τ^c	0.183	0.196	0.15
Capital tax rate^T	τ^k	0.2143	0.3158	0.2236
Labor income tax rate^T	τ^l	0.3039	0.2765	0.2543
Social contribution rate^T	τ^{sc}	0.1667	0.3280	0.153
Lump-sum tax^e	$\bar{\tau}$	-0.0685	-0.1149	-0.0327
Social Security:				
UI replacement rate (short-term)^T	$\bar{\kappa}^{B,s}$	0.6	0.6	0.6
UI replacement rate (long-term)^T	$\bar{\kappa}^{B,l}$	0.53	0.46	0.4
Duration of short-term benefits^T	$\bar{\vartheta}$	1/3	1/3	1/3
Monetary Policy:				
Autocorrelation in Taylor rule	ρ^{mp}	0.7	0.7	0.7
Inflation coefficient in Taylor rule	ζ^{π}	2.0	2.0	2.0

Source: The superscript T marks targets, e endogenously derived values to meet these targets. Parameters without a mark are set exogenously as described in the main text. We omit the country index i for convenience.

4 Analysis

In this section, we present our analysis step-wise. In a first step, we replicate the analysis by Gadatsch et al. (2016) and simulate the *Agenda 2010* reform measures in our model framework. In a second step, we introduce population aging and pension reforms. In a third step, we take into account the developments of diverging debt-to-GDP ratios in Germany, the rest of the Euro area and the remaining OECD economies over time. In the last step, we compare the resulting model-based current account developments to those that we observe in the data and discuss potential further drivers.

[8] Assuming an inflation target of zero is mainly done for technical reasons. It facilitates the steady-state calculation of β to match a steady-state world interest rate of 4% in a multi-country model. Given the model structure, an inflation target of close to 2% (as is announced by the ECB, for example) should not change our results, but deriving the steady state would become much more difficult (see also Schön and Stähler, 2020, for a discussion).

4.1 The impact of the agenda reforms

Reform implementation: The *Agenda 2010* reforms consisted of multiple fiscal and labor market reforms which changed the mix of taxes, increased labor market matching efficiency and reduced the generosity of the unemployment insurance system. More precisely, the reform measures are

i.) a tax shift from social security contributions (for employees and employers) to consumption taxation from 1999 to 2003, which we term fiscal devaluation ("Deval 99-03" in the Figures below),

ii.) a reduction in the labor and capital income tax rates in 2001 (termed "Tax 01"),

iii.) a reduction in the labor income tax rate and an improvement in the labor market matching efficiency (Hartz III) in 2004 (termed "Tax 04 and H3"),

iv.) a further cut in labor income taxation and a reduction in the generosity of the unemployment benefit system (Hartz IV; termed "Tax 05 and H4"),

v.) another fiscal devaluation in 2007 (termed "Deval 07") and

vi.) a reduction in capital income taxation in 2008 (termed "Cap 08").

Table 4 summarizes the induced changes in the model parameters and the timing. Given the similarity of the general economic structure of our model to Gadatsch et al. (2016), the implemented structural changes are analogous to how the agenda reforms are implemented there. A detailed description of the reform measures and how to implement them in a macro DSGE model can also be found in Röhe and Stähler (2018).

Table 4: Agenda 2010 reform measures and timing

Year	$d\tau^c$	$d\tau^{sc}_{employee} = d\tau^l$	$d\tau^{sc}_{employer}$	$d\tau^l$	$d\tau^k$	$d\kappa^m$	$d\vartheta$	$d\rho^{B,l}$
1999	+0.51pp	-0.42pp	-0.42pp					
2000	+0.22pp	-0.15pp	-0.15pp					
2001	+0.23pp	-0.15pp	-0.15pp	-1.59pp	-1.08pp			
2002	+0.22pp	-0.15pp	-0.15pp					
2003	+0.22pp	-0.15pp	-0.15pp					
2004				-0.75pp		+5.00%		
2005				-2.12pp			+33.33pp	-8pp
2006								
2007	+1.45pp	-0.35pp	-0.35pp					
2008					-0.64pp			

Source: Gadatsch et al. (2016), adjusted for annual calibration if necessary.

As in Gadatsch et al. (2016), we assume that the single reform measures were not anticipated ex-ante, and anticipation effects are only relevant in case of multi-year reforms (the tax shift from 1999 to 2003). Therefore, in every period in which a reform is implemented, we solve the model fully non-linearly under perfect foresight for *this* specific reform only (assuming that households are not aware of the following reform). When the next reform is activated, we start the simulation at the corresponding point in the transition path of the previous reforms (and not at the steady state; see also Gadatsch et al., 2016, for a more detailed explanation of how this is implemented technically, we do exactly the same here). In order to guarantee stationarity of public debt, we assume that only lump-sum taxes respond to close the government's budget. All other fiscal instruments are kept constant (and only change according to their potentially new long-run target as summarized in Table 4, respectively).

Results: Figures 1 and 2 show the three main result of this subsection:[9] First, we observe positive domestic effects. In particular, output, consumption, savings and investments in domestic physical capital increase while unemployment falls. We therefore acknowledge a stimulating impact of the agenda reforms in Germany. The main reason for this is that all the reform measures have a production cost-dampening effect (as either effective wage payments or interest rate payments for capital rental falls). Comparing these with the representative agent economy of Gadatsch et al. (2016), our results are very close the their simulated responses. This indicates that the domestic impact in our model is generally in line with those in standard open-economy DSGE models.

Second, all reform measures increase the incentives for German households to save (see Figure 1).[10] Although the reforms also augment the incentives to invest in domestic capital, as described in the previous paragraph, the former effect is stronger than the latter such that a part of the additional savings is invested internationally. Hence, the *Agenda 2010* measures have a persistent positive impact on the German net foreign asset and current account positions, as we can see in Figure 2.

We can assert that the effects on the current account in our model are large compared to those in a conventional DSGE model. They amount to more than 25 times the effects observed in an analogous model presented by Gadatsch et al. (2016) which does not include an endogenous savings motive. The effects are, nevertheless, still rather small relative to the data, as we discuss in Section 4.4. Higher effects relative to a conventional DSGE model are driven by the fact that the reforms incentivize Germans to save more.

Third, contrary to what is found in standard open-economy DSGE models, we observe that the *Agenda 2010* reform measures have a (small) negative effect on foreign consumption (see Figure 2). Because German price competitiveness improves (due to the reform-induced reduction in production costs), households substitute German for foreign goods. Hence, on impact and for some time thereafter, foreign output falls. However, as private consumption and investment demand in Germany picks up sufficiently, this negative price effect is overcompensated for by the positive income effect in Germany. Higher demand of German households – also for foreign goods – eventually improves output in the foreign economies, too. In a standard open-economy framework, this spills over to

[9] To save space, we keep the description of the Agenda effects short here. In the Appendix, we provide an in-depth discussion along the lines of Gadatsch et al. (2016) and also compare our results to theirs.

[10] Relatively lower wages, primarily induced by the labor market reforms, but also by tax shifts, reduce pension payments. At the same time, consumption becomes more expensive when consumption taxation rises. All this augments the incentive for households to save (more) to smooth consumption during the retirement period.

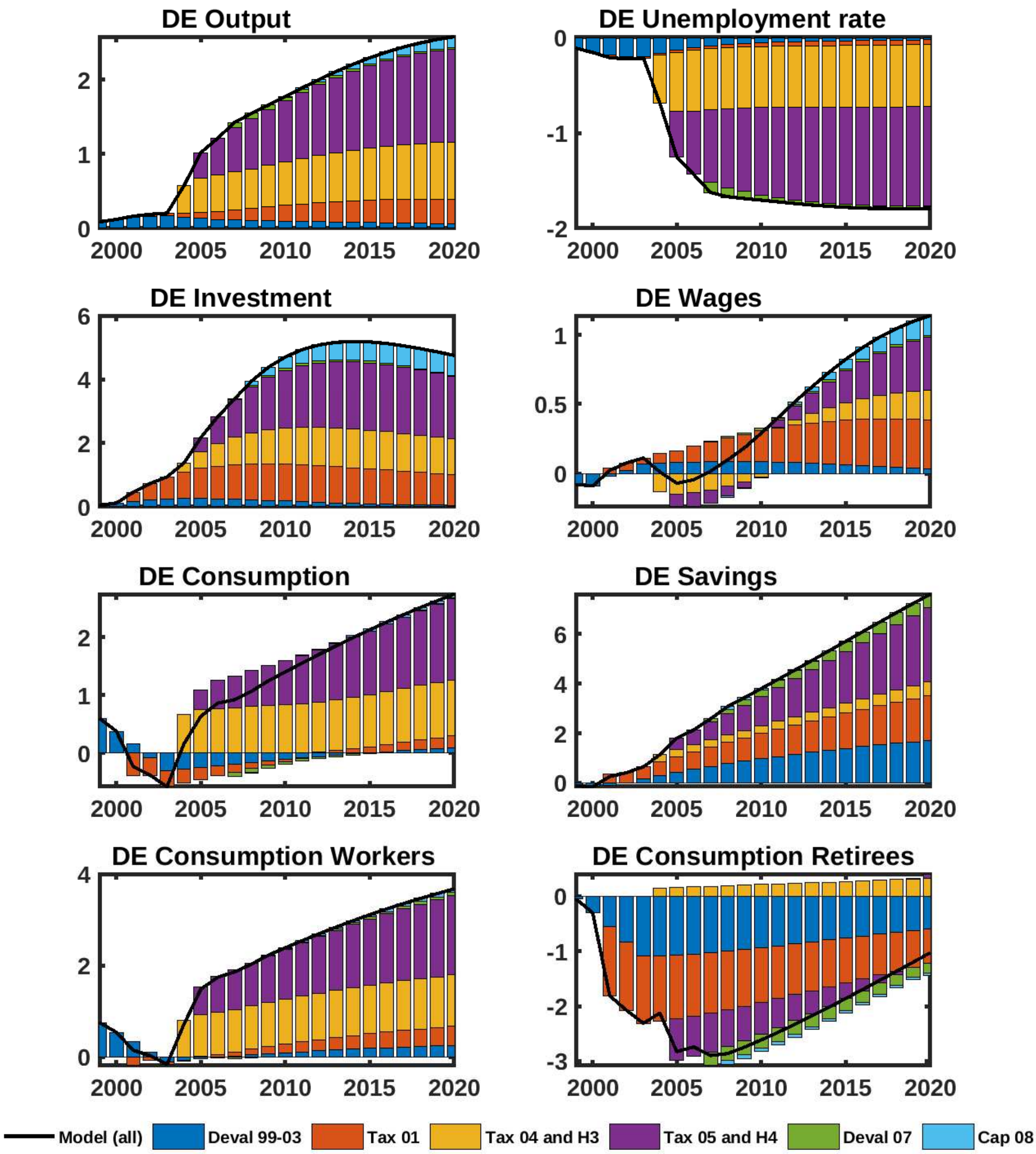

Figure 1: Domestic effects of Agenda 2010 reforms

Notes: Figure plots agenda reform-induced evolution of key domestic (macroeconomic) variables. Variables are shown in percentage deviations to initial steady state (percentage point deviations for rates and ratios). The black solid line shows the path for the entire agenda reform, the colored bars the single reform steps as indicated.

