When do fixed exchange rates work? Evidence from the Gold Standard*

Yao Chen† Felix Ward†

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Abstract

External adjustment under the Gold Standard – a fixed exchange rate regime – was associated with few, if any, output costs. This paper evaluates how flexible prices, international migration, and monetary policy contributed to this benign adjustment experience. For this purpose, we build and estimate an open economy model for the Gold Standard (1880-1913). We find that the output resilience of Gold Standard members that underwent external adjustment was primarily a consequence of flexible prices. When hit by a shock, quickly adjusting prices induced import- and export-responses that stabilized incomes. Crucial in this regard was a historical contingency: namely large primary sectors, whose flexibly priced products drove the export booms that stabilized output during major external adjustments.

Keywords: External adjustment; Migration; Target Zone; Price Rigidity; DSGE; Bayesian estimation; Real effective exchange rate.

JEL Codes: N1, F2, E5.

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†Department of Macroeconomics and Econometrics, University of Bonn; (chen.yao@uni-bonn.de); (s3feward@uni-bonn.de).

1. Introduction

The pre-1914 Gold Standard was a global fixed exchange rate regime of colossal extent: By 1913 economies responsible for 67% of world GDP and 70% of world trade had relinquished flexible exchange rates as a means to unwind external imbalances. Yet external adjustments were associated with few, if any, output costs (see Meissner and Taylor, 2006; Adalet and Eichengreen, 2007). How did the Gold Standard (GS) equilibrate so smoothly despite inflexible exchange rates? There exist various competing, though not mutually exclusive explanations. First, prices were relatively flexible, allowing for a faster absorption of shocks (Backus and Kehoe, 1992; Basu and Taylor, 1999; Chernyshoff, Jacks and Taylor, 2009). Second, cyclical international migration helped to turn around the current account and took the pressure off of wages in depressed regions (e.g. Hatton, 1995; Khoudour-Castéras, 2005). Finally, central banks could smooth out temporary disturbances by making use of the considerable monetary policy independence that the Gold Standard, as a target zone regime, afforded in the short run (Krugman, 1991; Svensson, 1994; Bordo and MacDonald, 2005). The main purpose of this paper is to provide a comprehensive assessment of the relative importance of each of these channels. Can we determine which one reduced output volatility the most? Were they equally important – or were they most effective in combination?

A study of external adjustment under the Gold Standard is particularly interesting in light of the often painful adjustment experiences in fixed exchange rate regimes today. Figure 1, for example, contrasts external adjustment under the Gold Standard with that in the euro area:[1] Under the Gold Standard as well as in the euro area the current

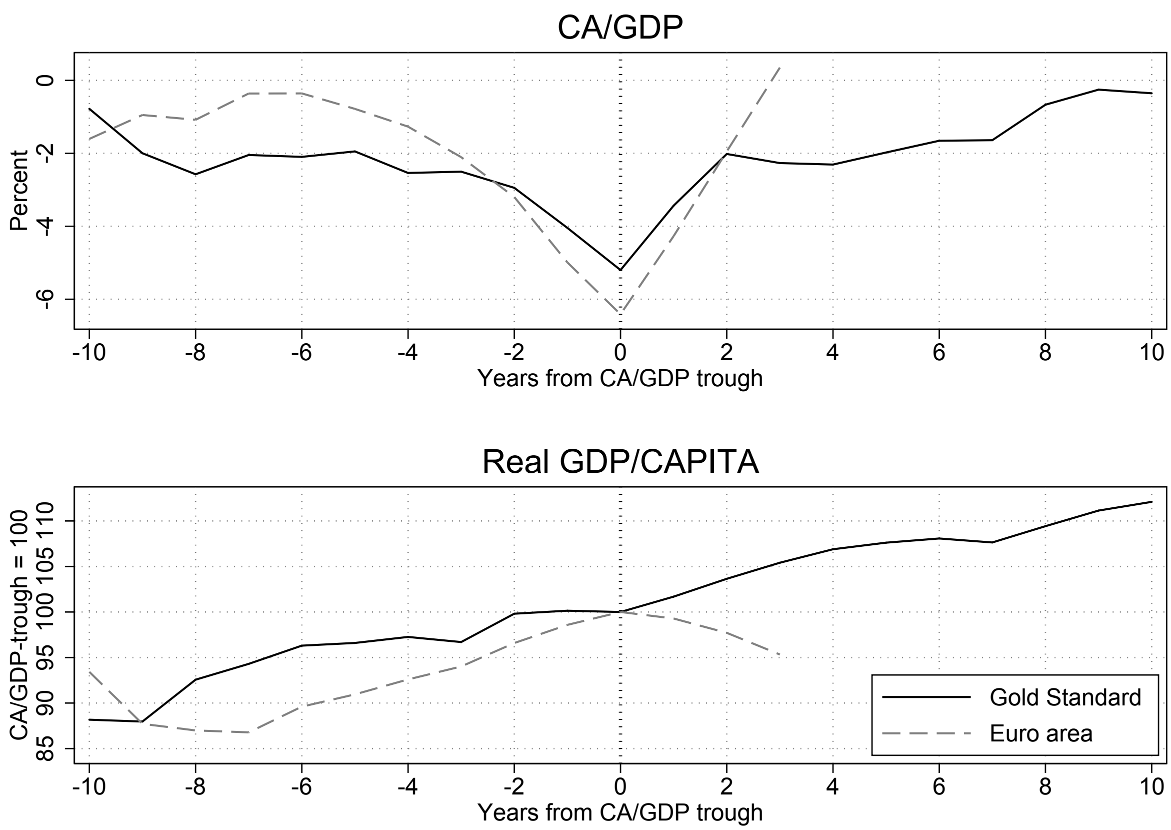
[1]CA/GDP troughs are defined according to a turning-point algorithm (see Bry and Boschan, 1971). CA/GDP-troughs are defined as the lowest CA/GDP-value in a ±10-year window. For the EZ a ±8-year window was chosen and border conditions were weakened because of the shorter sample length.

account-to-GDP (CA/GDP) ratio on average decreased by about 5 percentage points in the 10 years prior to reversing sharply. However, while reversals were associated with major recessions in the euro area, under the Gold Standard output continued to grow on trend. The Gold Standard thus also provides an auspicious historical contrast to more recent external adjustments where exchange rates are fixed. Additionally, the pre-1913 Gold Standard lasted longer than most international fixed exchange rate regimes and thus provides a unique opportunity to analyze external adjustment under fixed exchange rates for an unaltered set of countries over more than three decades.

The first part of this paper gives an empirical outline of the behavior of prices, migration and monetary policy during major external adjustment episodes under the Gold Standard. We find that: (i) a strong price-decline in regions facing a current account-reversal quickly increased their price-competitiveness, (ii) migration flows redistributed labor supply from deficit regions to surplus regions, and (iii) central banks made use of the short-run independence they enjoyed within the "gold points" (i.e. the target zone bands) to conduct countercyclical interest rate policy. Central bankers were furthermore willing to run down their gold reserves in order to pay for a more accommodative monetary policy during major external adjustment episodes (see Bazot, Bordo and Monnet, 2014; Eichengreen and Flandreau, 2014).

Against the backdrop of these empirical regularities, the second part of the paper evaluates the relative importance of prices, migration and monetary policy for keeping output volatility in check. For this purpose, we build the first open-economy model of the Gold Standard that features international migration, various degrees of price flexibility and an elaborate monetary structure. We estimate the model with Bayesian methods for the U.K., Sweden and Belgium. The model-Gold Standard's behavior is then studied through counterfactual simulations: How would output volatility have looked had prices been less flexible? What if there had been no release through migration? How important was countercyclical monetary policy? We found that price flexibility was paramount

Figure 1: *Average GDP- and CA/GDP-behavior around major CA/GDP-reversals*



Notes: The averages are based on a sample of 14 GS countries and 12 EZ countries respectively. Major adjustment periods are defined as the periods lasting from one CA/GDP trough to the next. CA/GDP troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP-troughs are defined as the lowest CA/Y-value in a ±10-year window. For the EZ a ±8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 9 CA/GDP troughs. EZ: 7 CA/GDP troughs.

for the benign adjustment experience under the Gold Standard. Neither restrictions on migration, nor the elimination of countercyclical monetary policy would have given rise to substantially higher output-volatility.

In this regard, large primary sector shares proved to be crucial: Agricultural products generally exhibit significantly more flexible prices than industrial or service goods. Prior to 1913 agricultural products still made up the majority of all merchandise exports, even among early industrializers. This fortunate coincidence of the nominally most

flexible sector also being the most important tradable sector is the main explanation for the ease of external adjustment under the pre-1913 Gold Standard. On the basis of newly collected disaggregate export, price and production data we show that Gold Standard economies experienced a pronounced shift in sectoral structure in the face of a current account reversal. That is a shift, away from the production of non-tradables (primarily services) towards the production of tradable agricultural goods. This sectoral shift was brought about by quickly falling agricultural prices that directly translated into a boom in agricultural exports. Against the backdrop of otherwise rapid industrialization and declining agricultural sector shares these sectoral adjustments simply required a temporary slow-down in industrialization, thus allowing them to avoid the costly labor- and capital-reallocation that is commonly associated with major external adjustment episodes.

The paper is structured as follows: The following section introduces our data. Section 3 discusses the behavior of prices, migration and monetary policy during the major external adjustments under the Gold Standard. Sections 4 and 5 presents the Gold Standard-model and its estimation. The relative importance of prices, migration and monetary policy are then analyzed on the basis of counterfactual simulations in section 6. Section 7 substantiates our findings from the model simulations with evidence from disaggregate price- and export data that suggests sectoral structure played a crucial role for external adjustment under the Gold Standard. Section 8 then concludes our analysis.

2. Data

The empirical foundation of our analysis is a new annual dataset for 14 countries that were members of the Gold Standard throughout the 1880-1913 period, namely Australia, Belgium, Canada, Denmark, Finland, France, Germany, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the U.K. and the U.S.. In many cases we were able to draw

extensively from previous historical data collections by economic historians. In other cases new data had to be compiled from the historical publications of contemporary statistical offices, central banks and trade agencies. Particular effort went into the construction of a novel set of effective exchange rates, gold cover ratios and sectoral export- and price level data. The construction of which are described in more detail in the following section. All in all our dataset covers the following annual time series: nominal GDP, real per capita GDP, consumer prices, the current account, imports and exports, the nominal exchange rate, immigration and emigration, population, discount rates, note circulation, nominal and real effective exchange rates, gold cover ratios, sectoral production shares, sectoral exports and sectoral price level data. A detailed listing of all the sources is provided in Appendix A

2.1. *Effective exchange rates*

The real effective exchange rate of country i is calculated as the trade-weighted geometric average of bilateral real exchange rates ($RER_{i,j,t}$) with respect to countries $j \in 1, ..., J$

$$REER_{i,t} = \prod_{\substack{j=1 \\ j \neq i}}^{J} RER_{i,j,t}^{w_{i,j,t}},$$

where $w_{i,j,t}$ is the bilateral trade weight. The real effective exchange rate is the product of the nominal exchange rate[2] and the ratio of consumer prices, $RER_{i,j,t} = NER_{i,j,t} \frac{CPI_{i,t}}{CPI_{j,t}}$.[3] Our baseline $REER$ estimate uses the bilateral trade flow data provided by López-Córdova

[2]Here the nominal exchange rate is written in quantity notation, i.e. foreign currency per domestic currency.

[3] This method of data aggregation into a foreign composite flows from a setup in which preferences are characterized by a unit-elasticity of substitution between foreign goods varieties. Another advantage of using the weighted geometric average is that the REER that is calculated on the basis of exchange rates quoted in price-notation is exactly the inverese of the REER calculated on the basis of exchange rates quoted in quantity

and Meissner (2008) as trade weights.[4] Trade weights $w_{i,j,t}$ equal the ratio of total bilateral trade to GDP, $(imports_{i,j,t} + exports_{i,j,t})/GDP_{i,t}$. In accordance with modern-day REER estimates, as provided for example by the ECB, we updated the bilateral trade-weights every three years. Note that we exclusively consider GS-member economies for the REER calculation. We do this in order to focus on competitiveness within the GS.[5] Along the same lines we constructed nominal effective exchange rates (NEER) and foreign effective consumer price indices as trade-weighted geometric averages. The final REER series can be seen in figure 5 in Appendix B.

2.2. *Gold cover ratios*

Another crucial variable for our attempt to characterize external adjustment under the GS are gold cover ratios. In its simplest form a legally defined gold cover ratio required the central bank to back a certain fraction of its note issue with gold. In more general terms, cover ratios required central banks to back their liquid liabilities with liquid assets. The exact legal definition of cover ratios however differed across countries and time.[6] In order to capture this definitional ambiguity we decided to construct two different measures of the gold cover ratio – one narrow and one broad. The narrow cover ratio is the ratio of metal reserves (gold and silver) to notes in circulation. The broad cover ratio adds foreign

notation.

[4]We linearly intrapolate the trade-weights and use the first and last observation of each country-pair to fill in missing values at the beginning and end of the sample.

[5]This differentiates our REER series from those introduced by Catão and Solomou (2005), whose REER series are affected by fluctuations in the nominal exchange rate with respect to non-Gold Standard members. In general, about two thirds of the GS-members' trade was conducted within the GS itself (see Catão and Solomou, 2005). For our 14 country sample of long-term Gold Standard adherents the corresponding figure is even larger: an average of 68% of imports came from other countries in the sample and an average of 89% of exports went to other countries in the sample.

[6]Bloomfield (1959) provides a summary of the main types of legal cover ratios.

exchange reserves to the numerator and central bank deposits to the denominator. This allowed us to select the cover ratio that comes closest to the legally defined one for each country. For example since 1877 the numerator of the cover ratio targeted by the National Bank of Belgium included foreign exchange reserves. Thus in our model estimation for Belgium we used the broad cover ratio series. The narrow and broad cover ratio series can be seen in figures 8 and 9 in Appendix D.

2.3. *Sectoral shares, prices and exports*

In order to see which sector drove external adjustment during the GS we collected disaggregated price- and export data, as well as primary sector shares. The export data are disaggregated into agricultural-, raw material- and industrial exports. The sectoral price data features the same three categories as well as service prices. While some sources provide data at this level of aggregation, in many cases we had to aggregate up from more readily available product-level data. Sectoral value-added share data come from Buera and Kaboski (2012).

3. Stylized facts

In order to get a first impression of how prices, migration and monetary policy behaved during major external adjustments under the Gold Standard (GS) this section introduces a set of stylized facts. To this end we identify troughs in the current account to GDP ratio (CA/GDP) through a Bry and Boschan (1971)-style algorithm: CA/GDP-troughs are defined as the lowest CA/GDP-value in a $\pm$10-year window. For the period between 1880-1913 we thus identify 9 CA/GDP troughs (see figure 6 in Appendix C).

We then look at how the average behavior of prices, migration and monetary policy ($x_{i,t}$) after such major CA/GDP-reversals differs from their average behavior after non-

reversal years. More formally we look at the sequence of differences

$$D_h(x_{i,t+h}, A_{i,t}) = E_{i,t}(x_{i,t+h}|A_{i,t} = 1) - E_{i,t}(x_{i,t+h}|A_{i,t} = 0), \quad h = 1, ..., H \tag{1}$$

where $A_{i,t}$ equals 1 if the economy i enters a major adjustment phase at time t, and 0 otherwise. h indicates the temporal distance from the start of the adjustment phase. Thus $D_h(x_{i,t+h}, A_{i,t}), \quad h = 1, ..., H$ stands for the different behavior of x_i after major CA/GDP-reversals relative to non-reversals.

Practically we estimate the sequence of differences $D_h(x_{i,t+h}, A_{i,t})$ through the following sequence of fixed effects models:

$$\frac{x_{i,t+h} - x_{i,t}}{x_{i,t}} = \alpha_{i,h} + \beta_h A_{i,t} + u_{i,t+h}, \quad h = 1, ..., H \tag{2}$$

where α_i are country-fixed effects and $u_{i,t}$ is an error term. The $\{\beta_h\}_{h=1,...,H}$ in expression 2 allow us to sketch out the average behavior of macroeconomic aggregates over the H years following a major CA/GDP-trough. This will provide us with a set of stylized facts on how GS-member economies typically behaved during major adjustment phases in contrast to their behavior during "normal" times.[7]

The first row of figure 2 shows that the typical adjustment during the GS featured a sharp increase in exports that led to a quick turn-around in the current account. Lower import levels also temporarily contribute to the reversal. In general, however, external adjustments under the GS were export-driven. How did prices, migration and monetary policy behave during these episodes? The second row in figure 2 shows that domestic prices fell strongly and swiftly during adjustments phases. The brunt of the adjustment is furthermore born by domestic prices, with foreign prices remaining stable. As a

[7]This approach is more familiar as the local projection framework for estimating impulse response functions (Jorda, 2005) . Here however the $\{\beta_h\}_{h=1,...,H}$ are used for the depiction of historical averages and should not be interpreted as impulse response functions.

consequence, the fall in domestic prices translates almost one-to-one to a gain in relative price competitiveness of around 8%.

How about migration? The third row of figure 2 shows that about 5 years into the adjustment, the average GS economy's population was about 0.5% smaller due to the reduction in immigration and an increase in emigration.[8] This indicates that in the typical external adjustment under the GS migration played only a minor, albeit systematic role. However, for some economies migration flows could be more sizable. Consider the case of Sweden in the 1880s, which for the best part of the decade lost close to 1% of its population per year. Assuming that at the end of such a decade the population level is only 5% lower than what it would have been without migration, a back-of-the-envelope calculation places the direct CA/GDP effect, stemming from emigrants lowering origin-country imports, in the +1 to +2 ppt range.[9] This constitutes a considerable contribution to external adjustment. The same 5% population decline furthermore increases origin-country wages, and thus stabilizes incomes. For a Cobb-Douglas production function, that is parametrized to a labor share of income of around 66%, a 5% decrease in the labor supply thus implies a non-negligible wage increase in the range of 1-2%.[10] Thus for Sweden, migration might have been more central to external adjustment than for other countries at the time. Note however that the effect of migration on output is not unambiguously stabilizing. Destabilizing effects arise in the short-run when recessionary

[8]Note that due to sample difference arising from the fact that there are several countries for which only immigration or emigration exists, but not both, the Immigration/Population and the Emigration/Population graphs do not necessarily add up to the Net Immigration/Population graph.

[9]This assumes that Swedish households consume around 75% Swedish-produced goods and 25% foreign-produced goods, which corresponds to Sweden's actual average import to GDP ratio for the period 1880 to 1913. Also note that the assumed 5% population decline can be considered conservative.