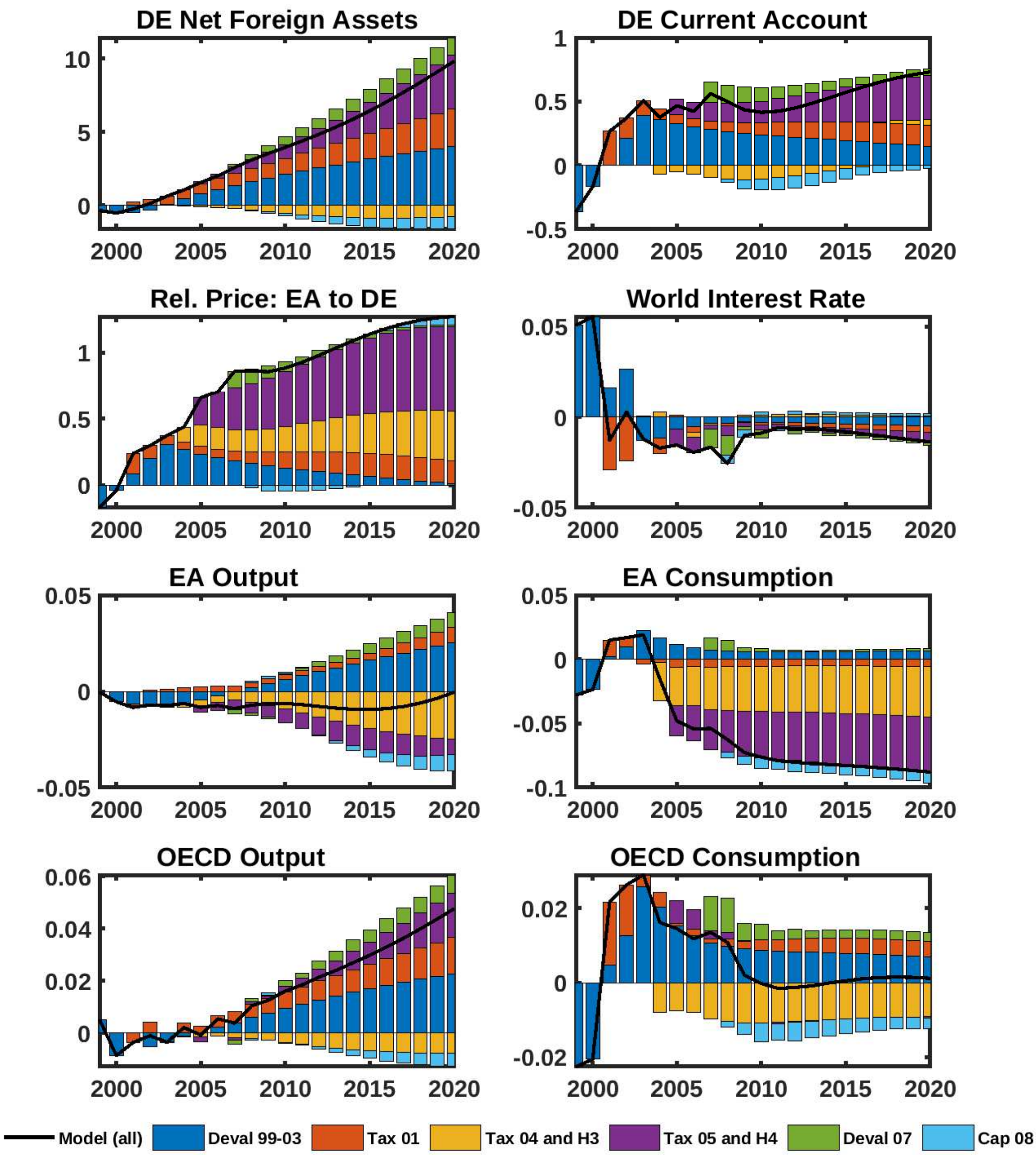

Figure 2: International effects of Agenda 2010 reforms

Notes: Figure plots agenda reform-induced evolution of key international variables. EA stands for Euro area excluding Germany and OECD indicates the remaining OECD countries. Variables are shown in percentage deviations to initial steady state (percentage point deviations for rates and ratios). The black solid line shows the path for the entire agenda reform, the colored bars the single reform steps as indicated.

foreign private consumption. In our framework, it does not fully. The reason is that the amount tradable international assets held in Germany has increased. As the foreign economies need to pay interest on these assets held by Germans, part of their additional income (i.e. higher foreign output) is transferred to Germany. This transfer is slightly larger than the increase in output. Therefore, private foreign consumption eventually falls.

Summarizing, we find that all measures of the *Agenda 2010* positively affect German economic activity domestically, improve its price competitiveness and increase the current account.[11] These are findings that we can also find in standard open-economy models (such as Gadatsch et al., 2016), but the impact on the current account in our framework is much larger because (individual) savings and, thereby, net foreign assets are an additional state variable. In addition, we find small negative consumption spillover to the foreign regions, which is contrary to what is found in standard open-economy models. The reason is that foreign economies need to transfer part of their output to Germany in form of interest payments on a (relatively) higher German net foreign asset position.

4.2 The impact of aging and pension reforms

Demographic trends and pension reforms: The population developments from 2000 to 2080 around the world as projected by OECD (2017), are plotted in Figure 3.

Working-age population is defined as individuals aged 20 to 64, retirees are aged 65 and above and the old age dependency ratio is defined as the share of population above 65 divided by the population share between 20 and 65 (see also Schön and Stähler, 2020). In all regions, the old-age dependency ratio is projected to increase notably (it more than doubles), and the working-age population shrinks in Germany and the rest of the Euro area. Compared to the other regions, population aging happens faster in Germany initially. But the other regions tend to pick up after around 2040.

To introduce these developments in our model, it seems natural to use the growth rate for the working-age population, $n_t^{w,i}$, to match data-implied working-age population growth rates. Given that we assume zero steady-state population growth, we set $n_t^{w,i} = \epsilon_t^{nw,i}$, where $\epsilon_t^{nw,i}$ is a shock that is used to generate the growth rates observed in Figure 3. To match the old age dependency ratio, we assume that the survival probability evolves according to $\gamma_t^i = \mathbb{I}_t \cdot \left(\gamma^i + \epsilon_t^{\gamma,i}\right) + (1 - \mathbb{I}_t) \left[(1 - \rho^{\gamma,i})\,\gamma^i + \rho^{\gamma,i} \cdot \gamma_{t-1}^i\right]$. Here, γ^i is the steady-state survival probability and $\epsilon_t^{\gamma,i}$ is a shock that is used to generate the old age dependency ratio observed in the data (using equation (1) and taking into account the population growth rate $n_t^{w,i}$). $\mathbb{I}_t$ is an indicator function equal to one for $t \in [2000, 2080]$ and zero otherwise.[12]

To implement the major German pension reforms undertaken in Germany during the the first decade of the new millennium, namely the gradual cut in the replacement rate by 3 percentage points from 2004 until 2030 and the gradual increase in the statutory

[11] There are two exceptions: higher matching efficiency and lower capital taxation. They augment domestic capital investments above average and, thus, dampen the need to save internationally, even though domestic savings increase; see Appendix for details.

[12] This implies that the survival probability will gradually return to its initial steady-state value with persistence $\rho^{\gamma,i}$ after our simulation period. This simulation strategy follows Carvalho et al. (2016). We set $\rho^{\gamma,a} = 0.8$, $\rho^{\gamma,b} = 0.85$ and $\rho^{\gamma,c} = 0.9$ following Schön and Stähler (2020).

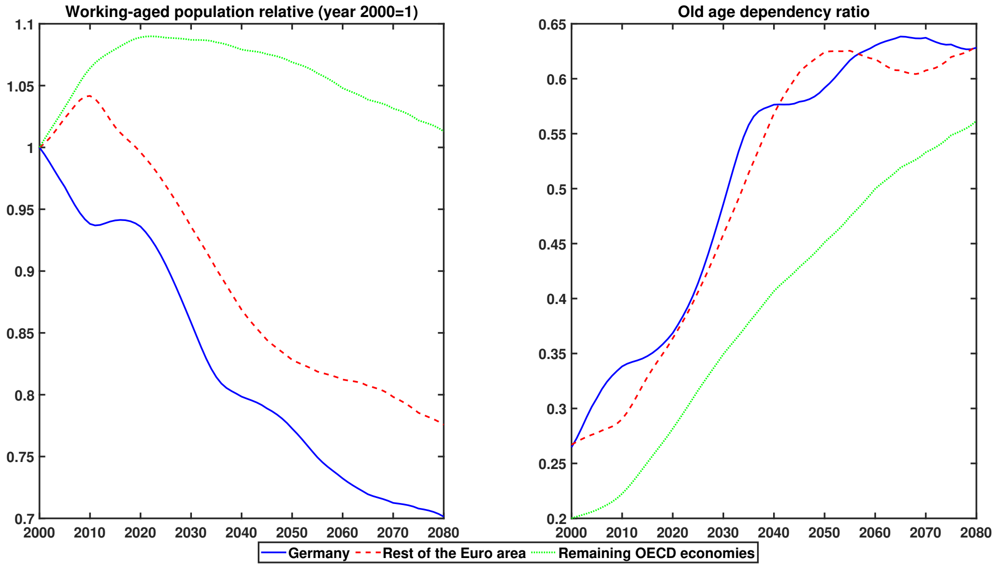

Figure 3: Population dynamics

Notes: Figure plots (projected) population developments for Germany (blue solid lines), the rest of the Euro area excluding Germany (red dashed lines) and the remaining OECD countries (greed dotted lines) from 2000 to 2080; source: OECD (2017). Working-age population in 2000 is normalized to one in the first subplot to make results comparable more easily. It was 64.432 million (Germany), 187.629 million (rest of the Euro area) and 700.785 million (remaining OECD countries).

retirement age from 65 to 67 years announced in 2006 and starting in 2012, we assume that (i.) the steady-state pension replacement rate μ^a is reduced from 51% to 48% in 2004. The gradual decline is simulated by assuming that $\mu_t^a = (1 - \rho^{\mu,a})\,\mu^a + \rho^{\mu,a} \cdot \mu_{t-1}^a$, with $\rho^{\mu,a} = 0.75$ to reach the new steady-state replacement rate by 2030. For the gradual increase in the retirement age, we assume that the probability for workers to remain a worker evolves according to $\omega_t^a = \mathbb{I}_t \cdot \omega^{a,initial} + (1 - \mathbb{I}_t) \cdot \left[(1 - \rho^{\omega,a})\,\omega^{a,final} + \rho^{\omega,a} \cdot \omega_{t-1}^a\right]$, where $\omega^{a,final} > \omega^{a,initial}$ and $\rho^{\omega,a} = 0.7$ such that the retirement age of 67 is reached by 2025. To capture the fact that the reform was pre-announced in 2006 (and, therefore, anticipation effects are likely), we set $\mathbb{I}_t$ to one for $t \in [2006, 2012]$ and zero otherwise. We then re-simulate the agenda reform (discussed in the previous section), now including population aging and pension reforms.

Results: Figures 4 and 5 show the evolution of key variables analogous to Figure 1 and 2 of the previous section. As has extensively been discussed in the literature, households start increasing their savings effort and reduce consumption once they become aware of population aging (blue bars in Figure 4; see also Carvalho et al., 2016, Papetti, 2019, Schön and Stähler, 2020, and Sudo and Takizuka, 2019). This is true for workers and retirees. They both reduce their marginal propensities to consume (not shown here). Retirees do so more than workers because they are more directly affected. The time span they spend in retirement is extended. Workers anticipate that they will retire eventually, so the effect is only indirect (and smaller). The positive impact of the *Agenda 2010* on aggregate per-capita consumption and output is overcompensated for by the negative effects resulting from population aging (see also Aksoy, Basso, Smith, and Grasl, 2019).[13] The increase in savings, which also happens in the foreign regions (as they also face population aging), significantly reduces the market clearing real interest rate and makes capital investment more attractive. However, in Germany, the increase in domestic investment falls short of the increase in domestic savings, and Germany starts exporting capital as a result of aging. The net foreign asset position as well as the current account increase notably. The fall in working-age population growth in Germany, which at least temporarily increases in the foreign regions, makes it harder for firms to fill a vacancy as the number of (unemployed) workers gradually declines. Higher wages and higher search costs eventually reduce German international price competitiveness.