[10]Note that such wage effects will slightly dampen the direct CA/GDP effect of migration.

origin economies lose internal demand to already expanding host economies (see Farhi and Werning, 2014).[11]

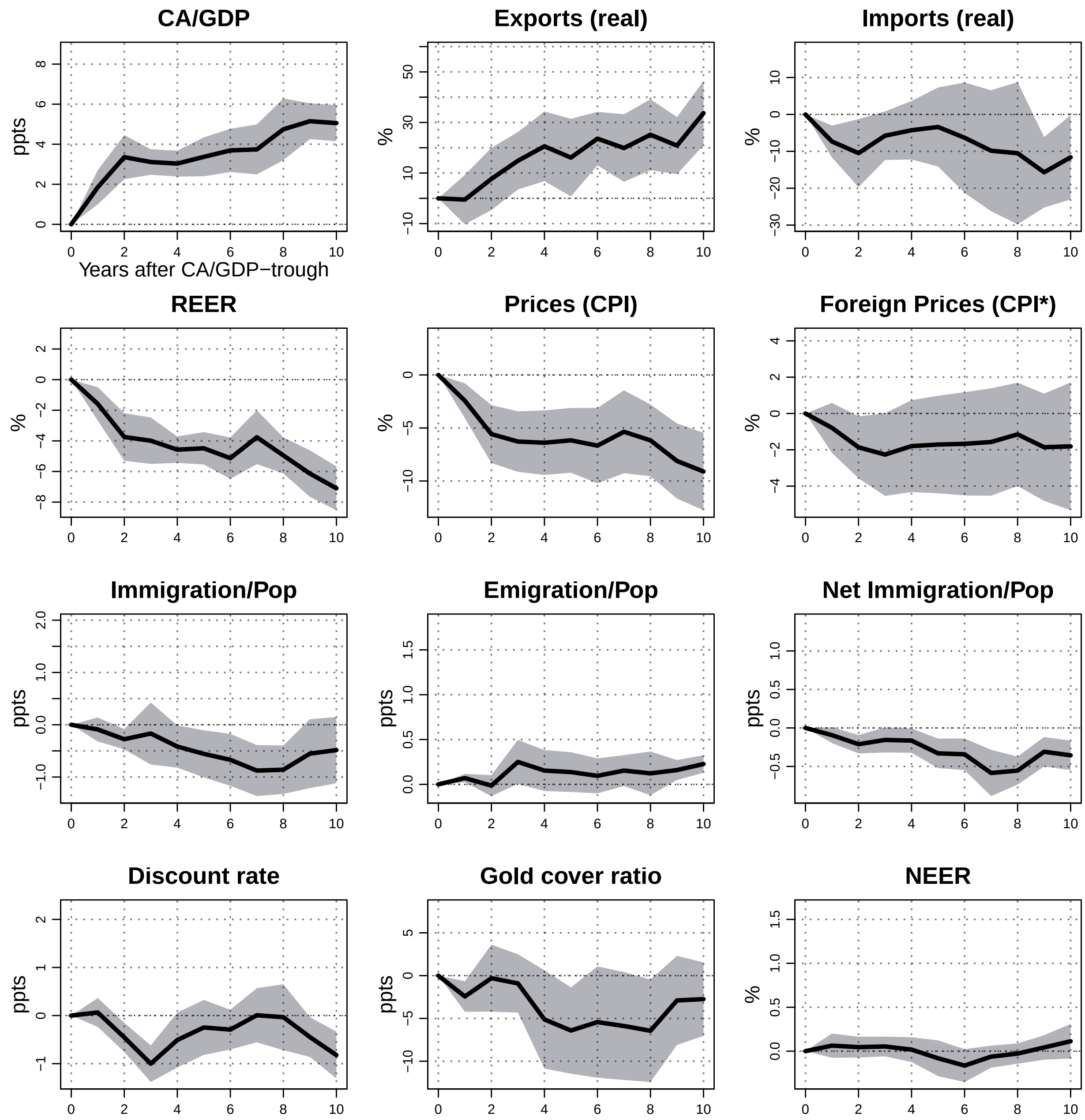
Turning to the monetary side of external adjustment under the Gold Standard, the last row in figure 2 displays the behavior of the central bank discount rate, gold cover ratio and the nominal effective exchange rate. In general, monetary policy turned accommodative during major external adjustments. Central bankers used their freedom to conduct independent discount rate policy within the target zone and on average lowered discount rates by 100 basis points. Some central banks made more extensive use of their freedom than others. To get an idea of how much discount rate independence a $\pm 1\%$ target zone regime allowed for, consider that a 1% depreciation of the exchange rate - that is expected to disappear within one quarter - allows a central bank to temporarily set its policy rate 4 percentage points below world levels.[12] This can explain how in some years the discount rates set by several Scandinavian central banks deviated by up to 3 percentage points from those set by the Bank of England.[13] In the short-run the GS left central bankers with considerable flexibility for setting their discount rates with a "concern for home trade" (Sayers (1976) vol I, p.44, Bordo and MacDonald (2005)). Beyond the limited monetary policy independence they enjoyed within the target zone, central bankers were furthermore willing to round the corners of the policy trilemma through

[11] In the model, migration's net effect on output stability will thus hinge upon the interaction of various parameters, such as home bias in consumption, the curvature of the production function with respect to labor input as well as all of the rigidities that influence the two regions' response to a short-run changes in aggregate demand.

[12] This example is taken from Bordo and MacDonald (2005). Note that, to the extent that the central bank's countercyclical policy rule is known and expected by agents, this influences ex ante inflation expectations and thus real rates even before the central bank has taken any action. Thus observed differences in nominal rates are imperfect indicators of the effectiveness of monetary policy independence during the GS.

[13] Due to the absence of large inflation differentials this translated into almost identical real rate differentials.

Figure 2: *Prices, migration and monetary policy after major reversals in the CA/GDP-ratio*



Notes: Black solid – Gold Standard. Shaded areas – 90% confidence bands based on robust Driscoll-Kraay standard errors (small sample corrected, autocorrelation lag order = 2 years). CA/GDP-troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP-troughs are defined as the lowest CA/GDP-value in a ±10-year window. The number of CA/GDP-troughs thus identified is nine.

active intervention in foreign exchange markets or through the passive accommodation of gold outflows. Figure 2 shows that during major external adjustments such policies resulted in a 5 ppt drop in gold cover ratios. The National Bank of Belgium and the Banque de France were particularly willing to let their gold cover ratios fluctuate in order to insulate the domestic economy from movements in world interest rates (Eichengreen and Flandreau, 2014; Bazot, Bordo and Monnet, 2014). All in all the pre-1913 GS was in possession of several safety valves on the monetary side that could ease external adjustment.

To sum up, a typical external adjustment under the GS was accompanied by a strong and swift gain in price-competitiveness. Activity along the migration- and monetary policy channels was less pronounced. For individual countries however – e.g. Sweden in the case of migration, and Belgium in the case of monetary policy – the latter two channels were important enough to exert a non-negligible stabilizing force on per capita incomes during major external adjustments. Against the backdrop of these empirical regularities we now introduce a structural model in order to evaluate the relative importance of price flexibility, migration and monetary policy in explaining the stability of incomes during external adjustments under the GS.

4. A model of the Gold Standard

To quantitatively analyze the relative importance of prices, migration and monetary policy for the ease of external adjustment under the Gold Standard we need to be able to disentangle their individual impact. To this end, we introduce a 2-region open economy model that features international migration flows, various degrees of price flexibility and a GS-specific monetary structure.

In the following section, we will first shortly outline the model and thereby focus mainly on decision problems in one of the 2 regions – the *H*-region. The economy in

the F-region is symmetric and we provide a more detailed description of the complete equation system that characterizes its state of equilibrium in Appendix F.

4.1. Households

There is a continuum of households $i \in [0,1]$, with households $[0, n_t)$ living in H and $[n_t, 1]$ in F. Household i's period utility follows the Greenwood, Hercowitz and Huffman (1988) (GHH) form. The household maximizes its life time utility[14]

$$V_t^i = \mathbb{E}_t \sum_{k\geq 0}^{\infty} \beta^k \frac{1}{1-\sigma_c} \left(c_{t+k}^i - \frac{1}{1+\sigma_l} {l_{t+k}^i}^{1+\sigma_l} \right)^{1-\sigma_c},$$

where β is the discount factor, l_t is hours worked and c_t is consumption, which is made up of H- and F-produced goods: $c_t = \left[(1-\alpha)^{\frac{1}{\epsilon}} c_{H,t}^{\frac{\epsilon-1}{\epsilon}} + \alpha^{\frac{1}{\epsilon}} c_{F,t}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$. The elasticity of substitution between these goods is ϵ and the openness parameter α reflects a home-bias in taste as well as trade frictions. Home bias furthermore allows for deviations from purchasing power parity.[15] The H and F goods themselves are CES bundles of differentiated goods that are produced by the n home- and $1-n$ foreign firms: $c_{H,t} = \left(\left(\frac{1}{n} \right)^{\frac{1}{\mu}} \int_0^n c_{H,t}(j)^{\frac{\mu-1}{\mu}} \, \mathrm{d}\, j \right)^{\frac{\mu}{\mu-1}}$ and $c_{F,t} = \left(\left(\frac{1}{1-n} \right)^{\frac{1}{\mu}} \int_n^1 c_{F,t}(j)^{\frac{\mu-1}{\mu}} \, \mathrm{d}\, j \right)^{\frac{\mu}{\mu-1}}$, where j is the firm index and μ is the elasticity of substitution between goods produced in the same region. The price indices for the H- and F-produced goods bundles are $P_{H,t} = \left[\frac{1}{n} \int_0^n P_{H,t}(j)^{1-\mu} \, \mathrm{d}\, j \right]^{\frac{1}{1-\mu}}$ and $P_{F,t} = \left[\frac{1}{1-n} \int_n^1 P_{F,t}(j)^{1-\mu} \, \mathrm{d}\, j \right]^{\frac{1}{1-\mu}}$. The H consumer price index

[14] Schmitt-Grohé and Uribe (2003), Mendoza (1991) and Mendoza and Yue (2012) point out that open economy models with GHH utility functions are better at replicating business cycle statistics than models with utility functions where labor supply is subject to wealth effects.

[15] See Diebold, Husted and Rush (1991) and Taylor (2002) for analyses of purchasing power parity (PPP) in the 19th and 20th centuries. While PPP held in the long-run, there could be considerable deviations from PPP over short and medium horizons.

is then given by $P_t = \left[(1-\alpha)P_{H,t}^{1-\epsilon} + \alpha P_{F,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$. We assume that the law of one price applies at the individual goods level so that $P_{F,t}(j) = P^*_{F,t}(j)\, e_t$, where F-variables are marked by an asterisk and e_t denotes the nominal exchange rate (domestic per foreign currency).[16] The households' budget constraint is

$$
\begin{aligned}
& B^i_{H,t-1} R^e_{t-1} + B^i_{F,t-1} R^{e*}_{t-1} e_t + TR_t + P_t w_t\, l^i_t + \Gamma_t + I^\tau_t \\
&= B^i_{H,t} + B^i_{F,t}\, e_t + P_t\, c^i_t + P_t\, \frac{K}{2} \left(\frac{{B^i}_{F,t} e_t}{P_t} - \bar{o} \right)^2
\end{aligned}
$$

where F-variables are marked by an asterisk. $P_t w_t$ is the nominal wage households receive for supplying their labor to local firms on competitive labor markets. Γ_t are local firms' nominal lump-sum dividends that are payed out to local households. $B^i_{H,t}$ and $B^i_{F,t}$ are household i's holdings of two internationally traded one-period risk-free bonds, denominated in H- and F currency respectively. R^e_t is the effective return, which is determined by the risk-free rate R_t and a risk premium shock ϵ^b_t as $R^e_t = R_t/\exp(\epsilon^b_t)$. The adjustment of foreign real asset holdings is subject to a quadratic adjustment cost, which is the last term of the budget constraint equation.[17] When households in F adjust their portfolio holding of H bonds, the associated cost is transferred to H households in a lump-sum fashion: $TR_t = e_t\, \frac{n^*_t}{n_t} P^*_t \frac{K^*}{2} \left(\frac{{B^i}_{H,t}}{P^*_t e_t} - \bar{o}^* \right)^2$. Portfolio adjustment costs and risk premium shocks allow for deviations from strict uncovered interest parity (UIP). Because of migrations, the model has four different household types - denoted by τ: H- and

[16]Note that we switch to price notation here. See Klovland (2005) for an outline on commodity market integration and the validity of the law of one price-assumption in the period from 1850 to 1913.

[17]We assume the same functional form as Benigno (2009). The adjustment cost also pins down the steady state gross foreign asset position. The model's steady state for net foreign assets is determined even without the adjustment costs due to migration (see Appendix G).

F-households that either stay or migrate $\tau \in \{H \to H, H \to F, F \to H, F \to F\}$, where $\to$ shows the direction of migration. The type-specific and possibly negative payment I_t^τ ensures that nominal asset holdings after migration are equalized across households within the region.

4.1.1 Endogenous migration

At the beginning of each period, exogenous shocks realize and households choose whether to migrate ($\delta_t^i = 1$) or to stay ($\delta_t^i = 0$). The decision to migrate is based on comparing the lifetime utilities of continuing to live in H (V_t^i) to that of moving to F. The utility of moving to F includes the utility of actually living there (V_t^{i*}) minus the costs of moving. There exist two short-term costs of moving: One is a time-invariant, region specific migration cost κ_d, which reflects the various hindrances migrants have to overcome (e.g. travel costs). The other is a stochastic utility shock v_t^i that captures the cross-population idiosyncrasy and cross-time variation in a household's preference for leaving its current location. The household i's migration decision is

$$\delta_t^i = \arg \max_{\delta_t^i \in \{0,1\}} \{V_t^i, \quad V_t^{i*} - v_t^i - \kappa_d\}.$$

We assume that the $i.i.d.$ utility shock v_t^i follows a logistic distribution with a mean of zero and scale parameter ψ. An individual household's migration probability is

$$d_t^i = Prob\left(V_t^{i*} - \kappa_d > V_t^i\right).$$

After migrations have taken place, the type-specific transfers I_t^τ ensure that nominal asset holdings at the beginning of the period are the same across households within a

region. They thus can be treated as identical and we drop the household index i.[18] As a consequence the population fraction that emigrates, $\widetilde{d}_t$, equals the emigration probability, d_t.[19] The aggregate population in H, therefore, evolves according to[20]

$$n_t = (1 - \widetilde{d}_t)\, n_{t-1} + \widetilde{d}_t^{*}\, n_{t-1}^{*}. \tag{3}$$

4.2. *Firms*

The model's production side consists of a continuum of monopolistic competitive firms $j \in [0, 1]$ that maximize expected discounted profits. The n home firms and $1 - n$ foreign firms produce with labor from H and F households respectively. The production technology is $y_t(j) = \exp(A_t) L_t(j)^{\gamma}$, where $y_t(j)$ is output, $L_t(j)$ is labor and A_t is the exogenous region-specific productivity level. γ parameterizes the curvature of the production function with respect to labor and thus determines the de- and reflationary effects of migration on wages in receiving and sending regions. As in Calvo (1983), firms face a nominal rigidity, where in each period only a random fraction $(1 - \theta)$ of firms can

[18] Type changing, or in our case migration, causes difficulties in tracking a household's asset position. Cúrdia and Woodford (2010) construct an insurance scheme for households that change types with an exogenous probability. The insurance equalizes the marginal utility of income for households of the same type. In our model, such an insurance scheme is, however, infeasible, due to the endogeneity of the migration decision. Here, we resort to the pooling assumption in order to keep the model tractable. A similar pooling assumption has been used in Corsetti et al. (2013, 2014).

[19] While migration often lags behind business cycle conditions, Jerome (1926, p.241) states that the "most common lag in migration fluctuations is from one to five months". Migration thus does not feature any intrinsic persistence in our annual model.

[20] Note that population levels in the model are stationary, although deviations from the steady state can be very persistent.

reset their prices.[21] θ, together with γ and μ determine the slope of the Phillips curve according to $\widetilde{\kappa} = \frac{(1-\beta\theta)(1-\theta)}{\theta(1-\mu+\mu/\gamma)}$.[22]

4.3. *Equilibrium*

In equilibrium the following market clearing conditions for financial-, goods- and labor markets hold:

$$
\begin{aligned}
0 &= n_t B_{H,t} + n_t^* B_{H,t}^* \\
0 &= n_t B_{F,t} + n_t^* B_{F,t}^* \\
y_t(j) &= n_t\, c_{H,t}(j) + n_t^*\, c_{H,t}^*(j), \quad j \in [0, n) \\
y_t^*(j) &= n_t\, c_{F,t}(j) + n_t^*\, c_{F,t}^*(j), \quad j \in [n, 1] \\
n_t\, l_t &= \int_0^n L_t(j)\, dj, \quad j \in [0, n) \\
n_t^*\, l_t^* &= \int_n^1 L_t^*(j)\, dj, \quad j \in [n, 1]
\end{aligned}
$$

4.4. *Monetary policy and gold flows*

Different strands of the literature have characterized monetary policy under the classical GS as either a money-quantity rule or a discount rate rule. According to the money-quantity view central banks were supposed to expand and contract the money supply in proportion to gold in- and outflows, such as to keep the ratio of gold-to-money - the gold cover ratio - stable. Another part of the literature however focuses on the importance of central bank discount rates in stabilizing the exchange rate. Here we model monetary

[21] In accordance with the GS results reported by Benati et al. (2008) our model does not feature price (backward-) indexation.

[22] See Beckworth (2007) for evidence that nominal rigidities in late 19th century-economies were important enough to affect real economic activity.

policy as a discount rate rule that targets the gold cover ratio γ_t. This formulation integrates the money quantity view and the discount rate view in that discount rate policy R_t contributes to a stable money-to-gold ratio in the long-run. At the same time in the short-run, within the target zone, the central bank is free to let the gold cover ratio fluctuate in order to stabilize the domestic output gap.

In contrast to strict money-quantity rules, this depiction of monetary policy under the GS is in line with the observed fluctuation in gold cover ratios (see Appendix D). Finally, we also allow central banks to directly target the nominal exchange rate e_t in order to accommodate the heterogeneity of discount rate policies that could be observed under the GS.[23] The discount rate rule is

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\rho} \left(\frac{y_t}{\bar{y}}\right)^{(1-\rho)\Phi_y} \left(\frac{\gamma_t}{\bar{\gamma}}\right)^{(1-\rho)\Phi_\gamma} \left(\frac{e_t}{\bar{e}}\right)^{(1-\rho)\Phi_e} \exp(\epsilon_t^r),$$

where we allow for persistence in the discount rate, and Φ_y, Φ_γ and Φ_e denote the sensitivity of the discount rate reaction with respect to the output gap, the gold cover ratio and the exchange rate.[24]

Adherence to this discount rate rule implies deviations from a strict money-quantity rule. Money M_t varies with money demand according to a money demand function as

[23]For instance Morys (2013) presents evidence that the core economies' discount rate policies were directly targeted at keeping the nominal exchange rate within the gold points, while in the periphery central banks put more weight on their gold cover ratios.

[24]Here the output gap is defined as the deviation of real output y_t from its steady state $\bar{y}$. We prefer defining the output gap in terms of deviations of real aggregate output from its steady state over definitions based on deviation from the *efficient* level of output or *per capita* output levels because we consider the former to cohere more with contemporary central banks' targets and information sets. While the use of retrospectively constructed GDP series harbors an element of anachronicity we consider them to be a reasonable proxy for the more general business climate that central banks were reactive to.

in much of the earlier GS literature.[25] Money demand is assumed to be a fraction of the nominal value of total production $n\, P_{H,t}\, y_t$ and depends on the discount rate R_t:

$$P_{H,t}\; n\, y_t = \exp(\chi_t)\, M_t\, k(R_t), \qquad k(R_t) > 0, \qquad v^r := \frac{\partial k}{\partial R_t} \geq 0,$$

where χ_t is an exogenous money demand shock. Central bank gold stocks evolve according to

$$\begin{aligned} G_t &= G_{t-1} + F(e_t)\exp(\epsilon_t^m), \qquad (4) \\ F(\bar{e}) &= 0, \quad \epsilon^e := \frac{\partial F}{\partial e_t} \leq 0 \end{aligned}$$

where gold moves between H and F according to deviations of the nominal exchange rate from the ratio of the two currencies' underlying gold parities – i.e. their mint ratio (Officer, 1985; Giovannini, 1993; Canjels, Prakash-Canjels and Taylor, 2004; Coleman, 2007). When H and F central banks commit to convert local currency into gold at a fixed parity, deviations of the nominal exchange rate from the mint parity makes shipping gold between regions profitable. ϵ_t^m indicates an exogenous gold shock.[26] Given money M_t

[25] Here, we consider M_t to be narrowly defined as central bank notes in circulation. The holding of notes does not appear in the budget constraint. This is the case because we implicitly assume a cash-in-advanced constraint for central bank notes where asset markets are opened before goods trading. Households will convert all notes into bond holdings at the end of the period, because note-holding means the forgoing of interest revenues.

[26] We also considered a version of the model in which gold flows are influenced by net-immigration and the trade balance. However, our estimations showed neither of them to be an important determinant of gold flows. Gold coins carried by migrants constituted only a minute fraction of total gold flows, and in contrast to the 18th century price-specie flow model (Hume, 1752) by the late 19th century trade deficits and surpluses were no longer primarily settled through gold flows.

and gold G_t the gold cover ratio γ_t is determined by the relation

$$M_t = \frac{1}{\gamma_t} P_g G_t,$$

where P_g is the legal gold parity.

5. Bayesian Estimation

We loglinearize the model around its non-stochastic steady state (see Appendix H) and estimate it with Bayesian techniques for the U.K., Sweden and Belgium. The selection of these three countries is explained by three factors: First, the availability of time series for immigration as well as emigration allows us to calculate a net-immigration series for model estimation. In contrast, for many other countries only immigration or emigration series are available. Second, all three countries have a central bank, whose policy response is of expressed interest here. Third, each of the three countries has a particular point of interest: the U.K. was in many ways the centerpiece of the Gold Standard (GS) – home to the world's largest financial center and hosting the most influential central bank of its time. Sweden was renown for its pronounced countercyclical net-immigration rate. We therefore expect Sweden to give us an upper bound of the efficacy of the migration channel under the GS. Belgium, due to its central bank's activist policy on foreign exchange markets, is similarly interesting with respect to the role of monetary policy under the GS. For each estimation, we choose the country in focus – the U.K., Sweden or Belgium – to be the *H* region, while all other GS members are aggregated into the *F* region.

5.1. Observables

We estimate each model on the basis of 11 observables: domestic and foreign time series of per capita GDP; central bank discount rates and CPI-inflation; domestic time

series for the ratio of net immigration to population[27]; the trade balance to GDP ratio; changes in the central bank notes in circulation; the gold cover ratio and the nominal effective exchange rate (NEER). The foreign time series are constructed as trade-weighted geometric averages, analogously to the previously discussed REER series (see section 3). The ratio of net immigration to population and the trade balance to GDP ratio are directly detrended by a one-sided HP-filter (λ = 100). All other variables are first logged before being detrended by the same one-sided HP-filter.

5.2. Calibration

Some parameters are calibrated, either because they are difficult to estimate (e.g. markups) or because their identification from observables is straightforward (e.g. discount factors) (see Table 1). We follow standard calibration strategies for the time discount factor β, the within-country intra-temporal elasticity of substitution μ, the curvature of the production function γ, the trade-openness parameters α and α^*, and the steady state gross foreign asset position $\bar{o}$. The time discount factor β is set to 0.9615, in order to match a sample average discount rate of 4%. The elasticity of substitution between the goods within a country μ is set to 11, implying a steady state price markup of 10%.[28] Given μ, we calibrate γ to target a steady state *labor income* to *GDP* ratio of 0.66 for the U.K. and 0.72 for all other countries (Sweden, Belgium and the *F*-regions).[29] The first value reflects the average labor share in the U.K. from 1880-1913 and the later is an approximation

[27]Most migration flows within our sample originate and end in one of the sample countries. Little of the large-scale migration to South America originated from within our sample. Instead it originated from non-persistent Gold Standard member countries, such as Italy, Spain and Portugal, that are also outside of our sample.

[28]See Eggertsson (2008), who uses this markup-value to calibrate his model of the early 20th century U.S. economy.

[29]The model's steady state labor income share is $\gamma(\mu - 1)/\mu$

Table 1: *Calibrated parameters*

Description		Value/Target
β	Discount factor	0.962
$\frac{\mu}{\mu-1}$	Markup	1.1
γ^*	Production function F	0.792
α	Openness parameter H	SST H import-to-GDP ratio
α^*	Openness parameter F	SST H export-to-GDP ratio
United Kingdom		
γ	Production function H	0.726
n	SST population H	0.160
$\bar{d}$	SST emigration H	0.0064
$\bar{o}$	Foreign portfolio H	SST H GFA-to-GDP ratio = 1.33
Sweden		
γ	Production function H	0.792
n	SST population H	0.020
$\bar{d}$	SST emigration H	0.0059
$\bar{o}^*$	Foreign portfolio F	SST F GFA-to-GDP ratio = 0.001
Belgium		
γ	Production function H	0.792
n	SST population H	0.027
$\bar{d}$	SST emigration H	0.0036
$\bar{o}^*$	Foreign portfolio F	SST F GFA-to-GDP ratio = 0.001

Notes: GFA gross foreign assets. SST steady state.

based on the average labor share in France and Germany during the same time period.[30] The trade openness parameters α and α^* are calibrated to target the historical average *import* to *GDP*-ratios (U.K.: 30%, Sweden: 25%, Belgium: 47%) and *export* to *GDP* ratios (U.K.: 29%, Sweden: 24%, Belgium: 37%) of the H region. The U.K.'s gross foreign asset holdings $\bar{o}$ are set to target a steady state *gross foreign asset* to *GDP* ratio of 1.33, which is consistent with the gross foreign asset estimates provided by Piketty and Zucman (2014) and Obstfeld and Taylor (2004).[31] Calibrating steady state gross foreign asset (GFA) positions for Sweden and Belgium is less straightforward due to the lack of historical data. We assume that in the steady state the F-region holds few Swedish or Belgian assets

[30] According to the datasets provided by Hills, Thomas and Dimsdale (2015) and Piketty and Zucman (2014).

[31] Since they also depend on estimated parameters, $\bar{o}$ ($\bar{o}^*$), α and α^* are re-calibrated during estimation for each draw from the prior distribution.

relative to its GDP, $GFA/GDP = 0.001$. Together with the steady state net foreign asset position, this pins down the steady state gross foreign asset holdings of Sweden and Belgium.[32]

The introduction of migration to the model necessitates the calibration of steady state values for population levels n and emigration rates $\bar{d}$. Fortunately this is relatively straightforward: The steady state population level of H is chosen to correspond to the average *domestic population* to *sample population* ratio. The steady state emigration probability in H ($\bar{d}$) is set to the average *emigration* to *population* ratio of the H country (U.K., Sweden or Belgium). This implies the corresponding steady state value for F according to the equality $\bar{d}\, n = \bar{d}^*\, n^*$.

5.3. *Prior distribution*

The prior distribution is selected according to the *endogenous prior* method introduced by Christiano, Trabandt and Walentin (2011), who use observables' moments to adjust an initial prior choice. The endogenous prior approach is particularly attractive for our analysis because prior information on the model parameters for the GS era is relatively scarce. In particular, we use the second moments of the observables to form the endogenous prior. This helps to improve the model's fit of the observables' variances.[33]

The prior distributions for the estimated parameters are summarized in Table 2. We assume that the inverse elasticity of intertemporal substitution σ_c and the inverse Frisch elasticity σ_l are identical across regions. Their prior distribution follows the literature standard (e.g. De Walque and Wouters (2005) and Smets and Wouters (2007)). For the trade elasticities ϵ and ϵ^* we choose a comparatively wide prior, reflecting the wide

[32]The model's steady state for net foreign assets is determined due to migration (see Appendix G).

[33]As in Christiano, Trabandt and Walentin (2011), we use the actual sample as our *pre-sample*.

range of modern-day estimates for these parameters. The migration parameters ψ and ψ^* determine how sensitive migration is to differences in the utility level between regions: a small ψ implies a stronger migration reaction for any given utility difference, whereas a large ψ implies that migration is largely a random phenomenon.[34] In accordance with the previously cited evidence for the responsiveness of migrants to economic conditions we choose a normal distribution with a relatively small mean of 2. According to current best-practice estimates for the U.S. (Kennan and Walker, 2011) a persistent 1% increase in one state's wages implies a 0.5% larger state-population after 5 years. In our model's framework, a value of 2 for ψ implies a similar reactivity of migration.

Nominal rigidity is characterized by the Calvo parameter θ, which together with γ, β and μ determines the slope of the Phillips curve, $\tilde{\kappa}$, according to $\widetilde{\kappa} = (1-\beta\theta)(1-\theta)/[1/\theta(1-\mu+\mu/\gamma)]$. Instead of estimating the Calvo parameters we choose to directly estimate the the Phillips curve slopes. Many modern day quarterly Calvo parameter estimates lie in the range of $[0.5, 0.8]$, which corresponds to an average price duration of 2 to 5 quarters or a quarterly Phillips curve slope between 0.01 and 0.13. Schmitt-Grohé and Uribe (2004) and Eggertsson (2008) convert the quarterly Phillips curve slope to an annual slope by multiplying the former by four. Thus today's Calvo parameter estimates in the $[0.5, 0.8]$-range imply an annualized Phillips curve slope between 0.04 and 0.52. Where can we expect the corresponding GS parameter to lie? Aggregate price indices exhibited substantially more flexibility (Gordon, 1990; Basu and Taylor, 1999; Obstfeld, 2007) and output responsiveness than today (Bayoumi and Eichengreen, 1996; Bordo, 2008; Chernyshoff, Jacks and Taylor, 2009).[35] We thus expect to find steeper Phillips

[34]Note that while ψ characterizes migration's sensitivity to cyclical fluctuations, the fixed migration cost κ_d determines the level of migration $\bar{d}$, which has already been calibrated in the previous section.

[35]Note however that the micro evidence based on product-group level prices indicates that prices have not become less flexible over time (Kackmeister, 2007; Knotek, 2008). This points towards a compositional effect: it is well known that pre-1913 price indices

curves for the GS era. To be on the safe side however, we chose a conservative beta-prior for $\widetilde{\kappa}$ and $\widetilde{\kappa}^*$, which gives almost equal prior weight to all but the most extreme values of the 0-1 range.

On the monetary side, following Benati et al. (2008) and Fagan, Lothian and McNelis (2013) we assume a prior mean of 0.1 for the interest-rate elasticity of money demand v^r (also see Bae and De Jong, 2007, for similar 1900-1945 estimates for the U.S.). Concerning the sensitivity of gold flows to the exchange rate ϵ^e we remain agnostic except for the sign, by selecting a wide $[-15, 0]$ uniform prior distribution. In our prior choice for the portfolio adjustment cost parameter K we select an inverse gamma prior with a mean of 0.04 (see Benigno, 2009), implying an average deviation of H- from F interest rates of 1 percentage point. This roughly corresponds to contemporary textbook estimates of an annualized 75 basis point wedge between London and New York interest rates (e.g. Haupt, 1894; Margraff, 1908; Escher, 1917).

For the discount rate rule, we use pre-sample data to inform our prior choice. We set the prior means of the discount rate coefficients close to the pooled regression coefficient estimates that we obtained for a sample of GS members for the years 1870-1879. We then chose wide prior standard deviations to reflect our uncertainty about these parameters. Consistent with historical accounts the regression results also show that the U.K. changed its discount rate much more frequently than the Swedish and Belgian central banks.[36] Accordingly, we estimate the discount rate rule for the U.K. without a persistence term. Furthermore, although foreign countries might have wanted to keep their nominal exchange rates stable vis-à-vis the U.K. (see Morys (2011)) there is little reason why they should directly target the nominal exchange rate vis-a-vis Sweden or

contain more flex-price items such as agricultural produce and raw materials than today's indices. However, for our macro model calibration the aggregate price level evidence has more relevance.

[36] The Bank of England decided upon its discount rate on a weekly basis (see Eichengreen, Watson and Grossman, 1985).

Belgium. Hence, only for the U.K. model do we include a reaction term for nominal exchange rate deviations into the *F* discount rate function.

Exogenous shocks generally follow AR(1) processes.[37] Only the discount rate shock is not allowed to exhibit any persistence beyond that which is intrinsic to the discount rate rule. All persistence parameters are given a wide beta prior with a mean of 0.3.[38] We allow for the region-specific technology shocks to be correlated. We chose a flat beta prior for the correlation σ_{aa^*}. The persistence and standard deviation of the gold shocks are assumed to be the same across regions.

Finally, we allow for measurement error in all trade-weighted observables (all *F*-aggregates and the NEER). We also allow for measurement error in the net immigration and *trade balance* to *GDP* ratio because some of the trade- and population flows end up in countries outside of our sample. Following Christiano, Trabandt and Walentin (2011) we calibrate the measurement errors to explain 10% of the variation in the observables. As shown in Appendix I, the data without measurement error very closely follow the original data.

[37]Note that in the case of money demand shocks, it is the changes $\Delta\epsilon_t^x \equiv \eta_t^x$ that follow an AR(1) process.

[38]The 0.3 mean for our annual model corresponds to the conventional prior mean from the $[0.5, 0.85]$ range that is usually applied in quarterly models: $0.3 \approx 0.75^4$.

Table 2: *Prior distribution*

	Description	Distribution	Mean	S.D.
Utility parameters				
σ_c	Inverse EIS	Normal	1.50	0.35
σ_l	Inverse Frisch elasticity	Normal	2.00	0.75
ϵ	Trade elasticity (H)	Normal	1.50	1.50
ϵ^*	Trade elasticity (F)	Normal	1.50	1.50
Migration parameters				
ψ	Migration sensitivity (H)	Normal	2.00	1.00
ψ^*	Migration sensitivity (F)	Normal	2.00	1.00
Price parameters				
$\tilde{\kappa}$	Phillips curve slope (H)	Beta	0.50	0.28
$\tilde{\kappa}^*$	Phillips curve slope (F)	Beta	0.50	0.28
Gold flow parameters				
ϵ^e	Gold flow due to exchange rate	Uniform	$[-15\,,\,0]$	
$\frac{\bar{G}}{\bar{G}^*}$	Relative gold stock	Inv. gamma	$\frac{n}{1-n}$	1.00
Discount rate parameters				
ρ	Discount rate persistence (H)	Beta	0.30	0.15
Φ^y	Output coefficent (H)	Beta	1.00	0.56
Φ^e	Exchange rate coefficent (H)	Beta	1.00	0.56
Φ^g	Cover ratio coefficient (H)	Beta	1.00	0.56
ρ^*	Discount rate persistence (F)	Beta	0.30	0.15
Φ^{y*}	Output coefficent (F)	Beta	1.00	0.56
Φ^{e*}	Exchange rate coefficent (F)	Beta	1.00	0.56
Φ^{g*}	Cover ratio coefficient (F)	Beta	1.00	0.56
Other parameters				
K	Foreign portfolio adjustment costs	Inv. gamma	0.04	2.00
υ^r	Interest rate elasticity of money demand	Inv. gamma	0.10	0.03

	Description	Distribution	Mean	S.D.
Shock parameters				
ρ^a	Persistence, technology (H)	Beta	0.30	0.15
ρ^{a*}	Persistence, technology (F)	Beta	0.30	0.15
ρ_g	Persistence, markup (H)	Beta	0.30	0.15
ρ^{g*}	Persistence, markup (F)	Beta	0.30	0.15
ρ^x	Persistence, money demand (H)	Beta	0.30	0.15
ρ^{x*}	Persistence, money demand (F)	Beta	0.30	0.15
ρ^b	Persistence, risk premium (H)	Beta	0.30	0.15
ρ^{b*}	Persistence, risk premium (F)	Beta	0.30	0.15
ρ^m	Persistence, gold (H & F)	Beta	0.30	0.15
η^a	S.D., technology (H)	Inv. gamma	0.50	2.00
η^{a*}	S.D., technology (F)	Inv. gamma	0.50	2.00
η^g	S.D., markup (H)	Inv. gamma	0.50	2.00
η^{g*}	S.D., markup (F)	Inv. gamma	0.50	2.00
η^x	S.D., money demand (H)	Inv. gamma	0.50	2.00
η^{x*}	S.D., money demand (F)	Inv. gamma	0.50	2.00
η^b	S.D., risk premium (H)	Inv. gamma	0.50	2.00
η^{b*}	S.D., risk premium (F)	Inv. gamma	0.50	2.00
η^r	S.D., monetary policy (H)	Inv. gamma	0.10	2.00
η^{r*}	S.D., monetary policy (F)	Inv. gamma	0.10	2.00
η^m	S.D., gold (H & F)	Inv. gamma	0.50	2.00
σ_{aa^*}	Correlation, technology	Beta	0.50	0.28

Notes: EIS – elasticity of intertemporal substitution. S.D. – standard deviation. The prior distributions for $\psi, \psi^*, \sigma_l, \epsilon$ and ϵ^* are truncated at zero. In case of the U.K., ρ is not estimated but set to zero. In the case of Sweden and Belgium, Φ^{e*} is not estimated but set to zero.

5.4. *Posterior distribution*

Table 4 summarizes the estimation results. Firstly, the posterior distributions for the Phillips curve parameters indicate that the price level was much more flexible in the time before 1914 than it is today. Annual Phillips curve (PC) slope estimates for the U.K., Sweden and Belgium are 0.35, 0.53 and 0.92 respectively, implying average price durations in the 1.5 to 2 quarter range. For comparison, estimates for the U.S. and the euro area today generally hint towards a much flatter Phillips curve. The Calvo parameter estimates obtained by De Walque and Wouters (2005) and Smets and Wouters (2003, 2007) for instance, imply annualized Phillips curve slopes in the [0.01-0.15]-range.

Secondly, consider the parameters ψ and ψ^* that pin down the sensitivity of migration to the business cycle. As expected, the comparatively small estimate for Sweden reflects that Swedish migrants were very responsive to economic fundamentals. Though less than in Sweden, U.K. migrants still responded strongly to cyclical differences in consumption and labor income. Given the U.K.'s ψ-estimate, a persistent 1% decrease in consumption in the U.K. relative to the F-region would result in a 3.8% decrease in the U.K.'s population after 5 years. By contrast, the comparatively high ψ-estimate for Belgium implies that Belgian migration flows were considerably less sensitive.[39]

Finally, the monetary side is characterized by the following parameter estimates: The discount rate policy in all three countries stabilized gold cover ratios ($\phi^g > 0$) and the nominal exchange rate ($\phi^e > 0$), whereas our evidence for output stabilization ($\phi^y > 0$) is restricted to the British and Swedish central banks. In both cases, the policy reaction to output is much less than what a modern-day Taylor rule would suggest ($\Phi^y_{Taylor} = 0.5$).

[39]Between 1880 and 1913 Belgium itself was a destination for many political refugees, which did not migrate primarily for economic reasons. Furthermore, unlike many other European countries Belgium did not encourage the emigration of its citizens to relieve domestic crises. Finally, overall net immigration relative to the general population level in Belgium was small in the period covered by our sample, 1880-1913.

These results reflect that the primary monetary policy target at the time were stable gold cover ratios and nominal exchange rates. The autocorrelation of Swedish and Belgian discount rates is 0.46 and 0.41 respectively, implying that some interest rate smoothing took place. Furthermore Belgian discount rates reacted the least to deviations of the exchange rate from its mint parity ($(1-\rho) \cdot \Phi^{e} = 0.30$) and fluctuations in the gold cover ratio ($(1-\rho) \cdot \Phi^{g} = 0.06$). In this sense the National Bank of Belgium made the most of the monetary policy independence that the Gold Standard allowed. Note, however, that it does not appear to have targeted the domestic output gap.

5.5. Model evaluation

To see whether the estimated models give a good description of the data, we conducted marginal likelihood comparisons between different model versions and extensive moment comparisons of real and simulated data. Note that our baseline model specification does not feature external consumption habits, which is a common feature of DSGEs estimated with modern data. A marginal likelihood comparison of the models with and without habit formation, however, shows that the latter is favored by our 1880-1913 data. Similarly we've also estimated a version of the model with a more elaborate law of motion for central bank gold stocks (see equation 4). Strictly speaking gold stocks do not only depend on exchange rate deviations, but also on net-immigration (migrants carrying gold coins) and the trade balance (trade deficits being settled through gold transfers). The estimated parameters however, confirm back-of-the-envelope calculations as well as historical narratives in that by the late 19th century these two gold flow determinants were of negligible importance. We thus opted for the more parsimonious version of the model.

We then compared the (auto-) correlations of the six variables that we are most interested in[40] – a total of 216 moments.

[40]Per capita GDP, inflation, the discount rate, the nominal exchange rate, changes in the

To obtain the simulated data we run the model with all parameters set to their posterior mean.[41] Figures 14 to 16 in Appendix J show the (auto-) correlation of the observables and those from the stochastic simulation together with the 90% coverage percentiles. The model fairly accurately represents the data's correlation structure.

net-immigration/population ratio and changes in the trade-balance/GDP ratio.

[41]We conducted 2000 simulations. Each simulation has 34 periods, corresponding to the length of our sample. To limit the results' dependence on initial conditions, we ran simulations for 134 periods and discarded the first 100 observations.