The reduction in the pension benefit replacement rate amplifies the incentive for German households to save and reduces consumption further (green bars in Figure 4 and 5). Now, individuals not only spend more time in retirement on average, they also receive relatively lower benefits per period (as the wage increase does not compensate for the reduction in the replacement rate). This translates into an additional increase in net foreign assets and the current account. The opposite is true for the increase in retirement age (yellow bars in Figure 4 and 5). As German households anticipate in 2006 already that retirement age will (start to) increase in 2012, and given that we perform a perfect foresight simulation, the effects become notable in 2006 already. An interesting observation we can make in passing is that pension reforms in Germany do not (or only mildly) affect the market clearing real interest rate. The main driver of this is population aging itself.

We also disentangle the aging shock of each region. When only considering aging in Germany, while assuming the population structure in the rest of the world to remain as it is in steady state, the effect of aging on the German current account is larger on impact. Taking into account aging around the world reduces the positive impact because people in the rest of the world also increase their saving efforts, which reduces the world interest rate and the attractiveness for Germans to invest abroad. Because the aging process starts earlier in German than it does in the other regions, capital exports from Germany to the rest of the world are positive until around mid-century and turn negative thereafter. Schön and Stähler (2020) provide an in-depth discussion of this issue. To save space, the figures showing simulation results with regional aging effects are relegated to the appendix.

4.3 The impact of the fiscal stance

Public debt and the fiscal stance: Figure 6 plots the public debt-to-GDP ratios for Germany, the rest of the Euro area excluding Germany and the remaining OECD countries from 2000 to 2018 as reported by IMF (2019). We take these number to approximate the differences in the fiscal stance between regions.

Before the great recession, the regional differences in the debt-to-GDP ratios were,

[13] While output per-capita falls, output per worker (not shown in the graphs) increases. The latter results from the fact that, due to the scarcity of labor, production becomes more capital intense. The former is a result of the fact that population composition shifts towards more retirees who do not participate in the production process. A more in-depth discussion can also be found in Schön and Stähler (2020), who use an analogous model without a search and matching labor market.

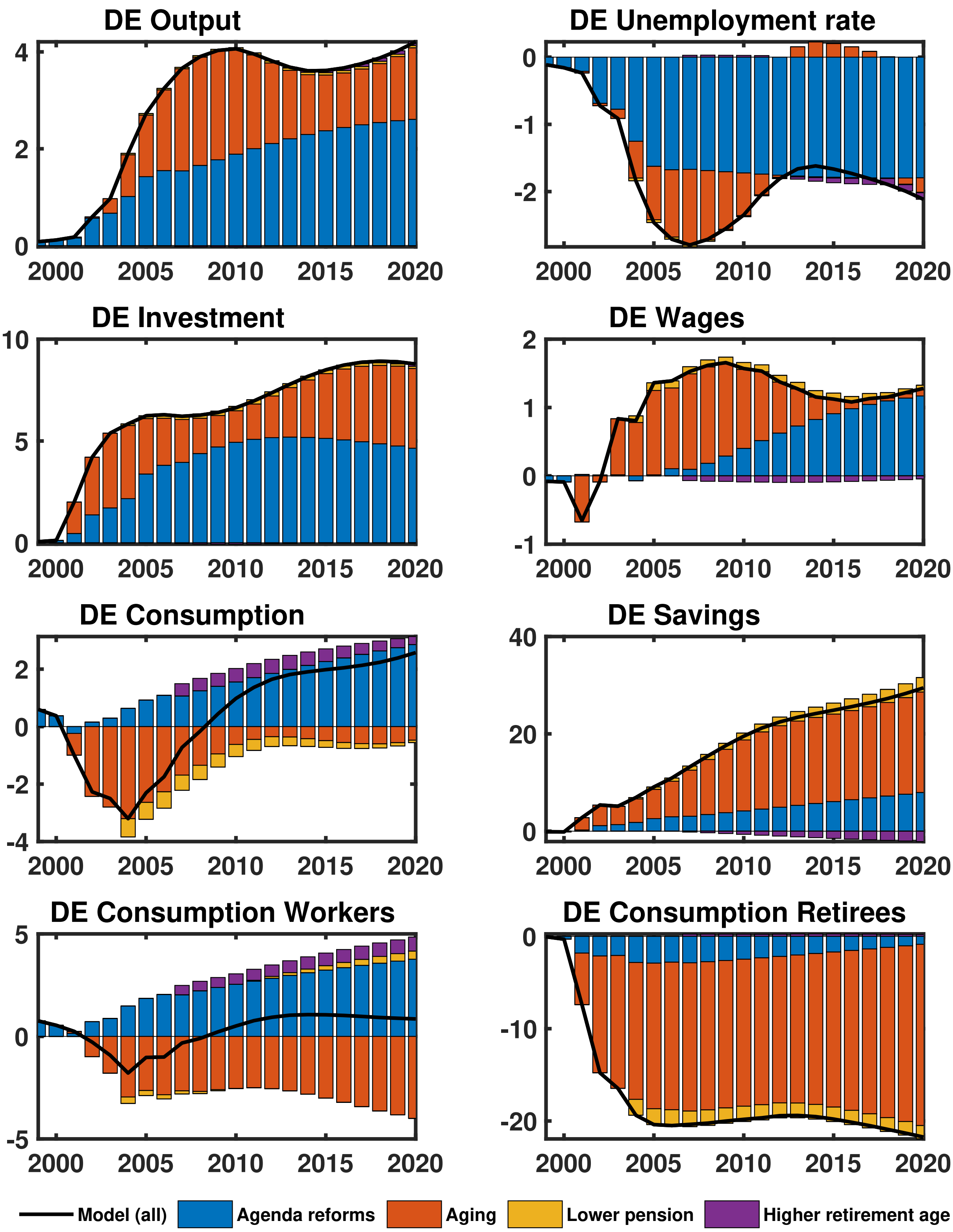

Figure 4: Effects of reform agenda, aging and pension reforms on key German macro variables

Notes: Figure plots agenda reform, aging and pension reform-induced evolution of key domestic (macroeconomic) variables in Germany. Variables are shown in percentage deviations to initial steady state. The black solid line shows the aggregate path for the entire agenda reform, aging and pension reform; the colored bars the single reform steps as indicated and described in the main text.

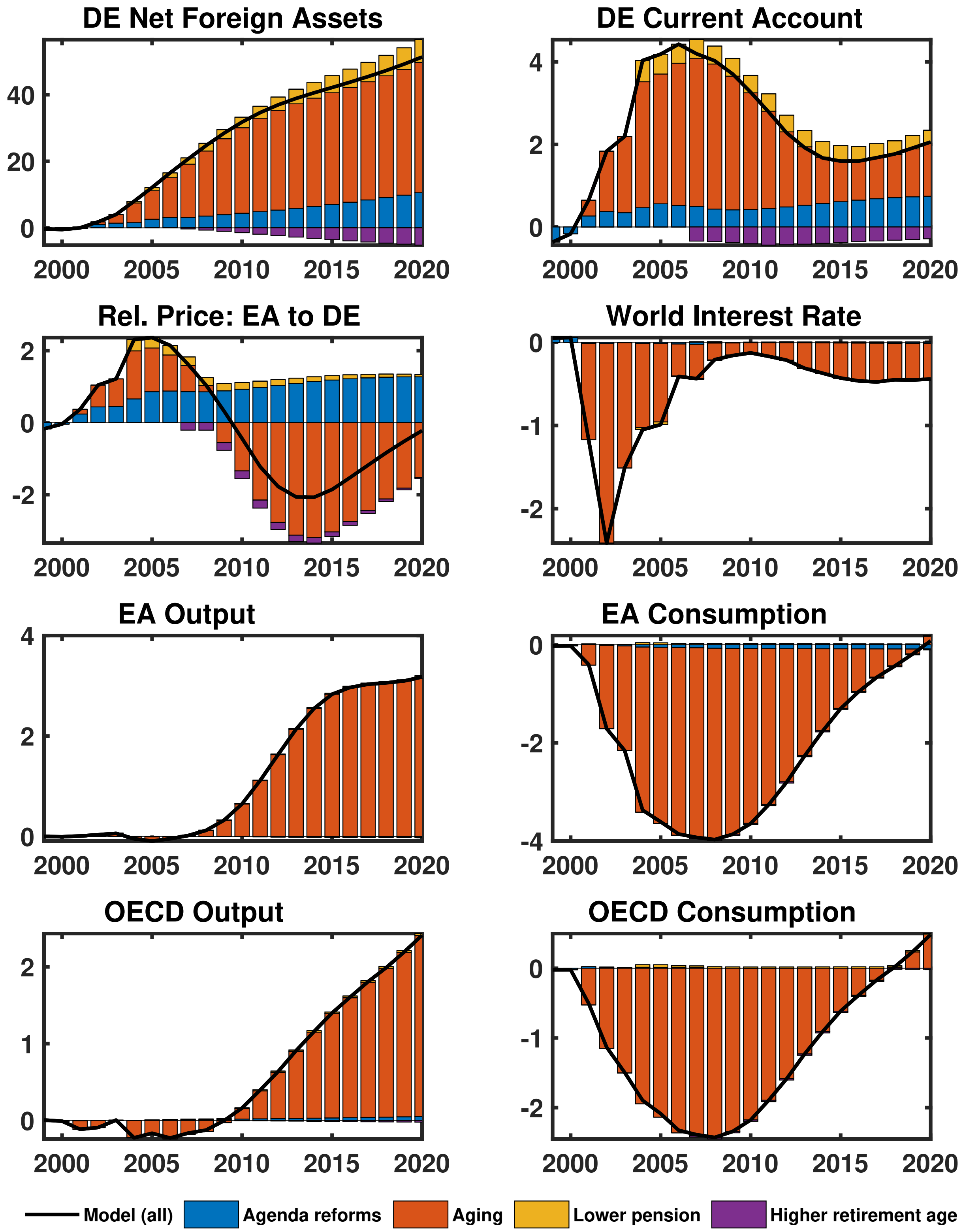

Figure 5: Effects of reform agenda, aging and pension reforms on key international variables

Notes: Figure plots agenda reform, aging and pension reform-induced evolution of key international variables. EA stands for Euro area excluding Germany and OECD indicates the remaining OECD countries. Variables are shown in percentage deviations to initial steady state. The black solid line shows the aggregate path for the entire agenda reform, aging and pension reform; the colored bars the single reform steps as indicated and described in the main text.