Table 3: POSTERIOR DISTRIBUTION

	Description	U.K. Mean	U.K. 90% HPDI		Sweden Mean	Sweden 90% HPDI		Belgium Mean	Belgium 90% HPDI	
Utility parameters										
σ_c	Inverse EIS	1.5822	1.0962	2.0622	2.4586	2.0455	2.8944	2.2847	1.9071	2.6490
σ_l	Inverse Frisch elasticity	2.6129	1.6210	3.6154	2.8173	1.9097	3.6976	3.4044	2.6477	4.1811
ϵ	Trade elasticity (H)	2.9550	0.9278	4.9334	1.4280	0.0968	2.6077	0.6358	0.0454	1.1739
ϵ^*	Trade elasticity (F)	3.3614	1.7318	5.0059	1.2528	0.2546	2.2639	0.4637	0.0294	0.8572
Migration parameters										
ϕ	Migration sensitivity (H)	0.2642	0.0489	0.4822	0.0699	0.0496	0.0869	2.1303	1.0660	3.2159
ϕ^*	Migration sensitivity (F)	2.0162	0.4123	3.4264	1.9879	0.0902	3.2688	1.9374	0.9219	2.9759
Price parameters										
$\tilde{\kappa}$	Phillips curve slope (H)	0.3512	0.1721	0.5332	0.5279	0.3280	0.7195	0.9224	0.8313	1.0000
$\tilde{\kappa}^*$	Phillips curve slope (F)	0.3146	0.1350	0.4863	0.6466	0.3933	0.9254	0.2016	0.1165	0.2860
Gold flow parameters										
ϵ^e	Gold flow due to exchange rate	-2.1376	-3.0397	-1.2108	-1.8969	-2.9635	-0.8446	-0.5727	-0.8231	-0.3198
$\frac{\bar{G}}{\bar{G}^*}$	Relative gold stock	0.0547	0.0373	0.0702	0.0379	0.0139	0.0614	0.0242	0.0132	0.0346
Discount rate parameters										
ρ	Discount rate persistence (H)	–	–	–	0.4621	0.2399	0.7015	0.4138	0.2719	0.5534
Φ^y	Output coefficent (H)	0.1344	0.0878	0.1820	0.1864	0.0113	0.3523	0.0168	0.0000	0.0363
Φ^e	Exchange rate coefficent (H)	0.6227	0.0854	1.1075	1.6988	0.3361	2.0000	0.5207	0.0948	0.9055
Φ^g	Cover ratio coefficient (H)	0.0450	0.0334	0.0562	0.1378	0.0635	0.2248	0.1063	0.0796	0.1327
ρ^*	Discount rate persistence (F)	0.2146	0.0537	0.3670	0.4236	0.1562	0.6899	0.2106	0.0426	0.3665
Φ^{y*}	Output coefficent (F)	0.0310	0.0000	0.0678	0.1429	0.0000	0.2924	0.0540	0.0000	0.1183
Φ^{e*}	Exchange rate coefficent (F)	1.5920	1.1544	1.9998	–	–	–	–	–	–
Φ^{g*}	Cover ratio coefficient (F)	0.3424	0.2048	0.4762	0.4902	0.1334	0.8962	0.2029	0.0886	0.3113
Other parameters										
K	Foreign portfolio adjustment costs	0.3524	0.0077	0.8222	0.0816	0.0170	0.1567	0.5361	0.3421	0.7321
υ^r	Interest rate elasticity of money demand	0.0991	0.0631	0.1346	0.1014	0.0638	0.1389	0.1037	0.0641	0.1422

Table 4: Posterior distribution (continued)

	Description	U.K.			Sweden			Belgium		
		Mean	90% HPDI		Mean	90% HPDI		Mean	90% HPDI	
Shock parameters										
ρ^a	Persistence, technology (H)	0.1701	0.0536	0.2829	0.0499	0.0073	0.0908	0.4889	0.3837	0.5928
ρ^{a*}	Persistence, technology (F)	0.9262	0.8939	0.9598	0.8635	0.8250	0.9013	0.5194	0.3387	0.7050
ρ_g	Persistence, markup (H)	0.3187	0.1118	0.5218	0.3855	0.2460	0.5292	0.2406	0.0800	0.3944
ρ^{g*}	Persistence, markup (F)	0.4923	0.2770	0.7129	0.2281	0.0725	0.3782	0.3536	0.1497	0.5505
ρ^x	Persistence, money demand (H)	0.1944	0.0504	0.3269	0.1966	0.0487	0.3369	0.0667	0.0104	0.1182
ρ^{x*}	Persistence, money demand (F)	0.4739	0.3175	0.6325	0.3470	0.1536	0.5302	0.4685	0.2800	0.6683
ρ^b	Persistence, risk premium (H)	0.2824	0.0622	0.4824	0.4943	0.2585	0.7314	0.3060	0.1032	0.5042
ρ^{b*}	Persistence, risk premium (F)	0.2442	0.0432	0.4329	0.3675	0.1163	0.6067	0.3101	0.0780	0.5282
ρ^m	Persistence, gold (H & F)	0.1820	0.0287	0.3316	0.2944	0.1075	0.4747	0.1278	0.0185	0.2304
η^a	S.D., technology (H)	1.5203	1.2484	1.7971	2.0634	1.7822	2.3363	1.5854	1.3850	1.7787
η^{a*}	S.D., technology (F)	0.3329	0.2464	0.4176	0.3155	0.2527	0.3793	0.3584	0.2681	0.4472
η^g	S.D., markup (H)	2.4932	1.7125	3.2682	4.5329	3.3713	5.6810	6.5990	5.2975	7.8968
η^{g*}	S.D., markup (F)	1.2184	0.7176	1.6808	2.0819	1.3225	2.8193	0.9239	0.5702	1.2581
η^x	S.D., money demand (H)	2.7975	2.3744	3.2015	7.4503	6.4380	8.4495	2.1181	1.9499	2.2848
η^{x*}	S.D., money demand (F)	0.8329	0.5866	1.0767	0.9347	0.5801	1.3145	0.5046	0.3234	0.6758
η^b	S.D., risk premium (H)	0.2498	0.1676	0.3293	0.2345	0.1619	0.3057	0.2348	0.1641	0.3062
η^{b*}	S.D., risk premium (F)	0.2083	0.1283	0.2829	0.2107	0.1319	0.2906	0.1989	0.1321	0.2615
η^r	S.D., monetary policy (H)	0.3655	0.2738	0.4516	0.6215	0.3820	0.8560	0.1839	0.1449	0.2221
η^{r*}	S.D., monetary policy (F)	0.3160	0.2102	0.4203	0.2860	0.1902	0.3777	0.2452	0.1813	0.3064
η^m	S.D., gold (H & F)	0.4747	0.3187	0.6220	0.3973	0.1716	0.6189	0.1955	0.1199	0.2680
σ_{aa^*}	Correlation, technology	0.2802	0.0242	0.5023	0.4291	0.2537	0.6081	0.0690	0.0000	0.1474

Notes: HPDI – highest posterior density interval. For the U.K. ρ is not estimated but set to zero. For Sweden and Belgium Φ^{e*} is not estimated but set to zero.

6. Counterfactual Analysis

This section presents counterfactual output volatilities, in order to evaluate the relative importance of price flexibility, migration and monetary policy to explain why external adjustment under the Gold Standard (GS) was associated with few output costs. The counterfactual volatilities are obtained from model simulations in which either the price-, the migration- or the monetary policy parameters are set to a counterfactual value of interest. Table 5 displays the results of this exercise. The first column shows the standard deviations of the observables under the baseline model. We simulated the model on the basis of the posterior mean of the estimated structural parameters and shock processes. More particularly, we ran 2000 simulations, each 34 periods long (corresponding to the length of our sample).[42] Columns 2 to 4 display the counterfactual standard deviations that result from conducting the same simulation with the respective counterfactual structural parameters.

First, for the price rigidity counterfactual we lower all Phillips curve slope parameters from our high GS estimates to a value which is representative of today's economies. In particular we set the average duration of price contracts to three quarters, implying annualized Phillips curve slopes of 0.13 for the U.K. and 0.17 for Sweden and Belgium. This comes close to what most price rigidity estimates for current advanced economies look like today (see Smets and Wouters, 2007; Schorfheide, 2008). In this scenario the counterfactual standard deviations for per capita output are substantially higher, increasing between 82% (for the U.K.) and 137% (for Belgium). According to these model simulations flexible prices were a major reason for the resilience of per capita incomes during the GS.

In the second counterfactual, we shut down the migration channel. This had little

[42] To limit the result's dependence on the initial conditions, we ran each simulation for 134 periods and discarded the first 100 observations.

effect on output volatility. The exception is Belgium, where the standard deviation of output increases by a notable 6.39%. The counterfactual "no migration"-simulations for the U.K. and Belgium even resulted in slightly less volatile per capita incomes. This acts as a reminder that the stabilizing effects of migration on regional output do not necessarily outweight the destabilizing effects that arise from the redistribution of aggregate demand. That is away from the already recessionary origin-region towards the actively expanding host-region.

For the monetary policy counterfactual we eliminated the freedom central banks enjoyed in setting their discount rates by assuming that H has to adjust its interest rate to ensure an absolutely fixed exchange rate, while F – a much larger region than H – sets its discount rate as estimated.[43] Column (4) in table 5 shows that this "no independence" counterfactual has the most impact for the U.K.. Here, the monetary policy independence that the GS allowed enabled the Bank of England to achieve a $\approx$ 5% lower per capita income volatility. A look at the counterfactual impulse response functions furthermore shows that particularly in the short-run monetary policy could exert a non-negligible stabilizing influence (see 20 in the Appendix). Such short-run dynamics get played down in table 5, which focuses on overall output volatility.[44] We find, however, no evidence that monetary policy substantially helped the adjustment experience of either Sweden or Belgium.

In the context of today's fixed exchange rate regimes an interesting question arises

[43]In H the interest rate thus has to satisfy

$$\widehat{R}^e_t = \widehat{R}^{e*}_t - \frac{Kn}{n + \bar{E}_r\,(1-n)}\left[\bar{b}_H\left(\widehat{b}_{H,t} - \widehat{E}_{r,t} + \widehat{n}_t - \widehat{n}^*_t\right) + \bar{b}_F\bar{E}_r\left(\widehat{b}_{F,t} + \widehat{E}_{r,t}\right)\right] + \tilde{\phi}_e\hat{e}_t \quad .$$

The last term ($\tilde{\phi}_e > 0$) is necessary to ensure $\hat{e}_t = 0$ (see Benigno and Benigno, 2008). In our counterfactual, we assume $\tilde{\phi}_e = 0.01$.

[44]See Angell (1926) for an early publication that points out that the efficacy of discount rate policy for external adjustment is restricted to the short-run.

Table 5: *Counterfactual per capita output volatilities*

	Baseline model (1)	Counterfactuals: Rigid prices (2)	No migration (3)	No independence (4)	No migration, given rigid prices (3|2)	No independence, given rigid prices (4|2)
United Kingdom	1.7715	3.2318 (82.44%)	1.7596 (-0.67%)	1.8649 (5.27%)	3.2291 (-0.08%)	3.5374 (9.45%)
Sweden	1.8846	4.2275 (124.32%)	1.8811 (-0.19%)	1.9093 (1.31%)	4.2465 (0.45%)	4.3813 (3.64%)
Belgium	0.8870	2.1028 (137.08%)	0.9437 (6.39%)	0.8891 (0.25%)	2.1020 (-0.04%)	2.1097 (0.33%)

Notes: In parenthesis – percentage change in counterfactual S.D. relative to baseline S.D. for (2), (3) and (4), and relative to rigid price counterfactual in columns (3|2) and (4|2).

as to whether international migration can alleviate the external adjustment problem given that prices are rigid. To see if migration would be substantially more effective in reducing output and inflation volatility in a rigid price economy, we ran the corresponding counterfactual GS model simulation. The result displayed in column (3|2) of table 5 does not support this supposition. Shutting down the migration channel in a rigid price economy does not substantially impact output volatilities relative to the rigid price-only counterfactual. Rigid prices somewhat heighten the stabilizing effect that monetary policy has on output, but the total effects still pale in comparison to the direct effects of price flexibility on output volatility (see column (4|2)).

In summary, our findings put nominal flexibility at the center of the explanation for why external adjustments under the GS were rather benign. The role of migration- and monetary policy in stabilizing per capita output was comparatively small and, in the case of migration, even ambiguous.

7. Sectoral structure, price flexibility and external adjustment

7.1. *Prices? Which prices?*

A notable feature of the Gold Standard-economies are their large primary sector shares, even among early industrializers. Primary sector products in turn generally exhibit much more flexible prices than industrial goods or services (Bordo, 1980; Han, Penson and Jansen, 1990; Jacks, O'Rourke and Williamson, 2011).[45] Sectoral inflation variances within our 14-country sample line up accordingly: the growth rates of prices for agricultural goods (variance = 0.76) and raw materials (variance = 0.64) exhibit close to three times the volatility of industrial price-growth rates (variance = 0.27) and more than five times the volatility of service prices (variance = 0.11).[46] To get an idea of the relative importance of

[45] The compositional explanation of pre-1914 flexibility was already put forth by economists in the 1930s (see Humphrey (1937), Mason (1938) and Wood (1938)) as a way of reconciling the wide-spread belief that the general price level had become more rigid (see Means, 1936) with product-level price studies that showed that neither the frequency nor the size of price changes had changed since the late 18th century (Mills et al., 1927; Humphrey, 1937; Mason, 1938; Bezanson et al., 1936; Tucker, 1938). The modern literature on price flexibility has extended this aggregation phenomenon into the 21st century (see Kackmeister (2007) and Knotek (2008) on product-level prices, and Backus and Kehoe (1992) and Basu and Taylor (1999) on aggregate price indices).

[46] The high flexibility of agricultural prices has been linked to their supply and demand elasticities, with short-run supply being highly inelastic (Cairnes, 1873). Perishability and storability play a role in this, with less durable products generally exhibiting more flexible prices (Mills et al., 1927; Telser, 1975; Reagan and Weitzman, 1982). Blanchard (1983) and Basu (1995) link the high number of production stages and roundaboutness of industrial production to the lower flexibility of industrial goods' prices (see Means, 1935, for a related empirical analysis of prices closer to our sample period). Market structure also becomes a factor in that most agricultural goods are traded on auction markets, while industrial goods are more likely to be sold in customer markets where long-term fixed contracts are more common (see Bordo, 1980; Sachs, 1980; Gordon,

primary sectors in the period from 1880 to 1913, consider that in our 14-country sample an average of 47% of employment is concentrated in primary sectors, and 31% of value added is generated in them (see table 6). Even the U.K., the most industrialized country of its time, still employed between 10 and 20% of its labor force in agriculture and mining. Among internationally traded goods, agricultural products and raw materials made up an even larger fraction: Within our 14-country sample 67% of all merchandize exports were primary products.[47] Even among early industrializing North Western European countries, primary product exports equalled the amount of manufacture exports (see Lamartine Yates, 1959, pp. 226-32).[48]

To get an idea how important the 20th century shift away from primary production was for the flexibility of general price levels consider the following back-of-the-envelope calculation. Today, estimates of the fraction of U.S. and euro area firms that reset their price every quarter – i.e. the Calvo parameter – concentrate on the $[0.65, 0.95]$-range (Smets and Wouters, 2003, 2007; Schorfheide, 2008). Assume that the primary sector is characterized by zero price-setting rigidity. Increasing the share of primary sector firms from today's 2% to the 40% characteristic of the pre-1914 world would yield a Calvo-parameter in the range of 0.40 to 0.60. Our estimates of the annual Phillips curve slope imply a quarterly Calvo-parameter of 0.52, 0.50 and 0.40 for the U.K., Sweden and Belgium respectively – all within the range suggested by the back-of-the-envelope calculation. Thus

1982).

[47] This comes very close to figures by Aparicio, Pinilla and Serrano (2009), according to which 63% of international trade between 1880 and 1939 consisted of primary products.

[48] This stands in sharp contrast to the sectorial structure of advanced economies today, whose agricultural output typically constitutes less than 2% of total value added, and less than 2% of merchandize exports. Note however, that today fuel – a flexible price commodity – can constitute a sizable fraction of merchandise exports (see Worldbank (2016). World Development Indicators.). Moreover, fuel exports for many advanced economies constitute re-exports for which price movements do not translate into REER movements.

Table 6: *Sectoral structure, export composition and price volatilities*

	Mean	N.obs
Agriculture, value-added share (%)	31	388
Agriculture, employment share (%)	47	238
Agricultural exports, share of total merchandize exports (%)	36	551
Primary exports, share of total merchandize exports (%)	67	517
	Variance	N.obs
Agricultural prices, year-on-year change (%)	0.76	601
Raw material prices, year-on-year change (%)	0.64	578
Industrial prices, year-on-year change (%)	0.27	539
Service prices, year-on-year change (%)	0.11	423

Notes: The number of observations differs due to data availability and frequency. Agricultural employment share figures are commonly decennial data. For several countries no service price indicators exist.

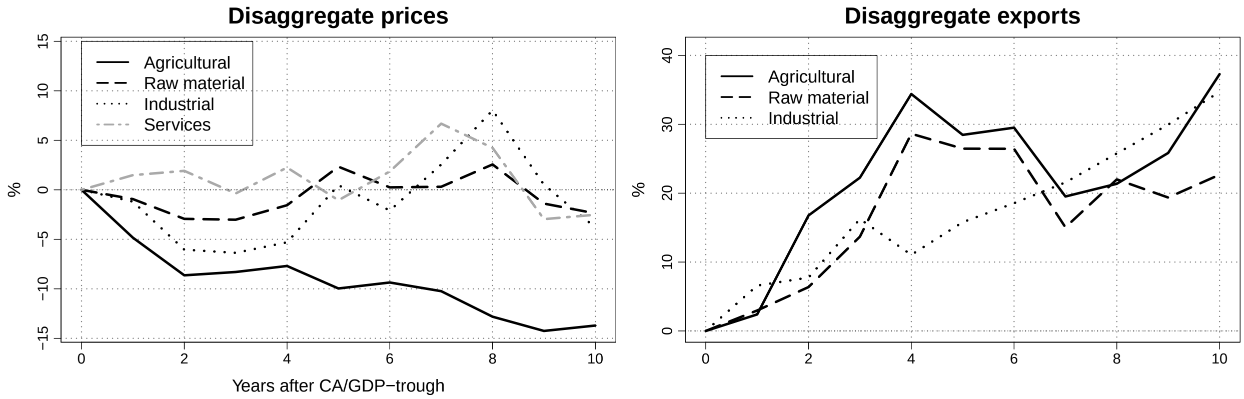
the 20th century sectoral shift away from agriculture is indeed quantitatively sufficient to explain most of the difference between the price rigidity estimates for today's economies and our comparatively low price rigidity estimates for the GS.

A look at the disaggregated price and export data confirms the crucial role agriculture played for external adjustment under the GS (see figure 3). Agricultural goods dominated the quick fall in domestic prices, and primary products generally dominated the export booms during major CA-reversals.[49] Four years into the adjustment agricultural- and raw material-exports were both up by 30%. At the same time industrial exports had increased by only 10%.[50] Agricultural exports in particular, dominated the early years of

[49]In contrast to industrial and raw material prices the relative decline in agricultural prices is persistent. Note however that $h = 0$ is unlikely to represent a steady state in this case.

[50]Note that while the sharp increase in agricultural exports is accompanied by an equally

Figure 3: *Sectoral prices and sectoral exports after major CA/GDP-reversals relative to non-reversals*



Notes: CA/GDP-troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP-troughs are defined as the lowest CA/GDP-value in a ±10-year window. The number of CA/GDP-troughs thus identified is nine.

CA-reversals, with exports up by 20% after only two years. This confirms that sectoral structure was crucial to external adjustment under the GS.

7.2. Domestic prices, the terms of trade and sectoral adjustment

While the price of domestically produced agricultural goods fell markedly, the terms of trade – the ratio of export- to import prices – remained stable (figure 4).[51] This conforms with evidence showing that by the late 19th century the law of one price held for internationally traded primary products (see Klovland, 2005). It also generalizes the observations made by Viner (1924) and Angell (1926) for Canada, and by Wilson (1931) and Pope (1986, 1990) for Australia. They note that tradables' prices moved little during external adjustments under the GS. Instead of tradables' prices adjusting directly, the

sharp fall in agricultural prices, this is not the case for raw materials. This possibly hints at differential price elasticities in the international demand for agricultural goods and raw materials.

[51]This acts as a reminder that deviations from purchasing power parity that are due to differential movements in non-tradables' prices are not inconsistent with the law of one price which pins down tradables' prices.

trade balance was adjusted indirectly, through an adjustment in domestic prices.

There are different ways in which a fall in domestic prices can bring about an adjustment in the trade balance. First, falling domestic prices can lower the input costs for the tradables sector. As tradables' output prices are pinned down in world markets, lower input costs increase the tradables sector's profits. This then induces the necessary sectoral adjustment, away from the production of non-tradables and towards the production of tradables. The fact that overall domestic prices fell while prices for exported goods remained stable is also indicative of imperfections in international market integration. Although by the late 19th century important trading centers and coastal cities were well internationally well-integrated there was considerable market segmentation further inland. Here, the higher transportation costs allowed for larger deviations from international prices (Uebele, 2011).[52] However, the fact that primary products are otherwise homogenous goods[53] that face an elastic global demand meant that as soon as differentials in transportation costs were overcome through domestic price deflation, global markets were willing to absorb additional domestic primary production.

The graph on the right side of figure 4 depicts the sectoral adjustment that accompanied the export-led external adjustments of the GS economies. Tertiary sector production, which is mostly made up of non-tradables, fell 20% below trend during major CA-adjustments, while the production of predominantly tradable primary sector goods

[52]To get an idea of the magnitude of these costs consider that for a low value-to-weight commodity like grain, shipping costs alone could range from 5% of the landed good price for the most efficient routes to up to 20% for the less efficient ones (Atkin, 1995). On top of this the much higher freight rates for overland transportion via railway and carriages could quickly blow up the wedge between origin- and destination prices. An increase in exports thus could require a substantial domestic price decline to compensate for higher transportation costs.

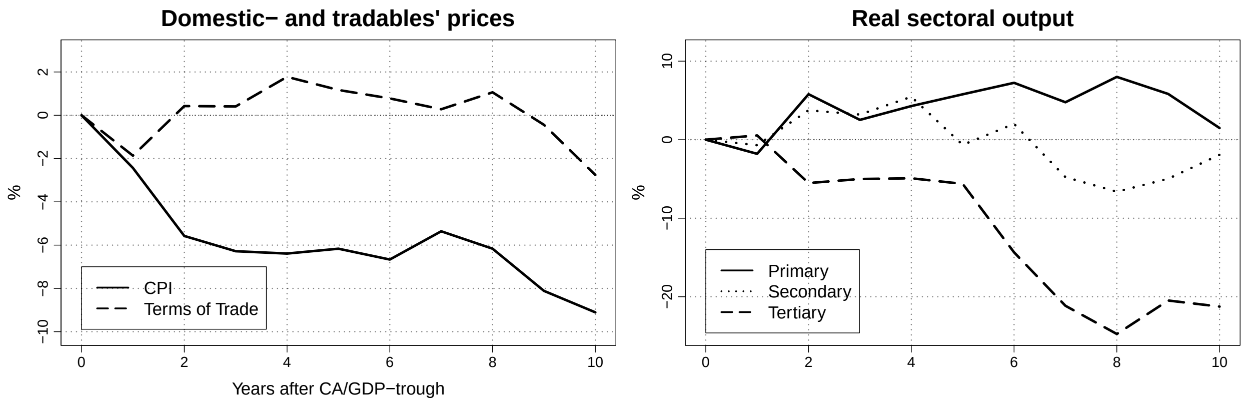
[53]See for example Atkin (1995) on the international standardization of contracts specifying the quality of grain to be delivered.

rose up to 10% above its trend level.[54] Secondary sector production, which here combines non-tradables (e.g. construction works) as well as tradables (e.g. raw materials and machines), roughly stayed on trend. This particular kind of sectoral adjustment, away from servicesand towards tradable primary goods, was easily accomplished by the rapidly industrializing Gold Standard economies, that were otherwise experiencing a decline in agricultural sector shares. To see why, notice that while external adjustments commonly require a costly re-allocation of labor and capital away from the production of non-tradables towards the production of tradables, external adjustment under the Gold Standard simply required a temporary slow-down in the secular transition from agriculture (the main tradables sector) to industry (mixed) and services (primarily non-tradable). This meant that, instead of releasing labor into unemployment, the non-tradable industrial and service sectors simply needed to temporarily hire less workers. At the same time, agriculture retained its labor supply for a little longer. In this vein, prospective rural emigrants could delay their move and continue working on their farms whenever job prospects in the secondary and tertiary sectors deteriorated relatively to those in agriculture (see Vivier, 2008, on the cyclical sensitivity of rural-urban migration flows).[55] Similarly for capital: Instead of the depreciation of sector-specific capital in the non-tradables sector that usually accompanies sectoral adjustment, the non-tradable industrial and service sectors simply needed to temporarily slow down their new capital formation. At the same, time agriculture again maintained its machinery and equipment

[54]Note, that in absolute terms a 20% decrease in service production was similarly-sized to a 10% increase in agricultural production, as agricultural sectors were considerably larger than service sectors for most economies at the time.

[55]Also, it was not uncommon for labor to shift from agriculture to industry and back according to season. Sectoral adjustment thus could be aided by changes in the time an individual worker spent working either in agriculture or in manufacturing (see Marchand and Thélot, 1991, pp.136-139). This further added to the flexibility of sectoral labor allocation.

Figure 4: *Tradables vs. non-tradables: sectoral adjustment after major CA/GDP-reversals relative to non-reversals*



Notes: CA/GDP-troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP-troughs are defined as the lowest CA/GDP-value in a ±10-year window. The number of CA/GDP-troughs thus identified is nine.

for a little longer. Consequently fewer of the real frictions that are commonly associated with sectoral adjustments materialized under the Gold Standard.[56]

In sum, the fortunate coincidence of the nominally most flexible sector – agriculture – also being the most important tradable sector is the main explanation for the ease of external adjustment under the pre-1913 Gold Standard. When hit by a shock that necessitated the reversal of the current account the agricultural sector retained more labor and capital and the resulting extra output was quickly absorbed by world markets.

[56]Note that large primary sector shares today are far less associated with benign external adjustments among developing economies (see Labys and Maizels, 1993; Kinda, Mlachila and Ouedraogo, 2016). One reason for this might be higher real sectoral adjustment costs. Another explanation may lie in the importance of primary product exports for fiscal revenue and thus its effect on fiscal policy. In contrast, prior to 1913 government spending usually made up less than 5% of GDP and revenue losses from lower-priced agricultural products would primarily be borne by private farmers. Note, however, that for some primary product exporters in the Gold Standard-periphery lowering the real value of public debt (denominated in domestic currency) was a motivation for exiting the Gold Standard (see Mitchener and Pina, 2016).

8. Conclusion

How international adjustment worked so smoothly during the 19th century Gold Standard, a colossus defying most tenets of optimum currency area, has continually fascinated scholars of international economics. The period from 1880 to 1913 did not lack in large international misalignments, that were comparable to those currently observable in the euro area.

In a typical adjustment phase under the Gold Standard prices declined swiftly, exports rose sharply, domestic monetary policy turned mildly countercyclical and net-emigration went up. To determine the relative importance of prices, monetary policy and international migration in stabilizing per capita output during external adjustments from 1880 to 1913 this paper introduced and estimated a structural model of the classical Gold Standard. Counterfactual simulations suggest that the ease of external adjustment under the Gold Standard was primarily due to flexible prices allowing for speedy expenditure switching. At best, monetary policy and migration played only minor supportive roles.

Crucial in this regard was an historical contingency: large agricultural sector shares. Agricultural products exhibited much more flexible prices than industrial or service goods. At the same time agricultural products made up a large part of all merchandize exports, even among early industrializers. This fortunate coincidence of the nominally most flexible sector simultaneously being the most important tradable sector is the main explanation for the ease of external adjustment under the pre-1913 Gold Standard. More generally, this result emphasizes that the benefits and costs of pegging the exchange rate can critically depend upon an economy's stage of development.

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Mitchell (2013) (1890-1910). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries. Agricultural, raw material, industrial and service prices: Historical Statistics of Switzerland Online. Terms of trade: Historical Statistics of Switzerland Online.

United Kingdom: Nominal GDP: Hills, Thomas and Dimsdale (2015). Real per capita GDP: Barro and Ursúa (2010). CPI: Hills, Thomas and Dimsdale (2015). Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows). Exports & imports: Hills, Thomas and Dimsdale (2015). Nominal USD-exchange rate: Officer (2015). Immigration & emigration: Mitchell (2013). Population: Maddison-Project (2013). Central bank discount rate: Hills, Thomas and Dimsdale (2015) (1870-1875), Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925) (1876-1879) and Flandreau and Zumer (2004) (1880-1913). Narrow and broad cover ratio: Bank of England Historical Balance Sheet. Notes in circulation: Bank of England Historical Balance Sheet. Primary, secondary and tertiary sector shares (value added): Buera and Kaboski (2012). Agricultural labor share: Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the United Kingdom. Agricultural, raw material, industrial and service prices: Clark (2004) (agricultural), Layton and Crowther (1935) (raw material) and Maynard (1962) (industrial, 1870-1910) and Tinbergen (1956) (industrial, 1911-1913). Terms of trade: Hills, Thomas and Dimsdale (2015).

United States: Nominal GDP: Johnston and Williamson (2011). Real per capita GDP: Barro and Ursúa (2010). CPI: Hills, Thomas and Dimsdale (2015). Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows). Exports & imports: Mitchell (2013). Immigration & emigration: Mitchell (2013) (immigration) and Ferenczi (1929) (emigration). Population: Maddison-Project (2013). Narrow and broad cover ratio: Jones and Obstfeld (2004) (gold) and Mitchell (2013) (notes). Notes in circulation:

Mitchell (2013). Primary, secondary and tertiary sector shares (value added): Buera and Kaboski (2012). Agricultural labor share: Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries (1870-1906) and Department of Commerce and Labor (1907) (1907-1913). Agricultural, raw material, industrial and service prices: Historical Statistics of the United States 1789-1945 (agricultural & industrial) and Brandau (1936) (raw material). Terms of trade: Lipsey (1963).

B. Real effective exchange rates

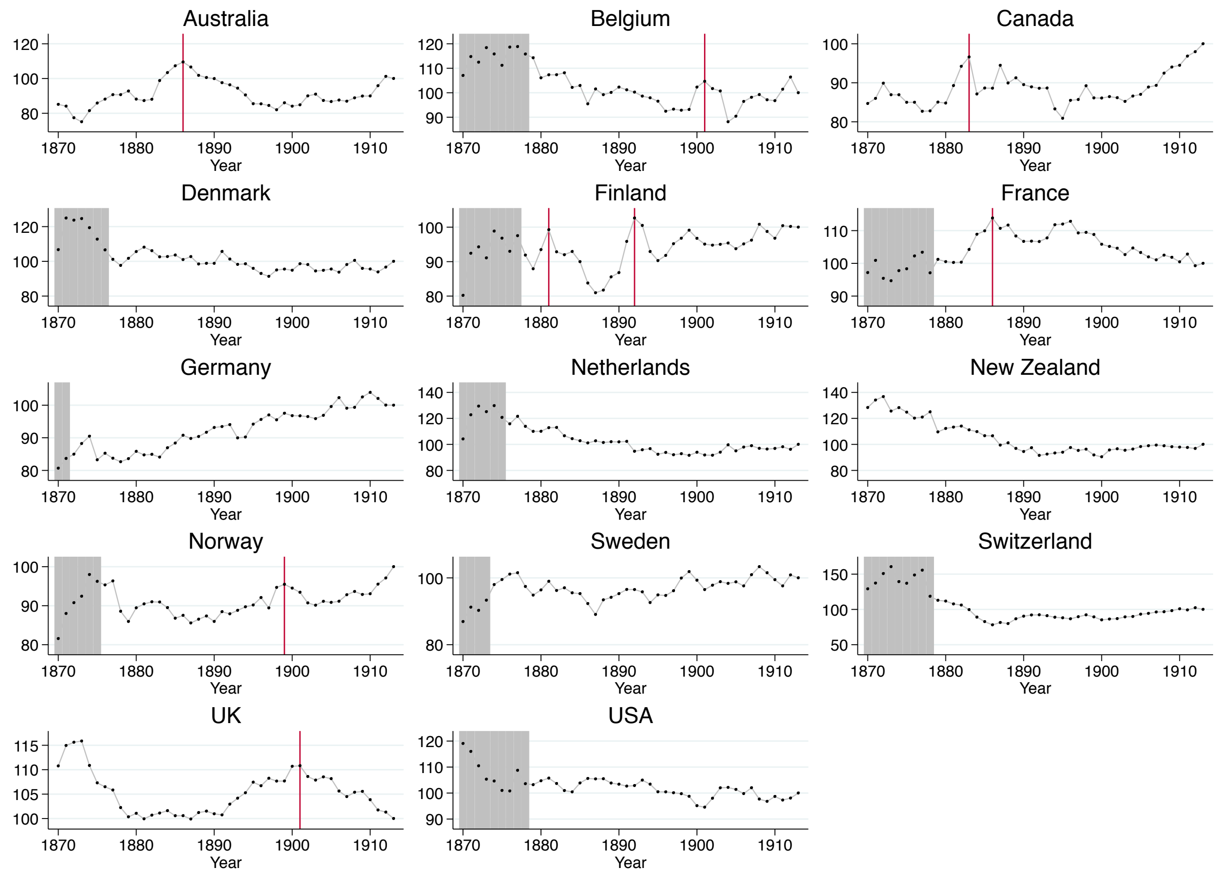


Figure 5: *REERs within the Gold Standard*

Notes: Grey – not on Gold Standard. Vertical bar – REER peak. REER peaks are defined according to a turning-point algorithm à la Bry and Boschan (1971): REER peaks are defined as the highest REER-value in a ±10-year window.

C. Adjustment periods

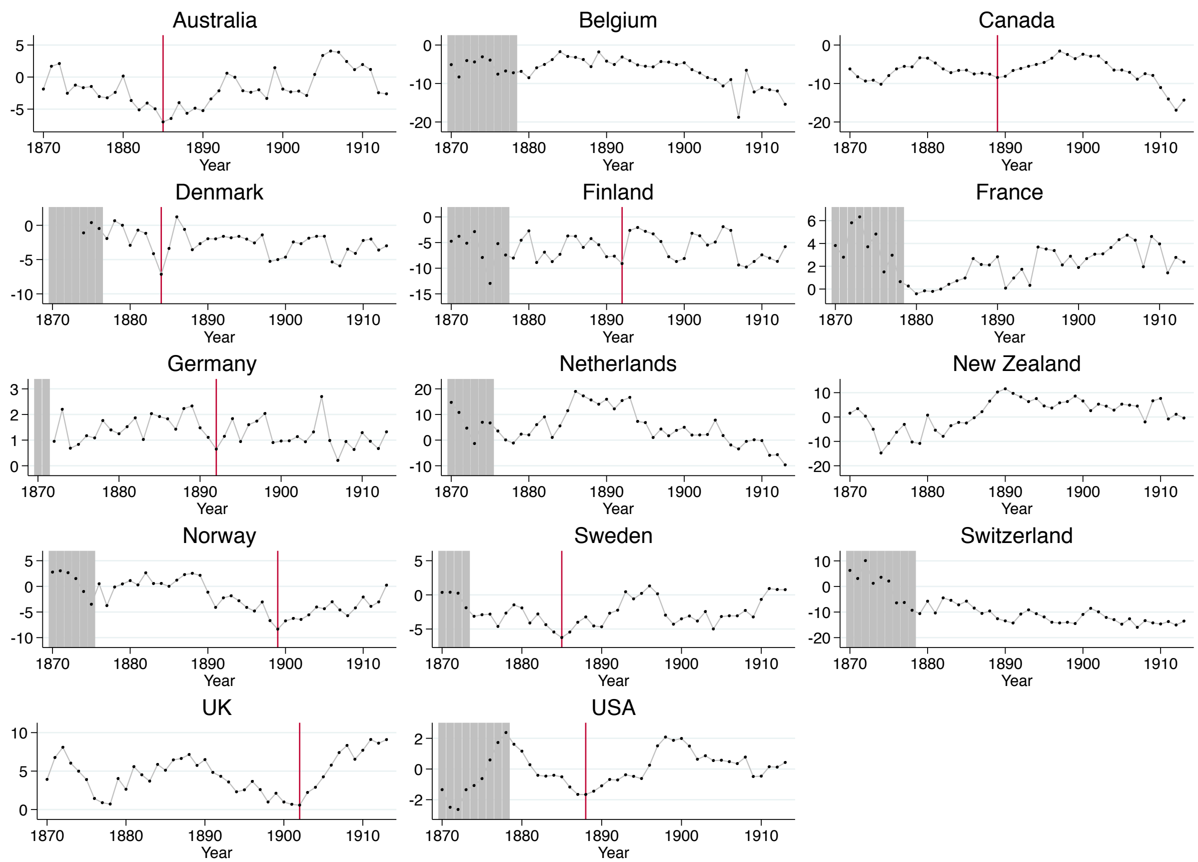


Figure 6: *CA/GDP within the Gold Standard*

Notes: Grey – not on Gold Standard. Vertical bar – CA/GDP trough. CA/GDP troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP troughs are defined as the lowest CA/Y-value in a ±10-year window.

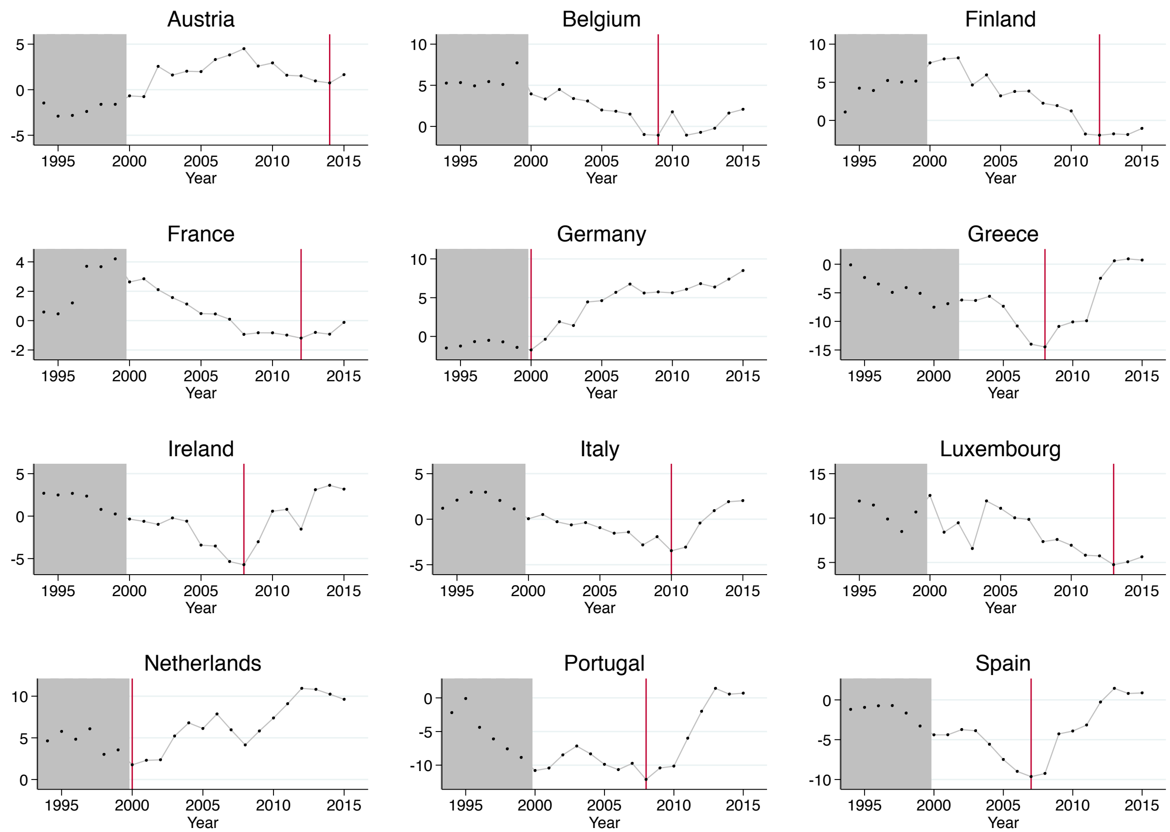


Figure 7: *CA/GDP within the euro area*

Notes: Grey – not in euro area. Vertical bar – CA/GDP trough. CA/GDP troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP troughs are defined as the lowest CA/Y-value in a ±8-year window. Border conditions were weakened because of the short sample length.

D. Gold cover ratios

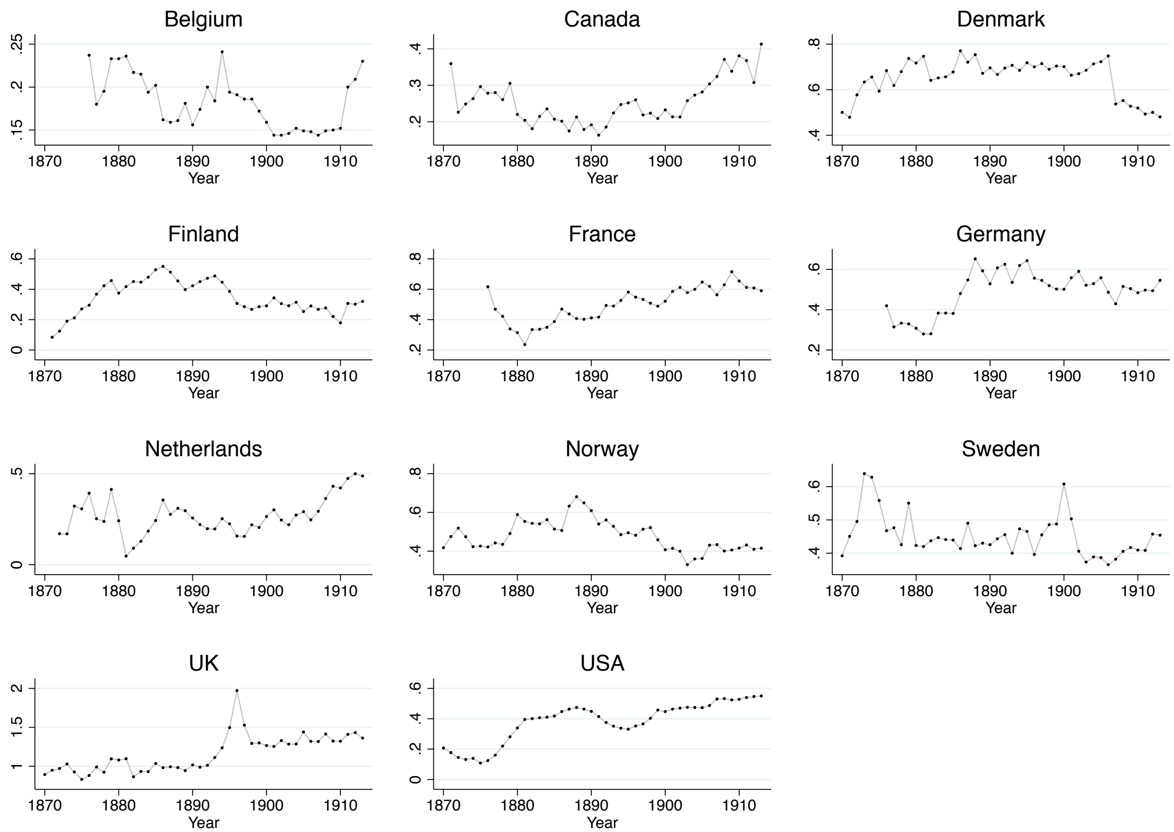


Figure 8: *Gold cover ratios, narrow*

Notes: The figure depicts narrowly defined gold cover ratios: Gold cover ratio = Gold divided by central bank notes in circulation. In the absence of a central bank (e.g. Australia, Canada and the U.S.) the gold cover ratio has been calculated as the ratio of gold- and specie reserves in the banking system relative to bank notes in circulation.