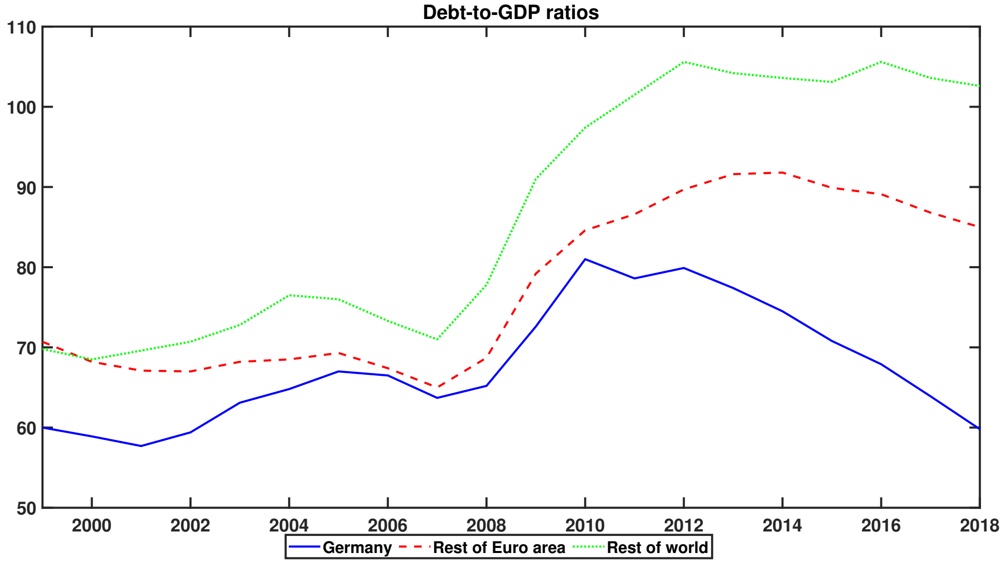

Figure 6: Public debt-to-GDP ratios

Notes: Figure plots the public debt-to-GDP ratios for Germany (blue solid lines), the rest of the Euro area excluding Germany (red dashed lines) and the remaining OECD countries (greed dotted lines) from 2000 to 2018; source: IMF (2019).

with some relatively minor fluctuations, more or less stable. They increased notably thereafter. While the debt-to-GDP ratios remained high in the rest of the Euro area and the remaining OECD economies, the ratio significantly fell in Germany until 2018 (after peaking in 2010). Germany again reached the public debt-to-GDP ratio of 1999 in 2018. According to IMF (2019), the debt ratio was still 1.3 (almost 1.5) times the pre-recession levels in the rest of the Euro area (remaining OECD countries) at that time.

To implement these developments into our model, we assume that the parameter determining the targeted debt-to-GDP ratio in our model, $\omega^{b,i}$, evolves according to $\omega_t^{b,i} = \mathbb{I}_t \cdot \left[\omega^{b,i} + \epsilon_t^{\omega^{b,i}}\right] + (1 - \mathbb{I}_t) \cdot \left[(1 - \rho^{\omega^{b,i}})\, \omega^{b,i,final} + \rho^{\omega^{b,i}} \cdot \omega_{t-1}^{b,i}\right]$. Again, $\epsilon_t^{\omega^{b,i}}$ is a shock that is used to generate the debt-to-GDP ratios observed in the data. $\mathbb{I}_t$ equals one for $t \in [2000, 2018]$ and zero otherwise.

In what follows, we will differentiate between two scenarios. In the first scenario, we assume that the debt-to-GDP ratio will eventually return to its initial steady-state value, i.e. $\omega^{b,i,final} = \omega^{b,i}$, with $\rho^{\omega^{b,i}} = 0.85$. In the second scenario, we assume that the debt-to-GDP ratio will stay at the final level shown in Figure 6, i.e. $\omega^{b,a,final} = 0.598$, $\omega^{b,b,final} = 0.850$ and $\omega^{b,c,final} = 1.026$.[14]

Results: Figures 7 and 8 show the impact of implementing these (admittedly stylized) differences in the fiscal stance on key macroeconomic variables. We see that, for households to invest into additional government bonds, the market-clearing world interest rate

[14]Note that, by increasing $\omega_t^{b,i}$ and assuming that fiscal policy adjusts by changing T_t^i, we take a rather stylized stance on fiscal policy. What we are interested in is the change in the possibility to invest in domestic (public) bonds. If we were to assume the structure of public spending and/or taxes changed the debt-to-GDP ratios, results could be amplified (as suggested by the analysis in Section 4.1).

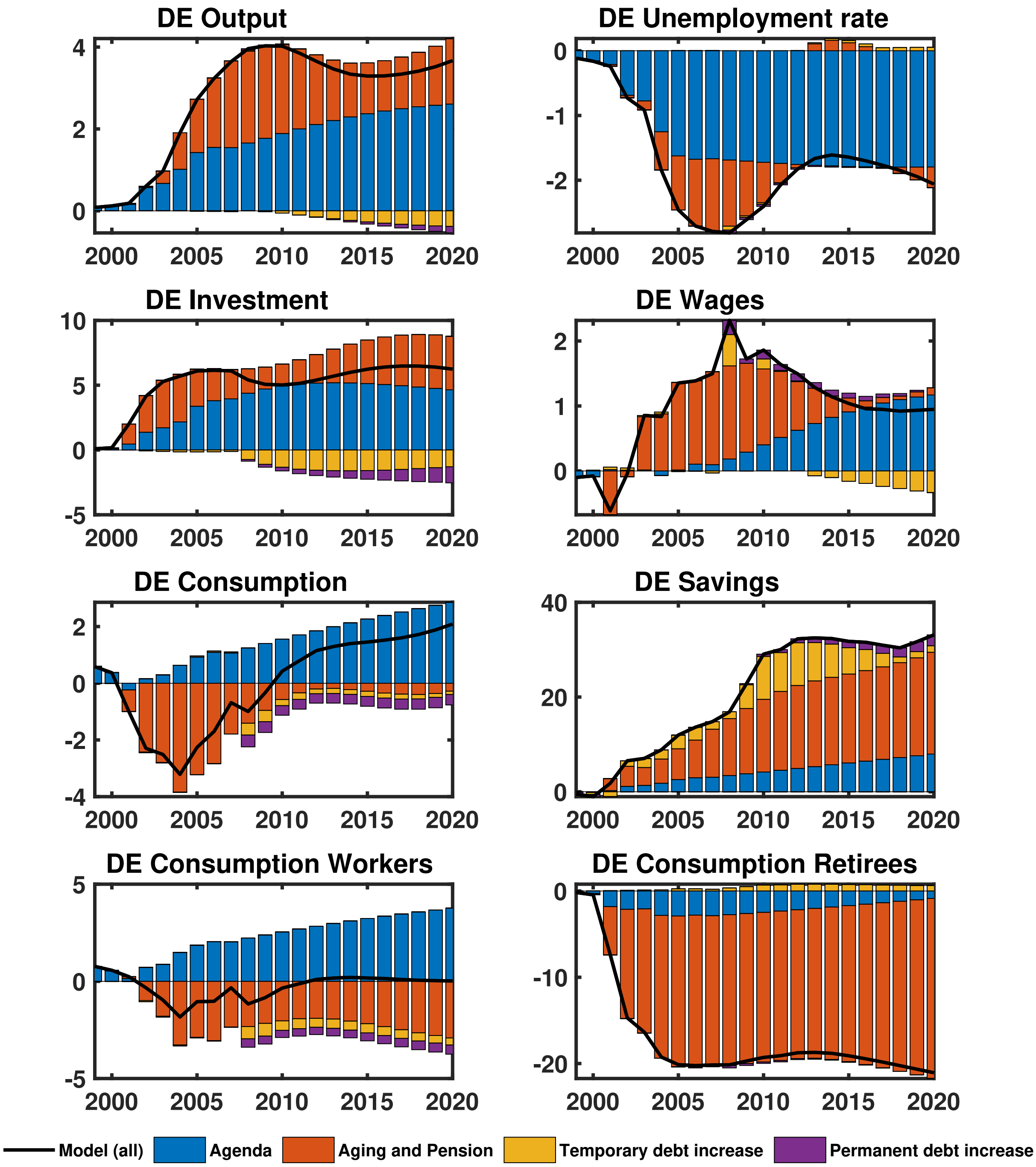

Figure 7: Effects of reform agenda, aging, pension reforms and fiscal stance on key German macro variables

Notes: Figure plots agenda reform, aging and pension reform-induced evolution of key macroeconomic variables in Germany. Variables are shown in percentage deviations to initial steady state. The black solid line shows the aggregate path for the entire agenda reform, pension reforms and the fiscal stance; the colored bars the single reform steps as indicated and described in the main text.

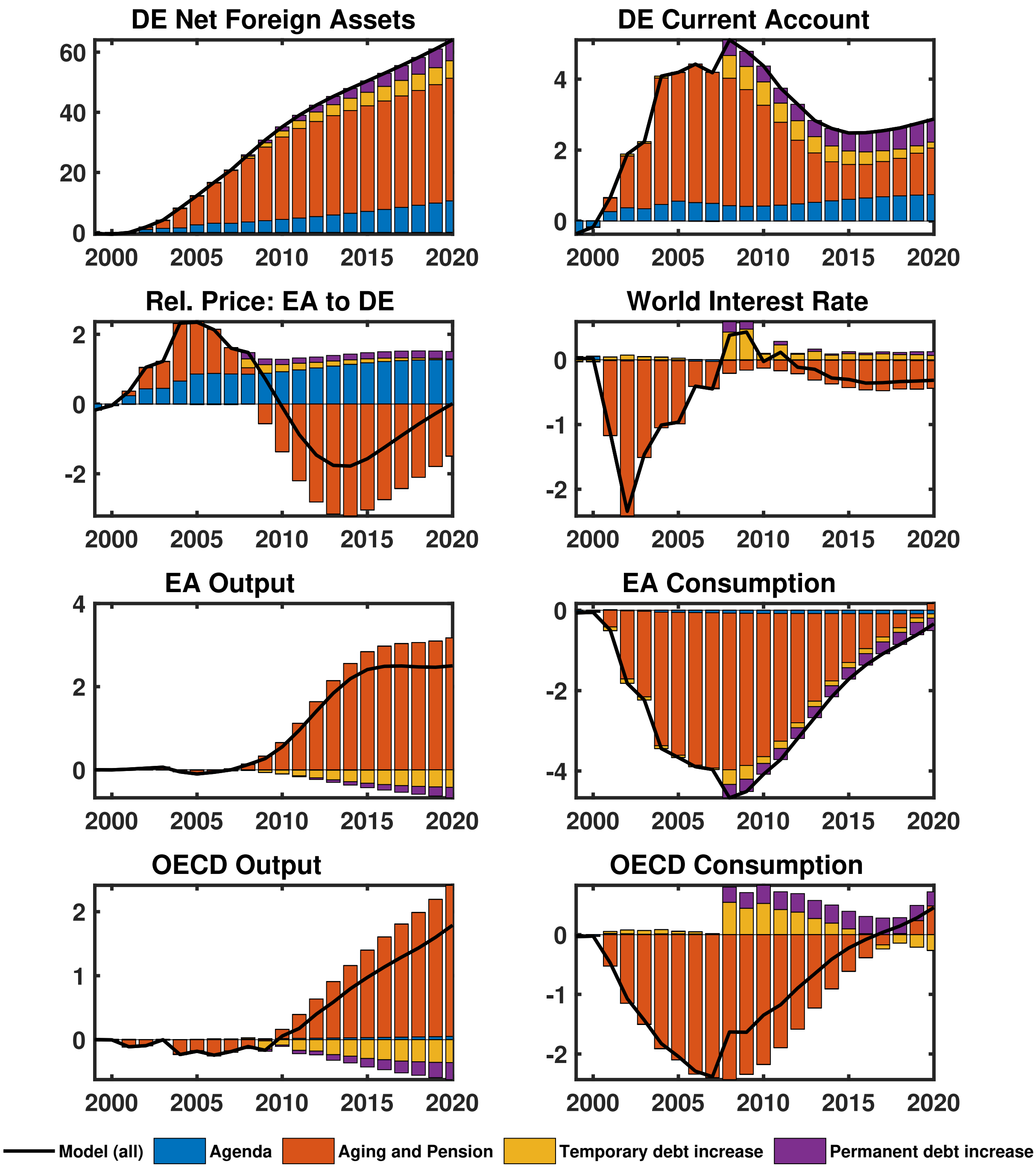

Figure 8: Effects of reform agenda, aging, pension reforms and fiscal stance on key international variables

Notes: Figure plots agenda reform, aging and pension reform-induced evolution of key international variables. EA stands for Euro area excluding Germany and OECD indicates the remaining OECD countries. Variables are shown in percentage deviations to initial steady state. The black solid line shows the aggregate path for the entire agenda reform, pension reforms and the fiscal stance; the colored bars the single reform steps as indicated and described in the main text.

must increase. In the simulation with constant levels of debt (shown in the previous subsections), households have already made their "optimal" savings decisions. If the government now issues more debt, which is the case in this simulation, it must provide households a further incentive to save. To save more, household demand higher interest rates, which holds even in the absence of risk premia in our model. Higher public debt around the world hence leads to a crowding out of private investment because of higher interest costs (not only in Germany). This is amplified by the fact that, in our model, Ricardian equivalence no longer holds. The lump-sum tax T_t^i, which is used to finance higher interest payments on public debt, have to be raised. This depresses households' expected (life-time) income, reduces private consumption and investment and increases savings further.

The issuance of more public debt around the world increases savings by 10 percentage points in all regions, not only in Germany. However, in Germany, the public debt-to-GDP ratio starts falling after 2010, while it keeps on rising in the rest of the world (see Figure 6). Therefore, while Germans save more and, at least in relative terms, lose domestic investment opportunities, investment opportunities in the rest of the world rise. This translates into an increase in the German current account-to-GDP ratio. The effects are stronger once the changes in the debt-to-GDP ratios are assumed to be permanent. This is the case because, then, permanent income is affected more negatively, and there is a stronger incentive for households to save.

4.4 Comparing the model-based current account to the data

Figure 9 summarizes the findings of our model simulations for the German current account and compares the developments to the data (IMF, 2019). What we can observe is that, according to our model, the Agenda 2010, aging and pension reforms as well as the fiscal stance are quite good explanations for the rise in the ratio up to 2010. Thereafter, the model-implied German current account-to-GDP ratio starts falling, while it keeps on rising in the data.

Our model basically explains the build up of the current account surpluses by the savings and investment decision of households. The rise in (German) household savings is indeed supported by the data until around 2010 (see EC, 2016, Appendix A4.8, and Kollmann et al., 2015). Data suggests that savings in the household sector remained high thereafter, but did not notably increase further. Our simulations results are in line with this (see Figure 7). Hence, the household savings story told by many to explain the German current account developments can be supported by the data and according to our model simulations until 2010. Thereafter, the contribution of households savings (and, therefore, the drivers analyzed so far) to the increase in the current account-to-GDP ratio in Germany beyond 2010 seems to be limited both, from a model and an empirical perspective.

Hence, it is natural to ask what may have changed after 2010. There are two further developments that are likely to have contributed to the further increase in the German current account-to-GDP ratio. First, under-investment in the German corporate sector is mentioned in the Macroeconomic Imbalance Procedure (EC, 2016, Box 3.5 and Appendix A4.8). This is in line with the theory of a corporate savings glut (Andre, Guichard, Kennedy, and Turner, 2007; Chen et al., 2017; Gruber and Kamin, 2015). And indeed,

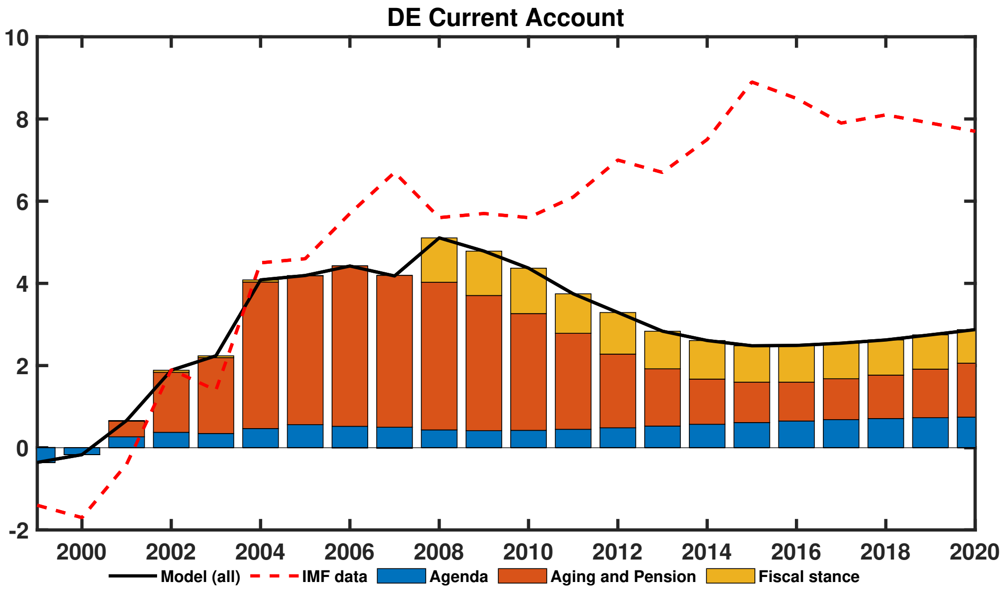

Figure 9: Model-implied German current account-ratio compared to the data

Notes: Figure plots agenda reform-induced evolution of the German current account-to-GDP ratio in levels (black solid line). This is compared to data (red dotted line; source: IMF, 2019). The colored bars the single reform steps as indicated.

Klug et al. (2019) show that private investment plunged down steeply in 2010. In the model-based simulations presented in Appendix A4.8 of EC (2016), negative investment shocks are one of the most significant drivers explaining the rise of the German current account after 2010. In a stylized simulation, we incorporate the German corporate savings glut by exogenously reducing private capital investment in Germany. We do this by introducing a wedge between the return on capita investment and the natural rate of interest in Germany. To be more precise, we replace $R_t = [(1 - \tau^{k,a}_{t+1}) \cdot r^{k,a}_{t+1} + \tau^{k,a}_{t+1} \cdot \delta^{k,a} + Q^a_{t+1} \cdot (1 - \delta^{k,a})]/Q^a_t$ by $R_t = [(1 - \tau^{k,a}_{t+1}) \cdot (1 - rp^a_{t+1}) \cdot r^{k,a}_{t+1} + \tau^{k,a}_{t+1}\, \delta^{k,a} + Q^i_{t+1}\,(1 - \delta^{k,a})]/Q^a_t$ in equation (4), where $rp^a_t = \rho^{rp} \cdot rp^a_{t-1} + \epsilon^{rp^a}_t$ is a financial friction that drives down the attractiveness of capital investment (see Klug et al., 2019, for a further discussion). $\epsilon^{rp^a}_t$ is an iid shock that takes the value 0.08 in 2010, and $\rho^{rp} = 0.97$ is assumed to give the shock some persistence.[15] As we see in Figure 10, this can indeed explain another significant share of the increase in the German current account-to-GDP ratio from 2010 onward as German domestic capital investment falls.

Second, as suggested by Chen et al. (2012), Kollmann et al. (2015), Dauth et al. (2017), OECD (2019), Albonico et al. (2019) and Hoffmann et al. (2020), we see that economic growth in emerging markets picked up notably after 2010 (growth rates in

[15] The contribution of this “shock” is lower when decreasing persistence. It would be larger if we were to assume a permanent increase in rp^a_t. Referring to the literature discussed in this paragraph, this does not seem very likely, however. Furthermore, it is also unclear still what exactly drives the investment draught, and there are most likely other reasons than an investment risk premium (see, for example, Kollmann et al., 2015, and Hohberger, Ratto, and Vogel, 2020, for a discussion). Hence, our modelling choice should be seen as a stylized short cut to generate an investment draught. Future research explaining it in more detail certainly is necessary.

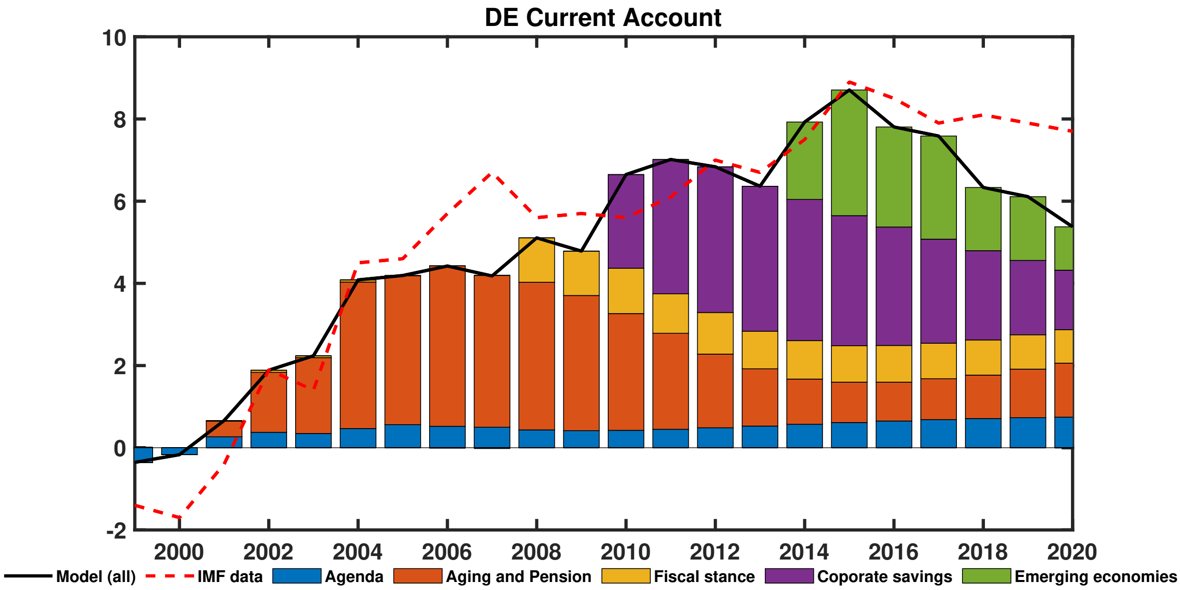

Figure 10: Model-implied German current account-ratio including corporate savings glut and higher demand in emerging economies compared to the data

Notes: Figure plots agenda reform-induced evolution of the German current account-to-GDP ratio in levels (black solid line). This is compared to data (red dotted line; source: IMF, 2019). The colored bars the single reform steps as indicated.

emerging markets exceeded those of developed economies more during the period 2010 to 2017 relative to the period 2001-2007). We implement this by assuming total factor productivity in region c, $\epsilon^{a,c}$ to increase from 0.925 to 0.95. We assume that productivity does not jump but that it follows an AR(1)-process with an autocorrelation parameter of 0.92. Higher productivity in emerging economies has two implications. First, it increases average income and average demand for foreign (also German) goods. Second, it becomes more attractive to invest in physical capital in these regions. Because savings in Germany are abundant, Germans move towards investing in these increasingly attractive regions. As we can see in Figure 10, the contribution of emerging market growth to the German current account surplus should not be underestimated. While the latter two simulations are indeed quite stylized, the two factors (corporate savings glut and productivity gains in emerging markets) have contributed to the build up of global imbalances (and a high German current account surplus) beyond 2010. Further research in this direction certainly seems to be in order.

5 Conclusions

High and persistent German current account surpluses since the turn of the millennium are said to be driven by the *Agenda 2010*, an aging population and pension reforms as well as a tight German fiscal stance. In this paper, we use a New Keynesian DSGE model with a life-cycle structure to quantify the impact that each of these alleged drivers has on the German current account surplus. We compare the model-implied current account developments to those observed in the data.