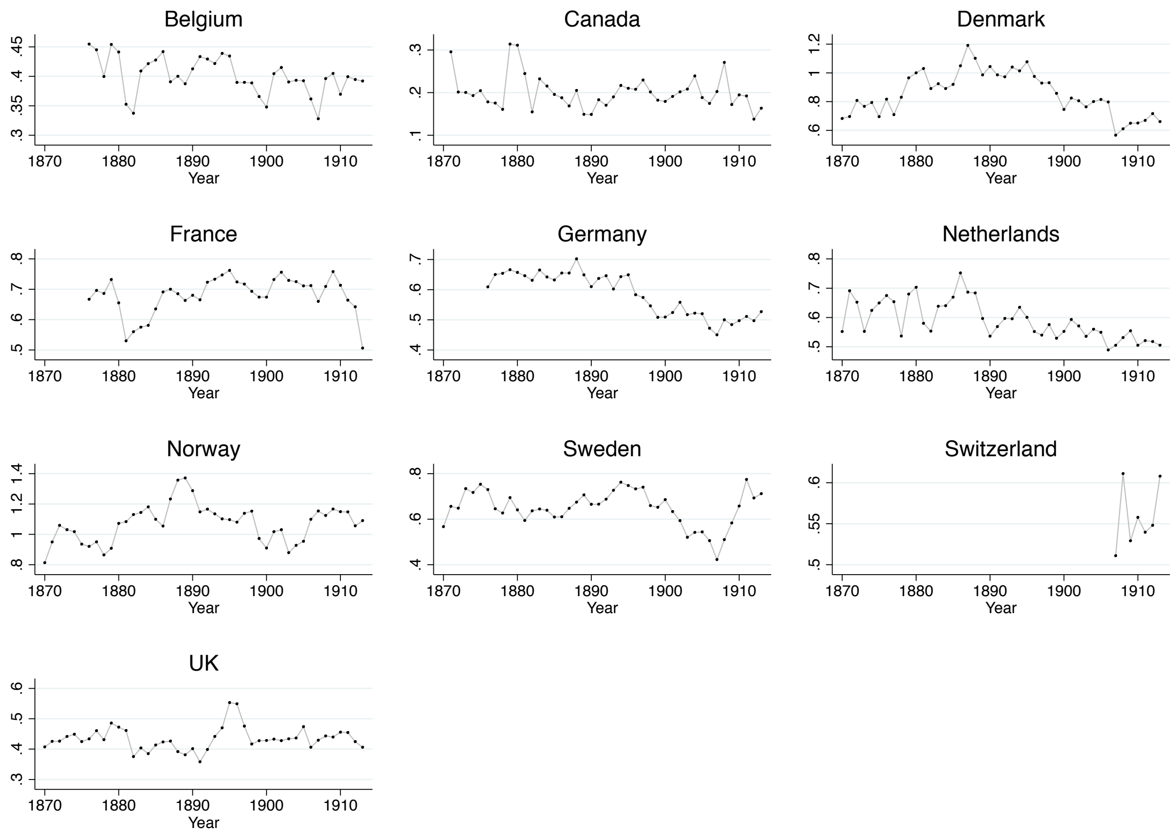


Figure 9: *Gold cover ratios, broad*

Notes: The figure depicts broadly defined gold cover ratios: Gold cover ratio = (Metal reserves + foreign exchange reserves)/(central bank notes in circulation + central bank deposits). In the absence of a central bank the gold cover ratio has been calculated as the ratio of gold-, specie and foreign exchange reserves in the banking system relative to bank notes in circulation and demand deposits.

E. Primary sector shares

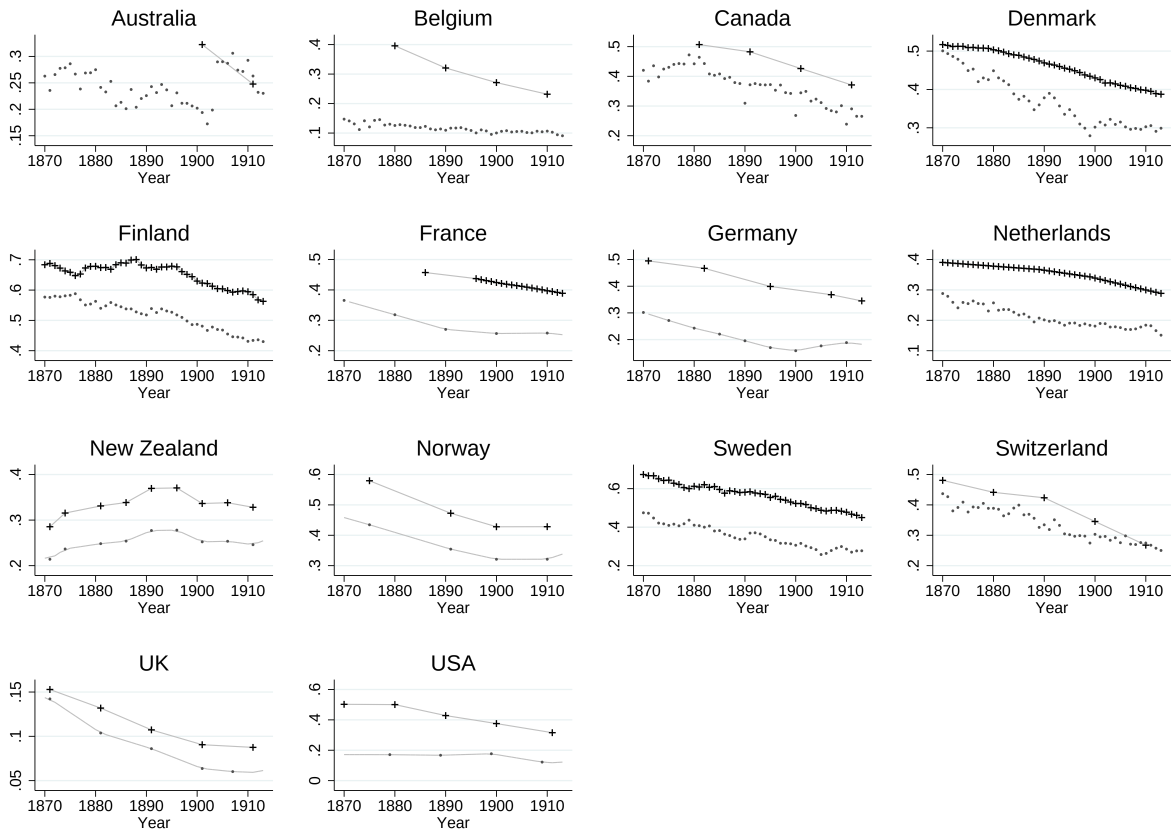


Figure 10: *Primary sector shares*

Notes: Plus sign – primary sector employment share (i.e. agriculture and raw materials). Circles – agricultural sector value added share. Plus signs and circles indicate observations. Grey lines are linearly interpolated values.

F. Nonlinear Model

In this section, we present the nonlinear model. In order to save space, we will focus on the Home region where possible. Foreign equations are analogs to the home ones and foreign variables are denoted by an asterisk. Small letters denote real variables defined as $x = X/P$ and $x^* = X^*/P^*$.

We first look at the household decision. The household's two-stage decision involves (i) the migration decision, and (ii) the decision on hours worked, consumption and savings. Households are indexed by i. The migration decision is described by the following equations:

$$\begin{aligned}
\Upsilon_t^i \quad &= \max_{\{\text{stay, migrate}\}} \{V_t^i, \quad V_t^{i^*} + v_t^i - \kappa_d\}, \text{ with } v_t^i \overset{iid}{\sim} Logistic\left(0, \frac{(\pi\psi)^2}{3}\right) \\
d_t^i \quad &= \text{Prob}\,(\,V_t^i \;\leq\; V_t^{i^*} + v_t^i - \kappa_d\,) \\
\Rightarrow \Upsilon_t^i \quad &= \quad \psi \ln\left(\exp\left(\frac{V_t^i}{\psi}\right) + \exp\left(\frac{V_t^{i^*} - \kappa_d}{\psi}\right)\right), \quad d_t^i = \left[1 + \exp\left(\frac{V_t^i - V_t^{i^*} + \kappa_d}{\psi}\right)\right]^{-1}
\end{aligned}$$

The second state decision is

$$\begin{aligned}
V_t^i \quad = \quad & \max_{c_t^i,\, l_t^i,\, B_{H,t}^i,\, B_{F,t}^i} \; \frac{1}{1-\sigma_c}\left(c_t^i - \frac{1}{1+\sigma_l}\, {l_t^i}^{1+\sigma_l}\right)^{1-\sigma_c} + \beta\, \mathbb{E}_t\, \Upsilon_{t+1}^i, \\
\text{s.t.} \quad & B_{H,t-1}^i R_{t-1}^e + B_{F,t-1}^i R_{t-1}^{e*} e_t + TR_t + P_t w_t\, l_t^i + \Gamma_t + I_t^\tau \\
& = B_{H,t}^i + B_{F,t}^i\, e_t + P_t\, c_t^i + P_t\, \frac{K}{2}\, \left(\frac{{B^i}_{F,t} e_t}{P_t} - \bar{o}\right)^2
\end{aligned}$$

The budget constraint for a F household is:

$$\begin{aligned}
& B_{H,t-1}^{i*} R_{t-1}^e / e_t + B_{F,t-1}^{i*} R_{t-1}^{e*} + TR_t^{e*} + P_t^* w_t^*\, l_t^{i*} + \Gamma_t^* + I_t^\tau \\
& = B_{H,t}^{i*}/e_t + B_{F,t}^{i*} + P_t^*\, c_t^{i*} + P_t^*\, \frac{K}{2}\, \left(\frac{B_{H,t}^{i*}}{P_t^* e_t} - \bar{o}^*\right)^2
\end{aligned}$$

where the nominal exchange rate e_t is expressed in price notation (home per foreign currency). As explained in the main text, all households within a region make the same decision, hence we drop the household index i. Writing the real exchange rate as $E_{r,t} = e_t P_t^* / P_t$ the first order conditions imply

$$\lambda_t = \left(c_t - \frac{l_t^{1+\sigma_l}}{1+\sigma_l} \right)^{-\sigma_c} \tag{F.1}$$

$$\lambda_t^* = \left(c_t^* - \frac{(l_t^*)^{1+\sigma_l}}{1+\sigma_l} \right)^{-\sigma_c} \tag{F.2}$$

$$\lambda_t = \beta\, R_t^e\, \mathbb{E}_t \left(\frac{(1-d_{t+1})\ \lambda_{t+1}}{\Pi_{t+1}} + \frac{d_{t+1}\, \lambda_{t+1}^*}{\Pi_{t+1} E_{r,t+1}} \right) \tag{F.3}$$

$$\lambda_t^* = \beta\, R_t^{e*}\, \mathbb{E}_t \left(\frac{(1-d_{t+1}^*)\ \lambda_{t+1}^*}{\Pi_{t+1}^*} + \frac{d_{t+1}^*\, \lambda_{t+1} E_{r,t+1}}{\Pi_{t+1}^*} \right) \tag{F.4}$$

$$\lambda_t = \beta\, R_t^{e*}\, \frac{1}{1+\mathsf{K}\ (b_{F,t}\, E_{r,t} - \bar{o})}\, \frac{e_{t+1}}{e_t} \mathbb{E}_t \left(\frac{(1-d_{t+1})\ \lambda_{t+1}}{\Pi_{t+1}} + \frac{d_{t+1}\, \lambda_{t+1}^*}{\Pi_{t+1} E_{r,t+1}} \right) \tag{F.5}$$

$$\lambda_t^* = \beta\, R_t^{e}\, \frac{1}{1+\mathsf{K}\ \left(b_{H,t}^*/E_{r,t} - \bar{o}^*\right)}\, \frac{e_t}{e_{t+1}} \mathbb{E}_t \left(\frac{(1-d_{t+1}^*)\ \lambda_{t+1}^*}{\Pi_{t+1}^*} + \frac{d_{t+1}^*\, \lambda_{t+1} E_{r,t+1}}{\Pi_{t+1}^*} \right) \tag{F.6}$$

$$l_t^{\sigma_l} = w_t \tag{F.7}$$

$$l_t^{*\sigma_l} = w_t^* \tag{F.8}$$

The population evolves according to

$$n_t = n_{t-1}\ (1-d_t) + d_t^*\, n_{t-1}^* \tag{F.9}$$

$$n_t^* = 1 - n_t \tag{F.10}$$

Firm j's optimization problem is

$$\max_{P_{H,t}(j)} \quad \mathbb{E}_t \sum_{k=0}^{\infty} \left\{ (\beta\theta)^k \ \frac{\lambda_{t+k}}{\lambda_t} \frac{P_t}{P_{t+k}} \left[P_{H,t}(j) y_t(j) - w_{t+k} P_{t+k} l_{t+k}(j) \right] \right\} \tag{F.11}$$

$$\text{s.t. } y_{t+k}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t+k}} \right)^{-\mu} y_{t+k} \tag{F.12}$$

$$y_{t+k}(j) = A_{t+k} l_{t+k}^{\gamma} \tag{F.13}$$

The first order condition leads to

$$F_t = \lambda_t \, y_t \left(\frac{P_{H,t}}{P_t} \right) \left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)^{1-\mu} + \beta \, \theta \, \mathbb{E}_t \left(\frac{\left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)}{\left(\frac{P_{H,t+1}^{opt}}{P_{H,t+1}} \right)} \frac{1}{\Pi_{H,t+1}} \right)^{1-\mu} F_{t+1} \tag{F.14}$$

$$K_t = w_t \, \frac{\lambda_t}{\gamma} \, \frac{\mu}{\mu - 1} \left(\frac{y_t}{A_t} \right)^{\frac{1}{\gamma}} \left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)^{\frac{-\mu}{\gamma}} + \beta \, \theta \, \mathbb{E}_t \left(\frac{\left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)}{\left(\frac{P_{H,t+1}^{opt}}{P_{H,t+1}} \right)} \frac{1}{\Pi_{H,t+1}} \right)^{\frac{-\mu}{\gamma}} K_{t+1} \tag{F.15}$$

$$K_t = F_t \tag{F.16}$$

The price dynamics are described by

$$1 - \theta \left(\frac{1}{\Pi_{H,t}} \right)^{1-\mu} = (1 - \theta) \left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)^{1-\mu} \tag{F.17}$$

$$\Delta_t^P = \theta \, \Delta_{t-1}^P \, \Pi_{H,t}^{\frac{\mu}{\gamma}} + (1 - \theta) \left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)^{\frac{(-\mu)}{\gamma}} \tag{F.18}$$

where $\Delta_t^P = \frac{1}{n} \int_0^n \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{\frac{-\mu}{\gamma}} dj$ denotes the price dispersion. The monetary side of the

model is described by the following four equations

$$R_t = \bar{R}^{1-\rho} R_{t-1}^{\rho} \left(\frac{y_t}{\bar{y}}\right)^{(1-\rho)\,\Phi^y} \left(\frac{\gamma_t}{\bar{\gamma}}\right)^{(1-\rho)\,\Phi_g} \left(\frac{e_t}{\bar{e}}\right)^{(1-\rho)\,\Phi_e} \tag{F.19}$$

$$P_{H,t}\; n\, y_t = \exp(\chi_t)\, M_t\, k(R_t) \tag{F.20}$$

$$G_t = G_{t-1} + F(e_t)\exp(\epsilon_{m,t}) \tag{F.21}$$

$$\gamma_t M_t = P_g G_t, \tag{F.22}$$

The market clearing conditions are

$$y_t\, n = \left(\frac{P_{H,t}}{P_t}\right)^{(-\epsilon)} \left((1-\alpha)\; c_t\, n_t + \alpha^*\, c_t^*\, n_t^*\, E_{r,t}^{\epsilon}\right) \tag{F.23}$$

$$\Delta_t^P\, n\, y_t^{\frac{1}{\gamma}} = l_t\, n_t\, A_t^{\frac{1}{\gamma}} \tag{F.24}$$

$$0 = n_t\, B_{H,t} + n_t^*\, B_{H,t}^* \tag{F.25}$$

$$0 = n_t\, B_{F,t} + n_t^*\, B_{F,t}^* \tag{F.26}$$

Auxiliary variables:

$$
\begin{aligned}
ToT_t &= \frac{P_{F,t}}{P_{H.t}} && \text{(F.27)}\\
\Pi_t &= \frac{P_t}{P_{t-1}} && \text{(F.28)}\\
\Pi_{H,t} &= \frac{P_{H,t}}{P_{H,t-1}} && \text{(F.29)}\\
y_t^p &= \frac{n\, y_t}{n_t} && \text{(F.30)}\\
TB_t &= n_t^* c_{H,t}^* P_{H,t} - n_t c_{F,t} P_{F,t} && \text{(F.31)}\\
c_{H,t} &= (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\epsilon} c_t && \text{(F.32)}\\
c_{H,t}^* &= \alpha^* \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\epsilon^*} c_t^* && \text{(F.33)}\\
c_{F,t} &= \alpha \left(\frac{P_{F,t}}{P_t}\right)^{-\epsilon} c_t && \text{(F.34)}\\
c_{F,t}^* &= (1-\alpha^*)\left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\epsilon^*} c_t^* && \text{(F.35)}
\end{aligned}
$$

G. Steady State

We log-linearize the nonlinear model around a steady state with zero inflation, constant population and $\beta R = 1$. Steady state values are denoted by a bar symbol. From (F.4) and (F.6) it follows that $\bar{R} = \bar{R}^*$. Using (F.4) and (F.5) we have $\frac{\beta\bar{R}^*\bar{d}^*}{1-\beta\bar{R}^*(1-\bar{d}^*)} = \frac{1-\beta\bar{R}(1-\bar{d})}{\beta\bar{R}\bar{d}}$. It is easy to see that $\beta\bar{R} = 1$, a standard assumption in the literature, is a solution to the equation. We also have

$$\bar{\lambda}\bar{E}_r = \bar{\lambda}^* \tag{G.1}$$

$$\bar{\lambda} = \left(\bar{c} - \frac{\bar{l}^{1+\sigma_l}}{1+\sigma_l}\right)^{-\sigma_c} \tag{G.2}$$

$$\bar{\lambda}^* = \left(\bar{c}^* - \frac{(\bar{l}^*)^{1+\sigma_l}}{1+\sigma_l}\right)^{-\sigma_c} \tag{G.3}$$

From (F.15), (F.16), and (F.16) and the corresponding equations for F, we obtain

$$\bar{w} = \gamma\,\bar{y}\,\frac{\bar{P}_H}{\bar{P}}\left(\frac{\bar{y}}{\bar{A}}\right)^{-1/\gamma}\frac{\mu-1}{\mu} \tag{G.4}$$

$$\bar{w}^* = \gamma\,\bar{y}^*\,\frac{\bar{P}_F^*}{\bar{P}^*}\left(\frac{\bar{y}^*}{\bar{A}^*}\right)^{-1/\gamma}\frac{\mu-1}{\mu} \tag{G.5}$$

The steady state labor supply satisfies

$$\bar{l}_l^{\sigma} = \bar{w} \tag{G.6}$$

$$(\bar{l}^*)^{\sigma_l} = \bar{w}^* \tag{G.7}$$

At the steady state, the asset pooling assumption gives us

$$\begin{aligned}
\bar{n}\,\bar{b} &= n\,(1-\bar{d})\,(\bar{b}_H\bar{R} + \bar{E}_r\bar{b}_F\bar{R}) + \bar{d}^*\,(1-\bar{n})\,(\bar{b}_H^*\bar{R} + \bar{E}_r\bar{b}_F^*\bar{R}) \\
(1-\bar{n})\,\bar{b}^* &= (1-\bar{n})\,(1-\bar{d}^*)\,(\bar{b}_F^*\bar{R} + \bar{b}_H^*\bar{R}/\bar{E}_r) + \bar{d}\,\bar{n}\,(\bar{b}_F\bar{R} + \bar{b}_H\bar{R}/\bar{E}_r)
\end{aligned}$$

Using the steady state bond market clearing conditions and writing real net foreign assets as $\bar{\Omega} \equiv \bar{b}_H + \bar{E}_r \bar{b}_F$, we have

$$\begin{aligned} \bar{n}\,\bar{b} &= \bar{R}\,(1-\bar{d}-\bar{d}^*)\,\bar{\Omega}\bar{n} \\ (1-\bar{n})\,\bar{E}_r\bar{b}^* &= -\bar{R}\,(1-\bar{d}-\bar{d}^*)\,\bar{\Omega}\bar{n} \end{aligned}$$

The budget constraints of the households in H and F give us $\bar{\Omega} = \frac{1}{(1-\bar{d}-\bar{d}^*)\,\bar{R}-1}\left(\bar{c} - \frac{\bar{P}_H}{\bar{P}}\bar{y}\right)$, and also

$$\bar{n}\,\frac{\bar{P}_H}{\bar{P}}\bar{y} + (1-\bar{n})\,\frac{\bar{P}_F^*}{\bar{P}^*}\bar{y}^*\bar{E}_r = \bar{n}\,\bar{c} + (1-\bar{n})\,\bar{c}^*\,\bar{E}_r \tag{G.8}$$

which reflects the resources constraint of the whole economy in terms of H currency. The goods and labor market clearing conditions imply

$$\bar{y}\,\bar{n} = \left(\frac{\bar{P}_H}{\bar{P}}\right)^{-\epsilon}\left((1-\alpha)\;\bar{c}\,\bar{n} + \alpha^*\,\bar{c}^*\,(1-\bar{n})\,\bar{E}_r^{\epsilon}\right) \tag{G.9}$$

$$\bar{y}^*\,(1-\bar{n}) = \left(\frac{\bar{P}_F^*}{\bar{P}^*}\right)^{-\epsilon}\left(\alpha\,\bar{c}\,\bar{n}/\bar{E}_r^{\epsilon} + (1-\alpha^*)\,(1-\bar{n})\,\bar{c}^*\right) \tag{G.10}$$

$$\bar{y} = \bar{A}\,\bar{l} \tag{G.11}$$

$$\bar{y}^* = \bar{A}^*\,(\bar{l}^*)^{\gamma} \tag{G.12}$$

Prices in the steady state satisfy

$$1 = (1-\alpha)\left(\frac{\bar{P}_H}{\bar{P}}\right)^{1-\epsilon} + \alpha\left(\frac{\bar{P}_{F^*}}{\bar{P}^*}\bar{E}_r\right)^{1-\epsilon} \tag{G.13}$$

Finally, the steady state populations satisfy $\bar{d}\,\bar{n} = \bar{d}^*\,(1-\bar{n})$. We solve for $\bar{c}$, $\bar{c}^*$, $\bar{E}_r$, $\frac{\bar{P}_H}{\bar{P}}$, $\frac{\bar{P}_F^*}{\bar{P}^*}$, $\bar{y}$, $\bar{y}^*$, $\bar{l}$, $\bar{l}^*$, $\bar{\lambda}$, $\bar{\lambda}^*$, $\bar{w}$, $\bar{w}^*$ using equations (G.1) - (G.13).