We find that the *Agenda 2010*, population aging, pension reforms and a tight German fiscal stance indeed seem to have been the major drivers of the current account surplus until 2010. The main story told by our model is that the reform measures and population aging significantly increased the incentives to save for German households. At the same time, opportunities to invest these savings domestically did not rise sufficiently (or were even reduced). Therefore, Germans started investing their savings abroad. This "household savings" glut also seems to be supported by the data until 2010.

Thereafter, however, household savings stayed high but did not increase further both, in the model simulations and in the data. The German current account surplus observed in the data nevertheless kept on rising. In an additional simulation exercise, we identify two further drivers that may be responsible for this. First, a "corporate savings" glut in Germany diminished the possibility for Germans to invest in Germany. Second, higher growth in emerging markets increased the attractiveness for Germans to invest abroad. While these factors can indeed explain the current account developments after 2010 quite well, future research certainly needs to assess their exact impact and the driving forces behind them, especially for emergence of the corporate savings glut.

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Appendix A: The effects of the *Agenda 2010* in detail

In this Appendix, we have a more detailed look at the impact of the *Agenda 2010* reform measures separately. We basically explain the replication of the analysis by Gadatsch et al. (2016) in detail and compare our simulation results to theirs. Given that the model, besides some slight modifications and the demographic structure, are quite similar, the effects of the Agenda reform measures should also be. Differences can mainly be attributed to the endogenous savings decision (unless otherwise indicated).

Figure A.1 shows that, relative to the initial steady state, output and private consumption both increase by more than 2% from 1999 to 2023 (plots of the full transition are relegated to the appendix). Private investment increases by around 4-5% and unemployment falls by almost 2 percentage points. Gross wages increase by around 2%. This fosters German international competitiveness (Figure A.3).[16] Qualitatively and quantitatively, the domestic effects are very similar to the findings in Gadatsch et al. (2016). This also holds for the pattern of the positive effects. While they were relatively small before 2004/2005, it seems as if the labor market reforms did have the main impact on the positive domestic developments on key macroeconomic variables in Germany.

The different reform steps impact the key macro variables differently. As Table 4 of the main text shows, the fiscal devaluations (dark blue and green bars called "Deval99-03" and "Deval07" in the Figures below, respectively) are associated with a reduction of social security contribution rates (due to parity funding in Germany, equally high for employers and employees) and an increase in the consumption tax rate. Reducing the employees' contribution rate increase net labor income directly and eventually has a wage-dampening effect (as workers are interested in their net wage income in the bargaining game), which reduces labor costs for firms. Reducing the employers' contribution rate directly decreases labor costs for firms but has a wage-increasing effect eventually, given that wages depend on (expected) firm profits according to the sharing rule. Overall, the latter effect dominates with respect to wages, but total labor costs from the firms' perspective (including payroll taxes) fall (see also Attinasi, Prammer, Stähler, Tasso, and van Parys, 2019, for a more detailed discussion). This fosters job creation, output and capital investment via the increase in the marginal product of capital as a result of higher employment (see Figure A.1). Lower production costs foster Germany's price competitiveness (Figure A.3).

Labor as well as capital income of households increases, which should foster aggregate consumption ceteris paribus. As we see in Figure A.1, however, consumption falls mildly for the devaluation of 2007. The reason is the increase in the consumption tax rate, which augments policy-induce consumption costs. For workers, higher wages, employment rates and firm profits overcompensate for this effect, and they increase consumption. For retirees, the opposite is true. Although higher wages imply higher pension payments, consumption costs increase more (due to higher taxes) and they reduce consumption (see

[16]The increase in international competitiveness is about one percentage point lower than it is in Gadatsch et al. (2016). This is a result of the fact that, in the present model, the consumption and investment bundle is a CES aggregate. It is Cobb-Douglas in Gadatsch et al. (2016). The CES aggregate allows for more price-elastic substitution between domestic and foreign and thus affects relative prices differently. Qualitatively, the effects are analogous, however.

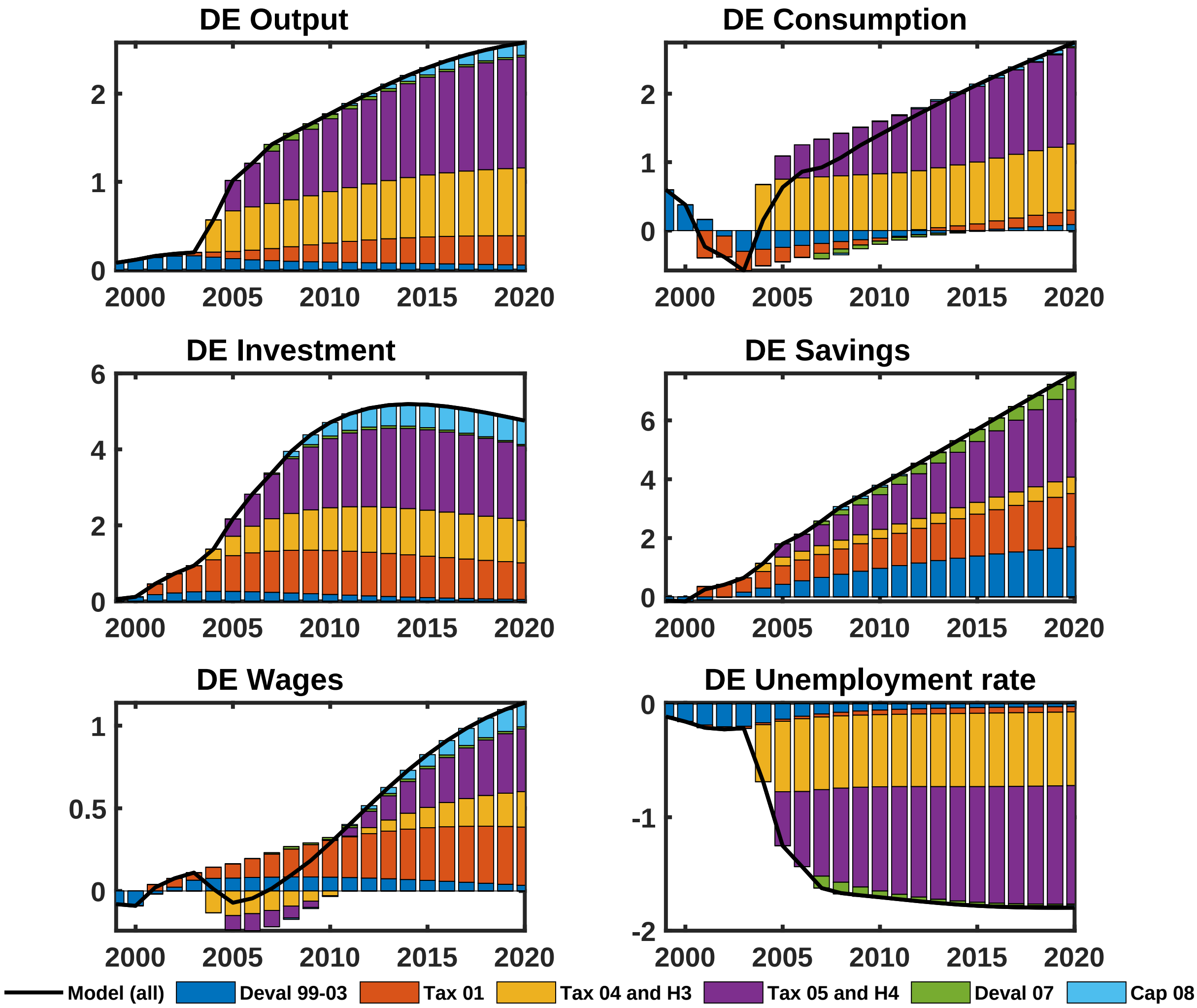

Figure A.1: Effects of reform agenda on key German macro variables

Notes: Figure plots agenda reform-induced evolution of key macroeconomic variables in Germany. Variables are shown in percentage deviations to initial steady state (percentage point deviations for unemployment). The black solid line shows the path for the entire agenda reform, the colored bars the single reform steps as indicated and described in the main text.

Figure A.2).[17] As consumption costs increase, "effective income" for retirees is reduced. This increases the incentive for households to save (Figure A.1). As the increase in savings exceeds the increase in domestic capital investments, households invest part of their savings in the foreign economies. German net foreign assets and the current account increase. The increase in consumption in the first two years after the fiscal devaluation 1999 to 2003 can be explained by anticipation effects. As households know that consumption taxation will gradually be increased until 2003, they have an incentive to consume today to avoid higher consumption costs tomorrow. This also explains why the current account-to-GDP ratio drops in 1999 and 2000. The anticipation effect is not present in the devaluation of the year 2007.

To describe the effects resulting from a capital and labor income tax rate reduction in 2001 (red bars called "Tax01"), it is convenient to first have a look at the effects of the cut in capital taxation in 2008 (light blue bars called "Cap08"). Lower taxes on capital income foster the incentive to invest in domestic physical capital (see Figure A.1). This positively affects output and, via the marginal product of labor channel, wages. Although the marginal product of labor rises, employment is hardly affected because wages increase and capital becomes cheaper. The German current account and its net foreign asset position are affected negatively because investing in domestic physical capital becomes more attractive (see Figure A.3). In addition to reducing the capital income tax rate, the labor income tax rate was reduced in 2001 as well (red bars called "Tax01"). As described above, this has a wage-dampening effect (which is overcompensated for by the wage-increasing effects via the marginal productivity channel in 2001). This fosters employment and price competitiveness. As described above, it also increases the incentive for households to save. Taken together, this has a positive effect on the German current account (see also Figure A.3).

In 2004, the German government re-structured the employment agency to ease job matching on the labor market (Hartz III), which we approximate by simulating an increase in the matching efficiency parameter (see Table 4). Higher matching efficiency makes it easier for firms to fill a vacancy and search costs decrease. As Figure A.1 indicates, this has positive employment and output effects. Wages increase because firm profits do. The wage increase is reduced somewhat as a result of the fall in the labor income tax rate (already described above), but this effect is not sufficient to overcompensate for the higher matching efficiency-induced wage increase. Although consumption increases, households also increase savings resulting from the positive aggregate (labor) income effect.[18] Taking into account search costs, German production costs fall and price competitiveness increases (Figure A.3). It is also true, however, that domestic investment increases significantly because higher employment augments marginal productivity of capital (Figure A.1). As domestic investment increases by more than domestic savings do, the German current account and net foreign assets are negatively affected by the reform measures undertaken in 2004 (see Figure A.3).

The reduction in the generosity of the unemployment insurance system in 2005 (Hartz

[17] In Gadatsch et al. (2016), a similar effect holds for liquidity-constrained households, who do not benefit from higher firm profits in that model; see also Röhe and Stähler (2018).

[18] Consumption increases for both, workers and retirees. The positive wage effect has a positive impact on pension income. Consumption smoothing implies that part of this (life-time) income increase is used to build up savings (slightly).

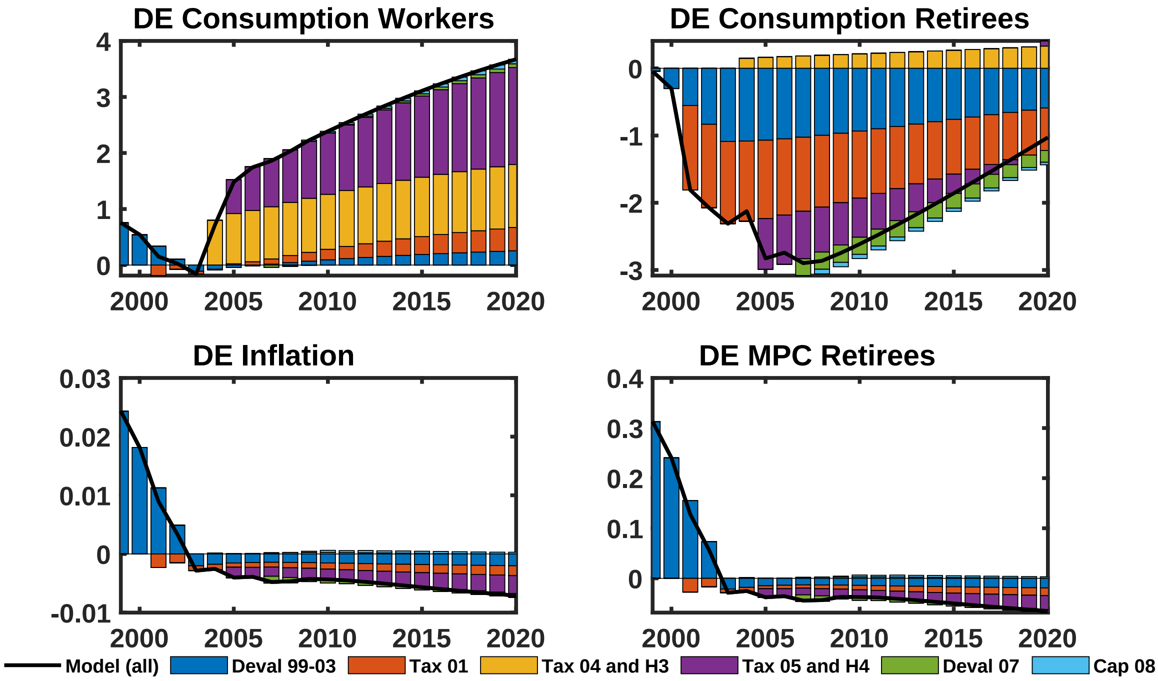

Figure A.2: Group-specific consumption and marginal propensities to consume

Notes: Figure plots agenda reform-induced evolution of workers' and retirees' consumption behavior. Consumption is shown in percentage deviations to initial steady state. For the marginal propensity to consume, we show percentage point deviations. The black solid line shows the path for the entire agenda reform, the colored bars the single reform steps as indicated and described in the main text.

IV) generated similar domestic macro effects (see Figure A.1). However, the transmission channel is somewhat different. Wages decline because the fall-back utility of workers in the bargaining game decrease significantly. This happens for two reasons. First, long-term unemployment benefits are cut, which has a direct income effect on those who are long-term unemployed. Second, the average duration to be eligible for short-term unemployment benefits falls, which reduces the expected average income during the unemployment spell. Although higher employment increases search costs for firms, which workers can use as a threat point in the bargaining game, this effect is not strong enough to overcompensate for the loss in the fall-back utility. Lower wages foster international competitiveness, employment and output, which positively affected consumption and investment. As the wage increase translates into an income reduction for retirees, the incentive for households to save increases. As this increase is larger than the increase in domestic physical capital investment, the German current account and its net foreign assets are affected positively (see Figure A.3). Again, in 2005, the evolution of the variables is also affected by the reduction in labor tax rate (for which the effects have been described above).

Summarizing, we find that all measures of the *Agenda 2010* positively affect German price competitiveness and increase the current account, with two exceptions: higher matching efficiency and lower capital taxation. These measures augment domestic capital investments above average and, thus, dampen the need to save internationally, even though domestic savings increase. In addition, our model simulations also allow us to draw another interesting conclusion regarding the international transmission of the agenda reforms. Higher German consumption and investment demand positively spill over to the foreign economies and, at least in the medium term (starting around 2020), generate permanent positive output effects there, too (see Figure A.4). Despite improved German price competitiveness, the demand effect overcompensates for the price effect. As discussed in Section 1, this is a relatively standard finding in the literature. What is not standard, however, is the fact that despite the positive output spillovers, consumption in the foreign economies is affected negatively eventually (Figure A.4). The reason is simple. The German net foreign asset position increases, while it falls in both foreign regions. This implies that part of the (higher) foreign income must be transferred to Germany by interest payments on net foreign debt. This is strong enough to overcompensate the income gain resulting from higher German demand for foreign products.

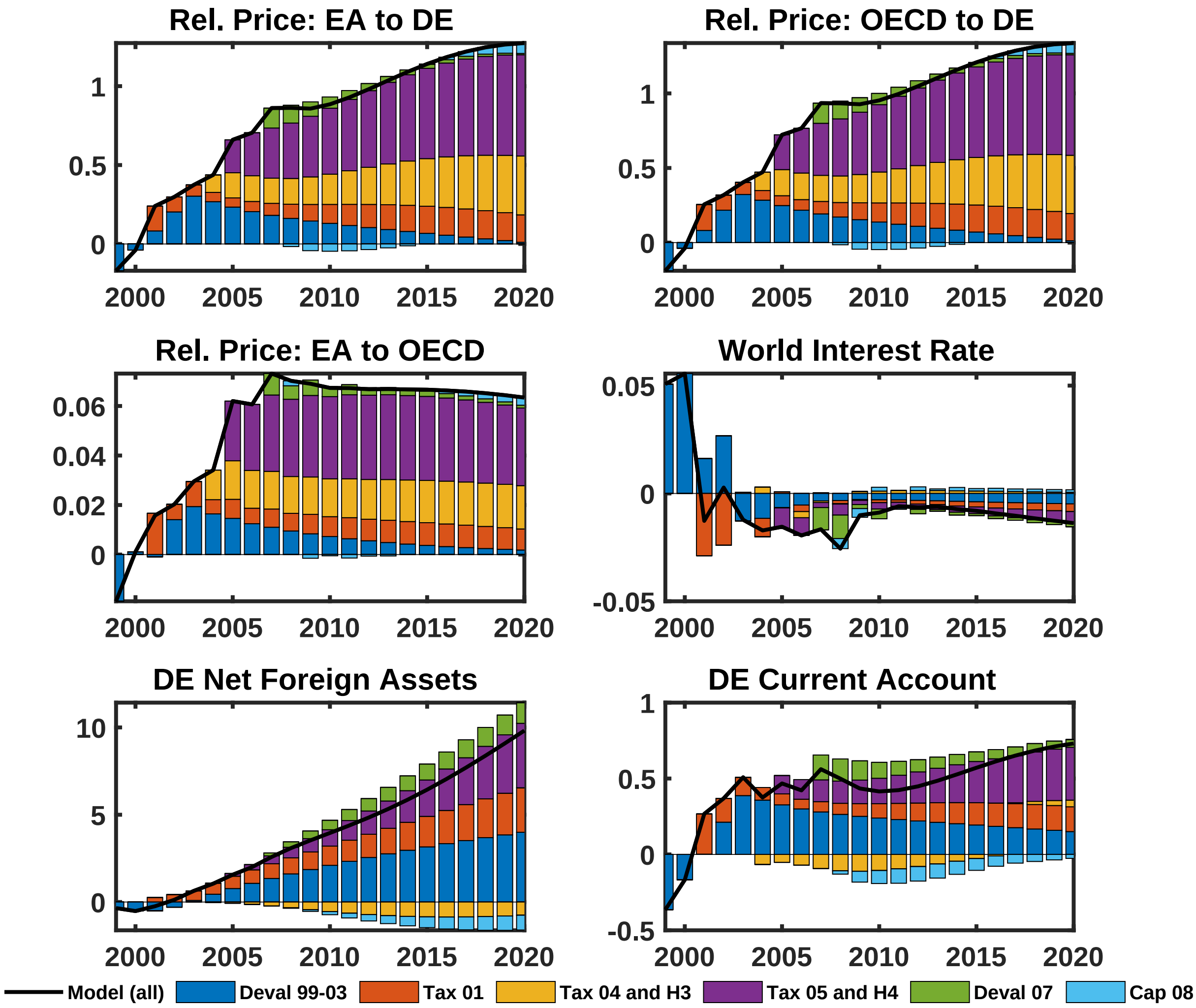

Figure A.3: Effects of reform agenda on current accounts and net foreign assets

Notes: Figure plots agenda reform-induced evolution of relative prices and German net foreign asset-to-GDP ratios in percentage point deviations to initial steady state. The German current account-to-GDP ratio is given in levels. The black solid line shows the path for the entire agenda reform, the colored bars the single reform steps as indicated and described in the main text.

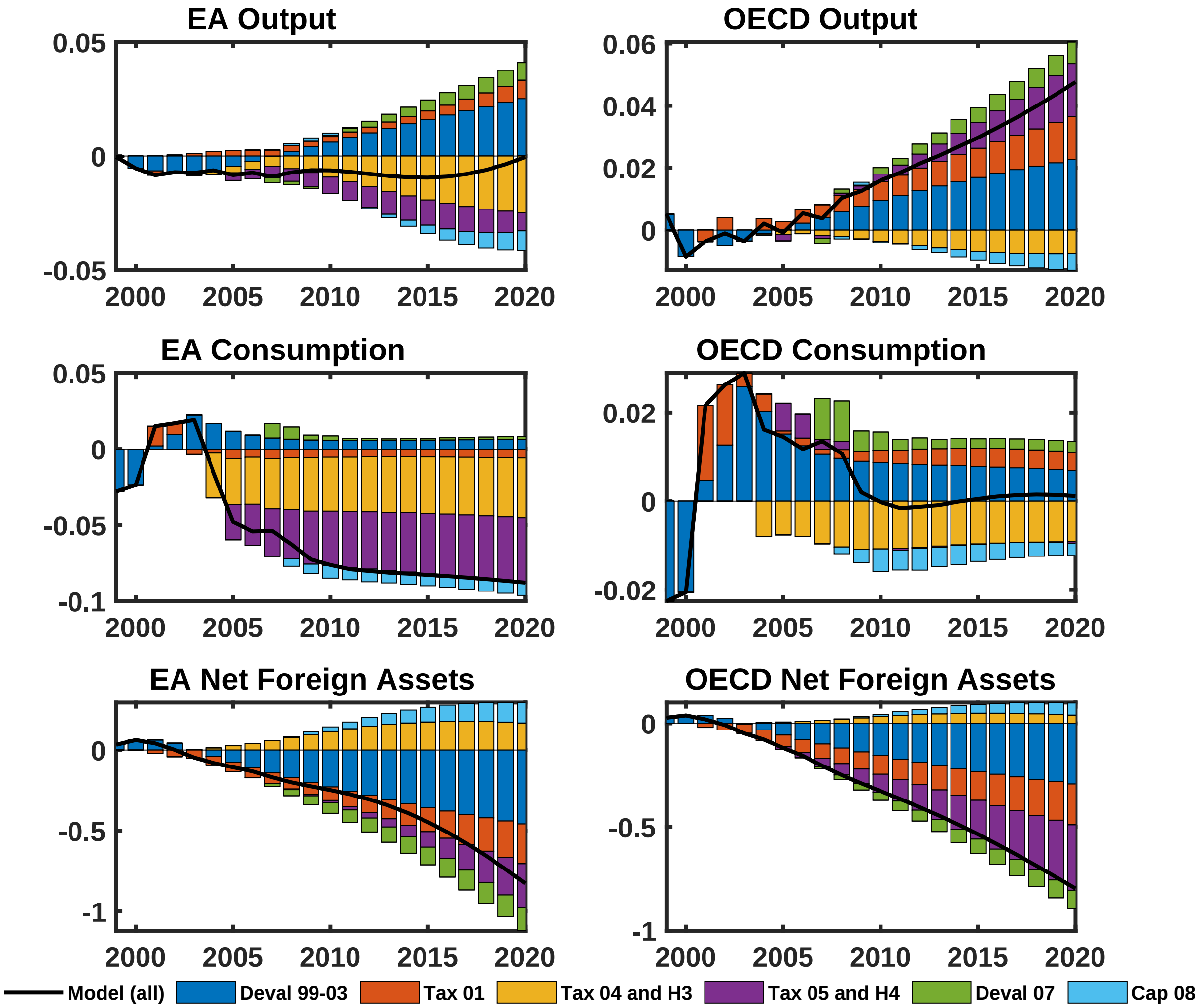

Figure A.4: Effects of reform agenda on key foreign macro variables

Notes: Figure plots agenda reform-induced evolution of key macroeconomic variables in the rest of the Euro area (excluding Germany) and the remaining OECD countries in percentage deviations from initial steady state. The black solid line shows the path for the entire agenda reform, the colored bars the single reform steps as indicated and described in the main text.