H. Log-linearized Model

In this section, we present the complete log-linearized model equation system that is used in the Bayesian estimation. Lower-case variables with a hat symbol represent logarithmic deviations from the steady state value of the variable (denoted by a bar symbol, $\hat{x} = \log\left(\frac{x}{\bar{x}}\right)$). Δ indicates the first difference ($\Delta\widehat{x}_t = \widehat{x}_t - \widehat{x}_{t-1}$). $\widetilde{\kappa}$ denotes the slope of the Phillips curve, which is related to the structural parameters β, γ, μ and θ according to $\widetilde{\kappa} = (1-\beta\theta)(1-\theta)/[1/\theta(1-\mu+\mu/\gamma)]$.

$$\hat{\lambda}_t = \frac{(-\sigma_c)}{\bar{c}\,(1-h) - \frac{1}{1+\sigma_l}\,(\bar{l})^{1+\sigma_l}}\,\left(\bar{c}\,\hat{c}_t - \,(\bar{l})^{1+\sigma_l}\,\hat{l}_t\right) \tag{H.1}$$

$$\hat{\lambda}^*_t = \frac{(-\sigma_c)}{(1-h)\,\bar{c}^* - \frac{1}{1+\sigma_l}\,(\bar{l}^*)^{1+\sigma_l}}\,\left(\bar{c}^*\,\hat{c}^*_t - \,(\bar{l}^*)^{1+\sigma_l}\,\hat{l}^*_t\right) \tag{H.2}$$

$$\hat{\lambda}_t = \widehat{R}^e_t - \mathbb{E}_t\widehat{\Pi}_{t+1} + \left(1-\bar{d}\right)\,\mathbb{E}_t\hat{\lambda}_{t+1} + \bar{d}\,\left(\mathbb{E}_t\hat{\lambda}^*_{t+1} - \mathbb{E}_t\widehat{E}_{r,t+1}\right) \tag{H.3}$$

$$\hat{\lambda}^*_t = \hat{R}^{e*}_t - \mathbb{E}_t\widehat{\Pi}^*_{t+1} + \hat{\lambda}^*_{t+1}\,\left(1-\bar{d}^*\right) + \bar{d}^*\,\left(\mathbb{E}_t\hat{\lambda}_{t+1} + \mathbb{E}_t\widehat{E}_{r,t+1}\right) \tag{H.4}$$

$$\hat{R}^e_t = \hat{R}^{e*}_t + \mathbb{E}_t\hat{e}_{t+1} - \hat{e}_t - \frac{\mathrm{K}\,n}{n + \bar{E}_r\,(1-n)}\,\left(\widehat{\Omega}_t + \left(\bar{E}_r\,\bar{b}_F - \bar{b}_H\right)\,\widehat{E}_{rt} + \bar{b}_H\,(\hat{n}_t - \hat{n}^*_t)\right) \tag{H.5}$$

$$\begin{aligned}
&\bar{b}\,\left(\hat{n}_{t-1} + \frac{1}{\bar{E}_r\,\bar{b}_F + \bar{b}_H}\,\left(\widehat{\Omega}_{t-1} + \bar{b}_H\,\left(\hat{R}_{t-1} - \hat{\Pi}_t\right) + \bar{E}_r\,\bar{b}_F\,\left(\hat{E}_{rt} + \hat{R}^*_{t-1} - \hat{\Pi}^*_t\right)\right)\right. \\
&\left. - \frac{1}{1-\bar{d}-\bar{d}^*}\,\left(\bar{d}\,\hat{d}_t + \bar{d}^*\,\hat{d}^*_t\right)\right) = \widehat{\Omega}_t - \bar{y}\,\frac{\bar{P}_H}{\bar{P}}\,\left(\hat{y}_t - \alpha\,\left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon}\,\widehat{ToT}_t\right) \\
&\quad + \hat{n}_t\,\left(\bar{c} + \bar{E}_r\,\bar{b}_F + \bar{b}_H\right) + \bar{E}_r\,\bar{b}_F\,\hat{E}_{rt} + \bar{c}\,\hat{c}_t
\end{aligned} \tag{H.6}$$

$$\begin{aligned}
\hat{d}_t = {} & \left(1-\bar{d}-\bar{d}^*\right)\,\beta\,\mathbb{E}_t\hat{d}_{t+1} \\
& + \frac{1-\bar{d}}{\psi}\,\left(\left(\bar{c}^*\,\left(\hat{c}^*_t - h\,\hat{c}^*_{t-1}\right) - \,(\bar{l}^*)^{1+\sigma_l}\,\hat{l}^*_t\right)\,\bar{\lambda}^* - \left(\bar{c}\,(\hat{c}_t - h\,\hat{c}_{t-1}) - \,(\bar{l})^{1+\sigma_l}\,\hat{l}_t\right)\,\bar{\lambda}\right)
\end{aligned} \tag{H.7}$$

$$\begin{aligned}
\hat{d}^*_t = {} & \left(1-\bar{d}-\bar{d}^*\right)\,\beta\,\mathbb{E}_t\hat{d}^*_{t+1} \\
& - \left(\left(\bar{c}^*\,\left(\hat{c}^*_t - h\,\hat{c}^*_{t-1}\right) - \,(\bar{l}^*)^{1+\sigma_l}\,\hat{l}^*_t\right)\,\bar{\lambda}^* - \left(\bar{c}\,(\hat{c}_t - h\,\hat{c}_{t-1}) - \,(\bar{l})^{1+\sigma_l}\,\hat{l}_t\right)\,\bar{\lambda}\right)\,\frac{1-\bar{d}^*}{\psi^*}
\end{aligned} \tag{H.8}$$

$$\hat{n}_t = \left(1 - \bar{d}\right)\ \hat{n}_{t-1} + \bar{d}\,\hat{n}^*_{t-1} - \bar{d}\,\hat{d}_t + \bar{d}\,\hat{d}^*_t \tag{H.9}$$

$$\hat{n}^*_t = \hat{n}_t\,\frac{-n}{1-n} \tag{H.10}$$

$$\hat{\Pi}_{H,t} = \beta\,\mathbb{E}_t\hat{\Pi}_{H,t+1} + \tilde{\kappa}\ \left(\alpha\left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon}\widehat{ToT}_t - \hat{y}_t + \hat{w}_t + \frac{1}{\gamma}\ \left(\hat{y}_t - \hat{A}_t\right)\right) + \epsilon^g_t \tag{H.11}$$

$$\hat{\Pi}_{F,t} = \beta\,\mathbb{E}_t\hat{\Pi}_{F,t+1} + \tilde{\kappa}\ \left(\widehat{ToT}_t\ \left(-\alpha^*\left(\frac{\bar{P}^*_H}{\bar{P}^*}\right)^{1-\epsilon^*}\right) - \hat{y}^*_t + \hat{w}^*_t + \frac{1}{\gamma}\ \left(\hat{y}^*_t - \hat{A}^*_t\right)\right) + \epsilon^{g*}_t \tag{H.12}$$

$$\widehat{ToT}_t\ \left(1 - \alpha^*\left(\frac{\bar{P}^*_H}{\bar{P}^*}\right)^{1-\epsilon^*} - \alpha\left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon}\right) = \hat{E}_{r,t} \tag{H.13}$$

$$\hat{\Pi}_{H,t} = \hat{\Pi}_t - \alpha\left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon}\ \left(\widehat{ToT}_t - \widehat{ToT}_{t-1}\right) \tag{H.14}$$

$$\hat{\Pi}_{F,t} = \hat{\Pi}^*_t + \alpha^*\left(\frac{\bar{P}^*_H}{\bar{P}^*}\right)^{1-\epsilon^*}\ \left(\widehat{ToT}_t - \widehat{ToT}_{t-1}\right) \tag{H.15}$$

$$\begin{aligned}\hat{y}_t = {} & \frac{\bar{c}}{\bar{y}}\ (1-\alpha)\ {\frac{\bar{P}_H}{\bar{P}}}^{-\epsilon}\ (\hat{c}_t + \hat{n}_t) + \frac{\frac{(1-n)\,\bar{c}^*\ {\frac{\bar{P}_H}{\bar{P}}}^{-\epsilon}}{n}}{\bar{y}}\,\alpha^*\,\bar{E}^{\epsilon}_r\ \left(\hat{c}^*_t + \hat{n}^*_t + \hat{E}_{rt}\,\epsilon\right) \\ & + \widehat{ToT}_t\,\frac{\frac{\alpha\left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon}}{n}}{\bar{y}}\ \left({\frac{\bar{P}_H}{\bar{P}}}^{-\epsilon}\ (1-\alpha)\ n\,\bar{c}\,\epsilon + \bar{E}^{\epsilon}_r\,\alpha^*\ (1-n)\ {\frac{\bar{P}_H}{\bar{P}}}^{-\epsilon}\ \bar{c}^*\,\epsilon\right)\end{aligned} \tag{H.16}$$

$$\begin{aligned}\hat{y}^*_t = {} & (\hat{c}^*_t + \hat{n}^*_t)\ \frac{\bar{c}^*}{\bar{y}^*}\ (1-\alpha^*)\ {\frac{\bar{P}^*_F}{\bar{P}^*}}^{-\epsilon} + {\frac{\bar{P}^*_F}{\bar{P}^*}}^{-\epsilon}\ \frac{\alpha\,\frac{\frac{\bar{c}\,n}{1-n}}{\bar{y}^*}}{\bar{E}^{\epsilon}_r}\ \left(\hat{c}_t + \hat{n}_t - \hat{E}_{rt}\,\epsilon\right) \\ & - \widehat{ToT}_t\,\frac{\frac{\alpha^*\left(\frac{\bar{P}^*_H}{\bar{P}^*}\right)^{1-\epsilon^*}}{1-n}}{\bar{y}^*}\ \left({\frac{\bar{P}^*_F}{\bar{P}^*}}^{-\epsilon}\ (1-\alpha^*)\ (1-n)\ \bar{c}^*\,\epsilon + {\frac{\bar{P}^*_F}{\bar{P}^*}}^{-\epsilon}\ \frac{\alpha\,n\,\bar{c}\,\epsilon}{\bar{E}^{\epsilon}_r}\right)\end{aligned} \tag{H.17}$$

$$\hat{R}_t = \hat{R}_{t-1}\,\rho^R + \hat{y}_t\ \left(1-\rho^R\right)\ \Phi^y + \hat{e}_t\ \left(1-\rho^R\right)\ \Phi^e + \left(1-\rho^R\right)\ (-\Phi^g)\ \hat{\gamma}_t + \epsilon^r_t \tag{H.18}$$

$$\hat{R}^*_t = \hat{R}^*_{t-1}\,\rho^{R^*} + \hat{y}^*_t\ \left(1-\rho^{R^*}\right)\ \Phi^{y^*} + \left(1-\rho^{R^*}\right)\ \Phi^{e^*}\ (-\hat{e}_t) + \left(1-\rho^{R^*}\right)\ \left(-\Phi^{g^*}\right)\ \hat{\gamma}^*_t + \epsilon^{r*}_t \tag{H.19}$$

$$\hat{R}^{e}_{t} = \hat{R}_{t} + \epsilon^{b}_{t} \tag{H.20}$$

$$\hat{R}^{e*}_{t} = \hat{R}^{*}_{t} + \epsilon^{b*}_{t} \tag{H.21}$$

$$\Delta\hat{G}_{t}\,\frac{\frac{\bar{G}}{\bar{G}^{*}}}{1+\frac{\bar{G}}{\bar{G}^{*}}} = \hat{e}_{t}\,\epsilon^{e} + \epsilon^{m}_{t} \tag{H.22}$$

$$\Delta\hat{G^{*}}_{t}\,\frac{1}{1+\frac{\bar{G}}{\bar{G}^{*}}} = \hat{e}_{t}\,\left(-\epsilon^{e}\right) + \epsilon^{m*}_{t} \tag{H.23}$$

$$\Delta\widehat{M}_{t} = \hat{y}_{t} + \hat{\Pi}_{H,t} - \hat{y}_{t-1} - v^{r}\,\left(\widehat{R}_{t} - \widehat{R}_{t-1}\right) - \Delta\epsilon^{\chi}_{t} \tag{H.24}$$

$$\Delta\widehat{M}*_{t} = \hat{\Pi}_{F,t} + \hat{y}^{*}_{t} - \hat{y}^{*}_{t-1} - v^{r}\,\left(\widehat{R}^{*}_{t} - \widehat{R}^{*}_{t-1}\right) - \Delta\epsilon^{\chi*}_{t} \tag{H.25}$$

$$\hat{\gamma}_{t} = \Delta\widehat{G}_{t} + \hat{\gamma}_{t-1} - \Delta\widehat{M}_{t} \tag{H.26}$$

$$\hat{\gamma}^{*}_{t} = \Delta\widehat{G}^{*}{}_{t} + \hat{\gamma}^{*}_{t-1} - \Delta\widehat{M}^{*}_{t} \tag{H.27}$$

$$\hat{y}^{p}_{t} = \hat{y}_{t} - \widehat{ToT}_{t}\,\alpha\,\left(\frac{\bar{P}_{F}}{\bar{P}}\right)^{1-\epsilon} - \hat{n}_{t} \tag{H.28}$$

$$\hat{y}^{p*}_{t} = \hat{y}^{*}_{t} + \widehat{ToT}_{t}\,\alpha^{*}\,\left(\frac{\bar{P}^{*}_{H}}{\bar{P}^{*}}\right)^{1-\epsilon^{*}} - \hat{n}^{*}_{t} \tag{H.29}$$

$$\hat{E_{r,t}} = \hat{\Pi}^{*}_{t} + \hat{e}_{t} + \hat{E}_{r\,t-1} - \hat{e}_{t-1} - \hat{\Pi}_{t} \tag{H.30}$$

$$\hat{t}b_{t}\,\bar{t}b = \left(\hat{y}_{t} - \widehat{ToT}_{t}\,\alpha\,\left(\frac{\bar{P}_{F}}{\bar{P}}\right)^{1-\epsilon}\right)\,n\,\bar{y}\,\frac{\bar{P}_{H}}{\bar{P}} - \left(\hat{c}_{t} + \hat{n}_{t}\right)\,\bar{c}\,n \tag{H.31}$$

$$\hat{n}_{t} - \hat{n}_{t-1} = \bar{d}\,100\,\left(\hat{d}^{*}_{t} + \hat{n}^{*}_{t-1} - \hat{d}_{t} - \hat{n}_{t-1}\right) \tag{H.32}$$

$$\hat{n}^{*}_{t} - \hat{n}^{*}_{t-1} = \bar{d}^{*}\,100\,\left(\hat{n}_{t-1} + \hat{d}_{t} + \left(-\hat{d}^{*}_{t}\right) - \hat{n}^{*}_{t-1}\right) \tag{H.33}$$

$$\hat{w}_{t} = \sigma_{l}\,\hat{l}_{t} \tag{H.34}$$

$$\hat{w}_t^* = \sigma_l \, \hat{l}_t^* \tag{H.35}$$

$$\widehat{\left(\frac{tb_t}{y_t}\right)} = \frac{\frac{(-\bar{c})}{\frac{\bar{P}_H}{\bar{P}}}}{\bar{y}} \left(\alpha \left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon} \widehat{ToT}_t + \hat{c}_t + \hat{n}_t - \hat{y}_t \right) \tag{H.36}$$

$$\hat{l}_t = \frac{1}{\gamma} \left(\hat{y}_t - \hat{A}_t\right) - \hat{n}_t \tag{H.37}$$

$$\hat{l}_t^* = \frac{1}{\gamma} \left(\hat{y}_t^* - \hat{A}_t^*\right) - \hat{n}_t^* \tag{H.38}$$

$$\hat{A}_t = \rho^a \, \hat{A}_{t-1} - \eta_t^A \tag{H.39}$$

$$\hat{A}_t^* = \rho^{a^*} \, \hat{A}_{t-1}^* - \eta_t^{A^*} \tag{H.40}$$

$$\epsilon_t^r = \rho^{\epsilon^R} \, \epsilon_{t-1}^r - \eta_t^R \tag{H.41}$$

$$\epsilon_t^{r*} = \rho^{\epsilon^{R*}} \, \epsilon_{t-1}^{r*} - \eta_t^{R^*} \tag{H.42}$$

$$\epsilon_t^g = \rho^g \, \epsilon_{t-1}^g - \eta_t^g \tag{H.43}$$

$$\epsilon_t^{g*} = \rho^{g^*} \, \epsilon_{t-1}^{g*} - \eta_t^{g^*} \tag{H.44}$$