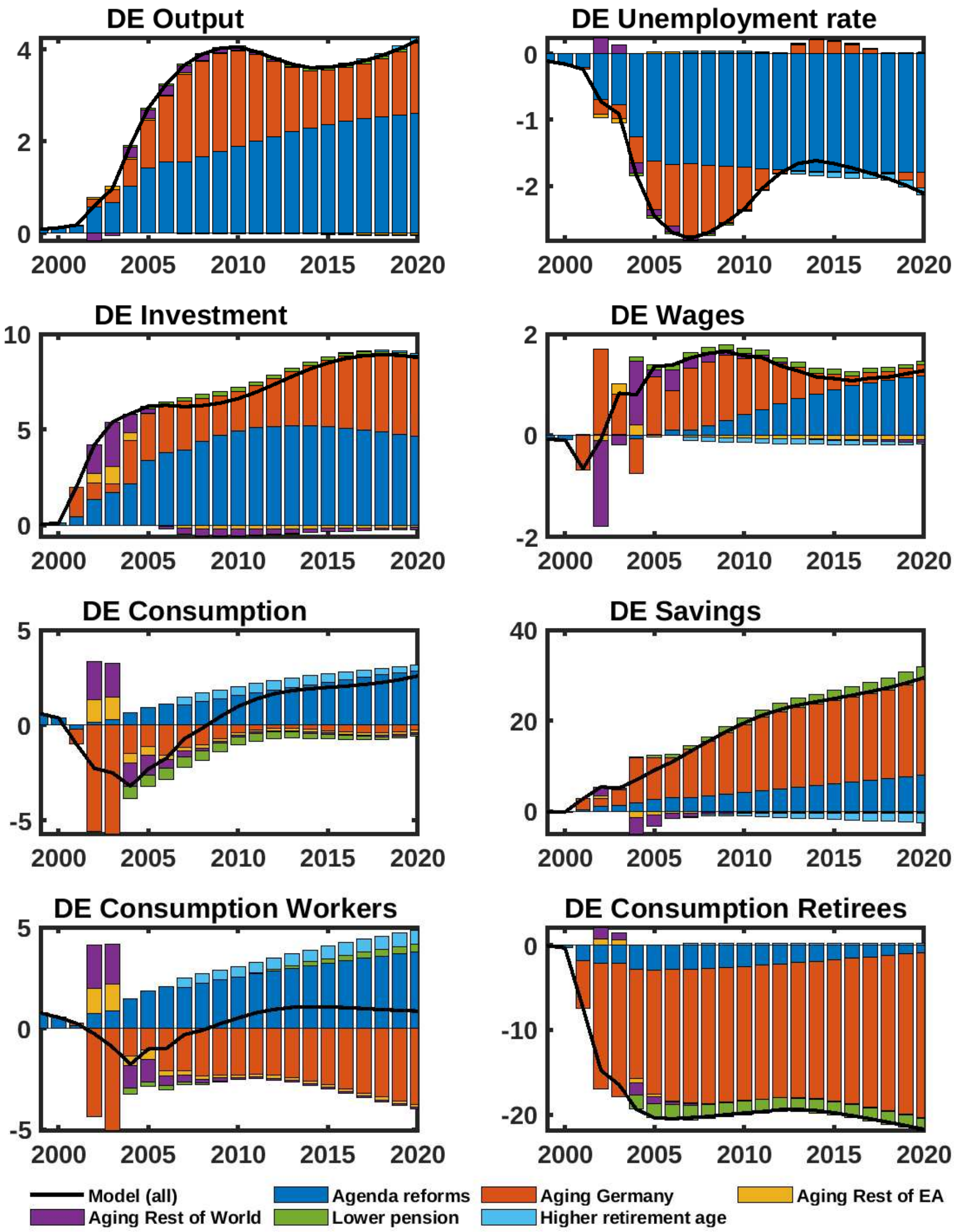

Figure A.5: Effects of reform agenda, regional aging and pension reforms on key German macro variables

Notes: Figure plots agenda reform, regional aging and pension reform-induced evolution of key domestic (macroeconomic) variables in Germany. Variables are shown in percentage deviations to initial steady state. The black solid line shows the aggregate path for the entire agenda reform, aging and pension reform; the colored bars the single reform steps as indicated and described in the main text.

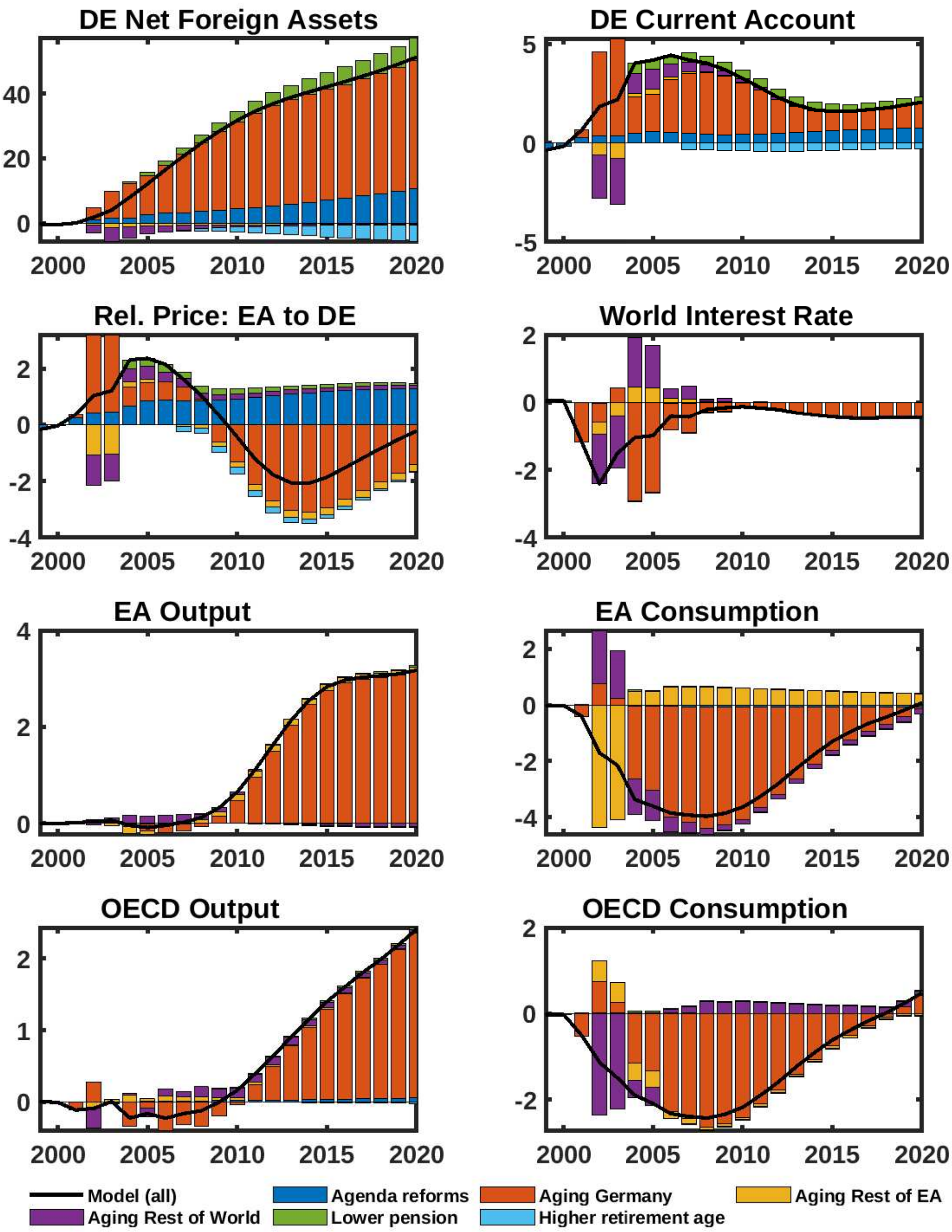

Figure A.6: Effects of reform agenda, regional aging and pension reforms on key international variables

Notes: Figure plots agenda reform, regional aging and pension reform-induced evolution of key international variables. EA stands for Euro area excluding Germany and OECD indicates the remaining OECD countries. Variables are shown in percentage deviations to initial steady state. The black solid line shows the aggregate path for the entire agenda reform, aging and pension reform; the colored bars the single reform steps as indicated and described in the main text.

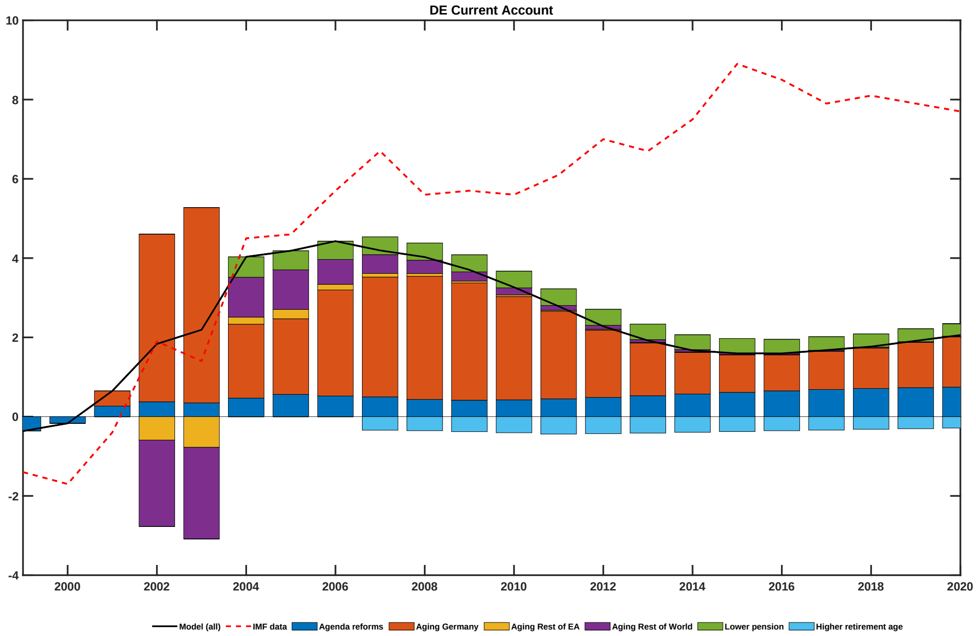

Figure A.7: Model-implied German current account-ratio with regional ageing effects

Notes: Figure plots agenda reform, regional aging and pension reform-induced evolution of the German current account-to-GDP ratio in levels (black solid line). This is compared to data (red dotted line; source: IMF, 2019). The colored bars the single reform steps as indicated.