$$\epsilon_t^m = \rho_m \, \epsilon_{t-1}^m - \eta_t^m \tag{H.45}$$

$$\epsilon_t^{m*} = \rho_m^*, \epsilon_{t-1}^{m*} - \eta_t^{m*} \tag{H.46}$$

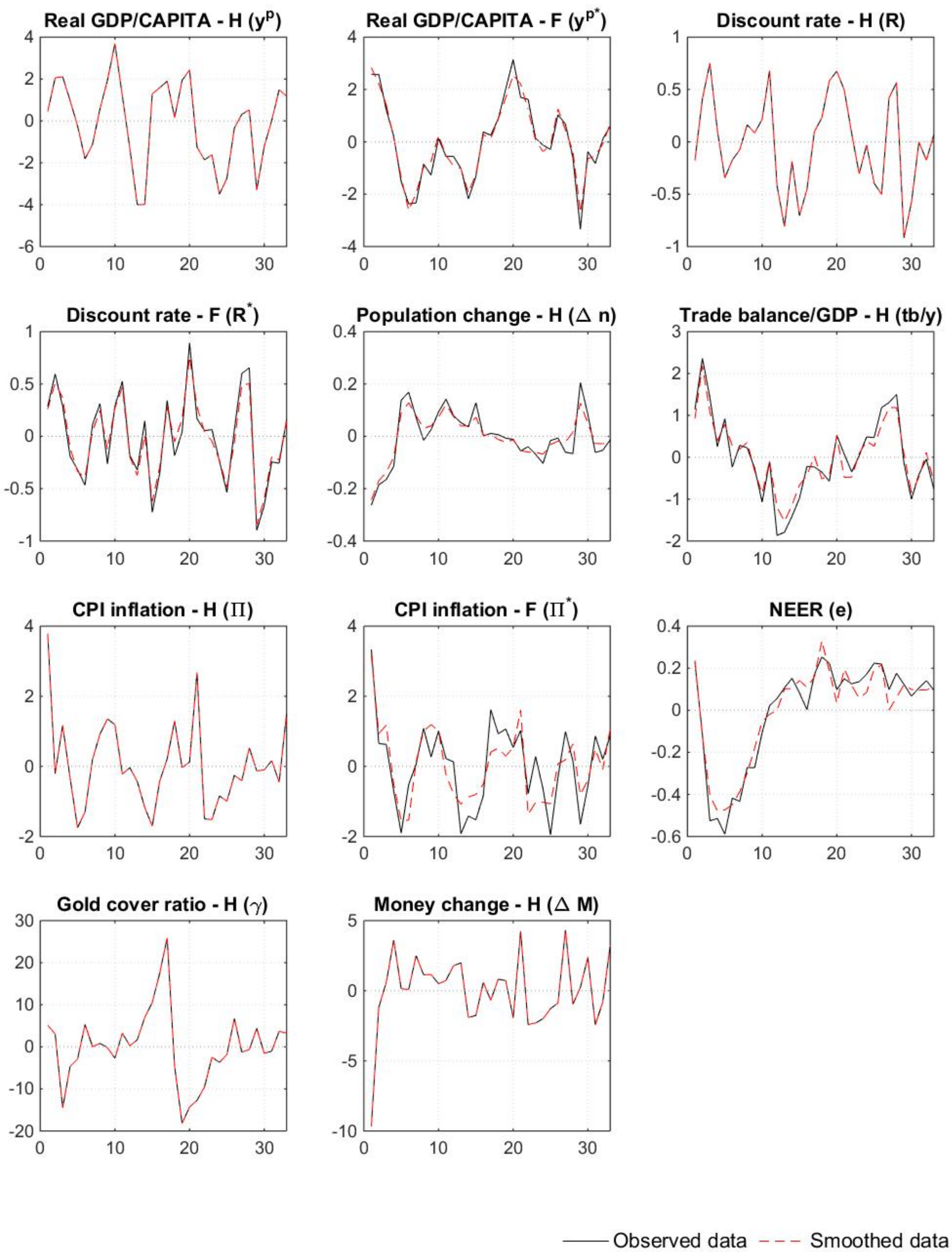
$$\epsilon_t^{\chi} = \rho^x \, \epsilon_{t-1}^{\chi} - \eta_t^x \tag{H.47}$$

$$\epsilon_t^{\chi*} = \rho^{x*} \, \epsilon_{t-1}^{\chi*} - \eta_t^{x*} \tag{H.48}$$

$$\epsilon_t^{uip} = \rho^{uip} \epsilon_{t-1}^{uip} - \eta_t^{uip} \tag{H.49}$$

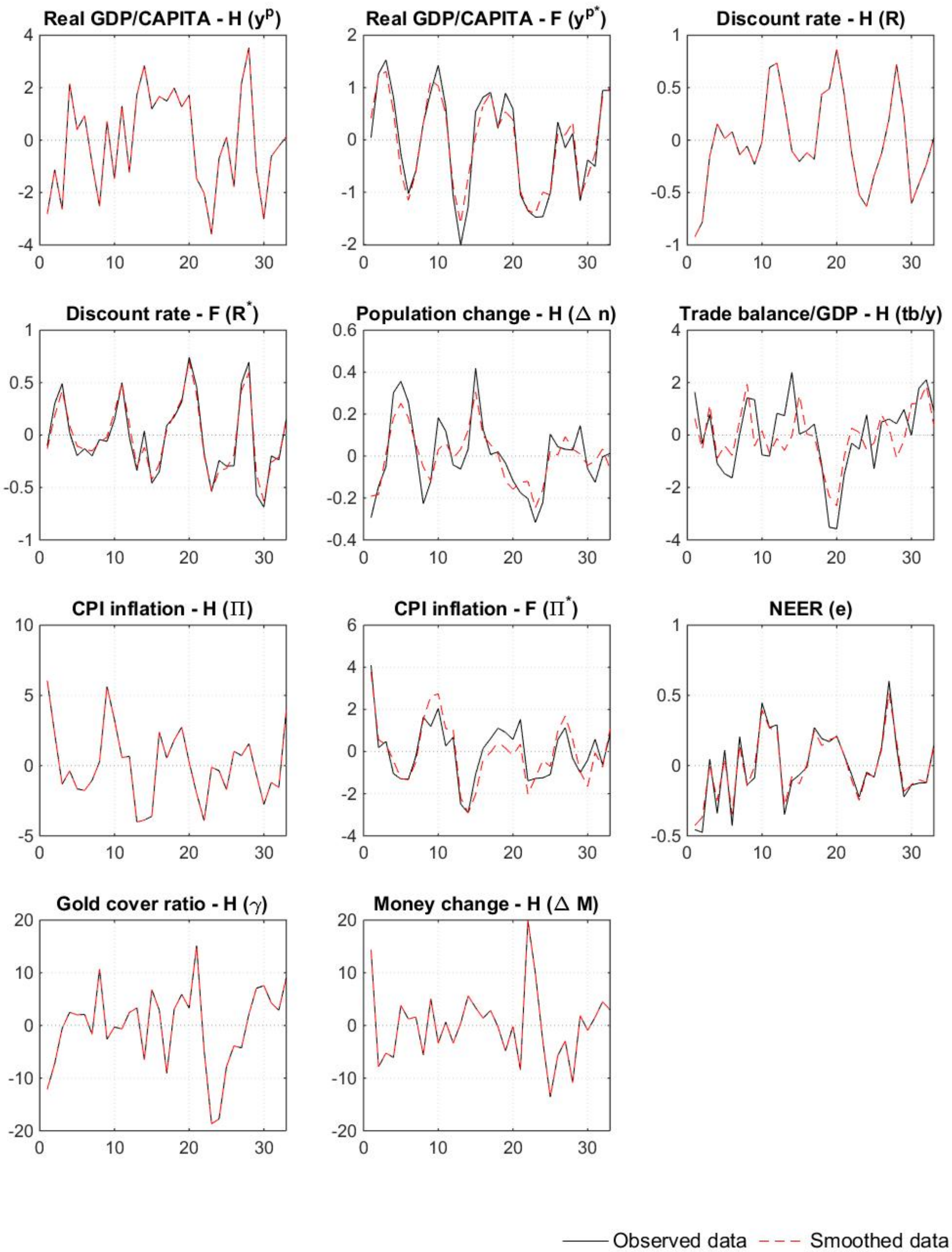
I. Historical observations and smoothed data

Figure 11: *U.K. – Observables and smoothed variables*



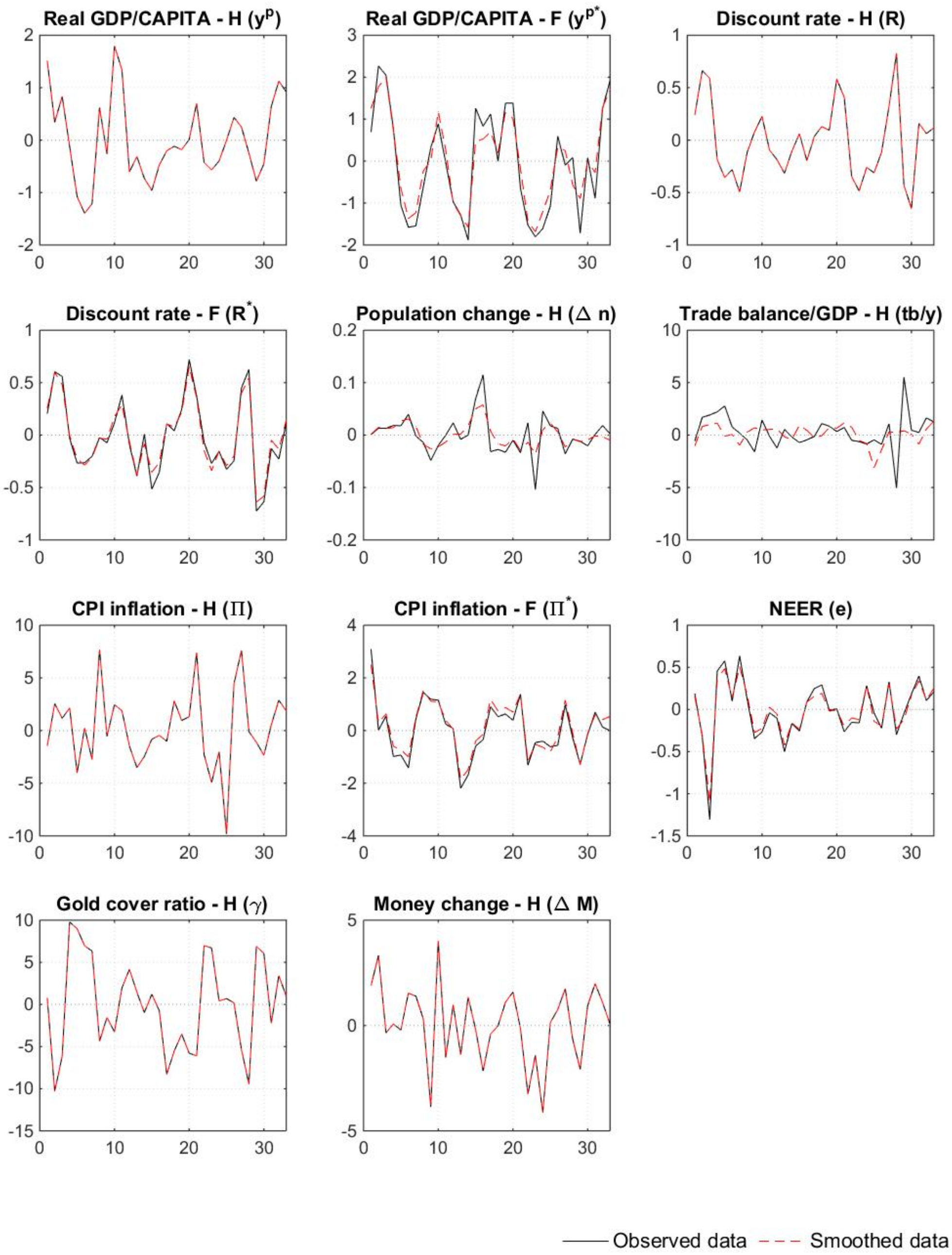
Notes: For variables without measurement error, the smoothed and observed series are identical.

Figure 12: *Sweden – Observables and smoothed variables*



Notes: For variables without measurement error, the smoothed and observed series are identical.

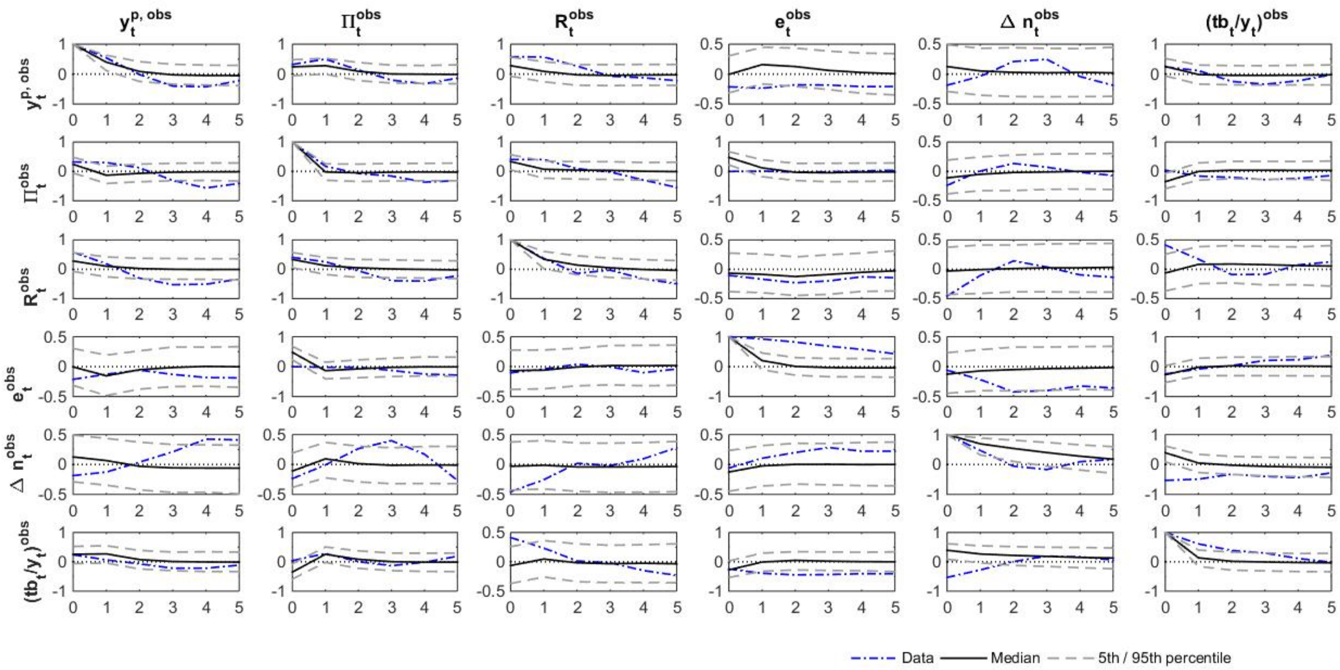
Figure 13: *Belgium – Observables and smoothed variables*



Notes: For variables without measurement error, the smoothed and observed series are identical.

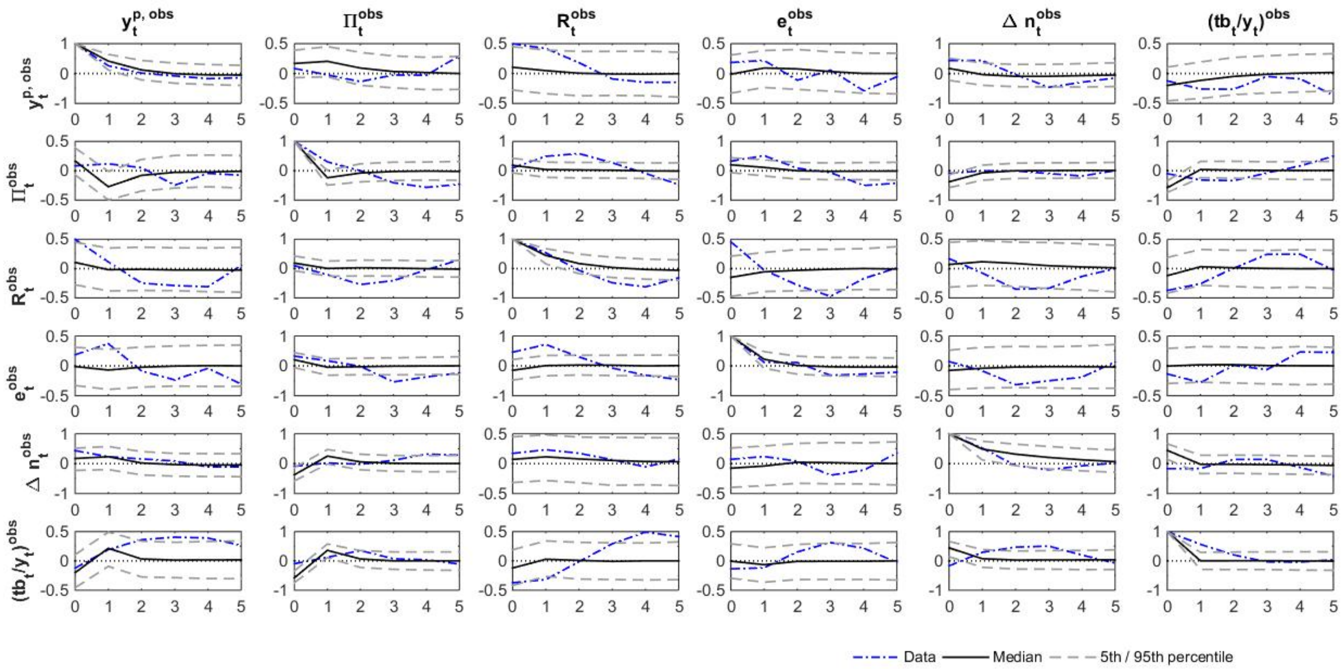
J. Autocorrelations - observed vs. simulated data

Figure 14: *(Auto-)correlations – U.K.*



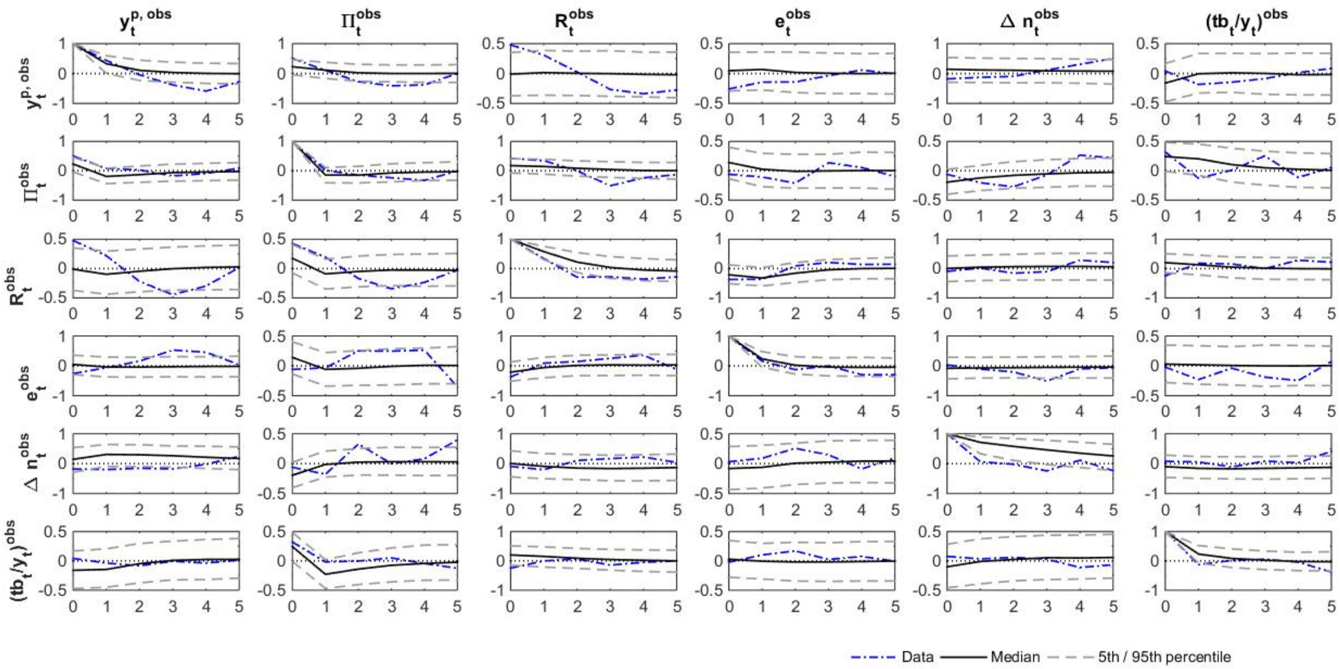
Notes: y-axes indicate correlations. x-axes indicate lags of column variables. Rows show reference variables. Black solid lines – median moment of simulated data. Grey dashed lines – 90 percent coverage percentiles of the simulated data. All simulated moments are based on 2000 simulation runs conditional on the posterior mean. y_t^p – Per capita output, Π_t – CPI inflation, R_t – Discount rate, e_t – Nominal exchange rate, Δn_t – Population change, tb_t/y_t) – Trade balance/output.

Figure 15: *(Auto-)correlations – Sweden*



Notes: y-axes indicate correlations. x-axes indicate lags of column variables. Rows show reference variables. Black solid lines – median moment of simulated data. Grey dashed lines – 90 percent coverage percentiles of the simulated data. All simulated moments are based on 2000 simulation runs conditional on the posterior mean. y_t^p – Per capita output, Π_t – CPI inflation, R_t – Discount rate, e_t – Nominal exchange rate, Δn_t – Population change, $tb_t/y_t)$ – Trade balance/output.

Figure 16: *(Auto-)correlations – Belgium*



Notes: y-axes indicate correlations. x-axes indicate lags of column variables. Rows show reference variables. Black solid lines – median moment of simulated data. Grey dashed lines – 90 percent coverage percentiles of the simulated data. All simulated moments are based on 2000 simulation runs conditional on the posterior mean. y_t^p – Per capita output, Π_t – CPI inflation, R_t – Discount rate, e_t – Nominal exchange rate, Δn_t – Population change, $tb_t/y_t)$ – Trade balance/output.

K. Forecast Error Variance Decomposition

Table 7: *Forecast error variance deomposition – U.K.*

	η^a	η^{a*}	η^r	η^{r*}	η^g	η^{g*}	η^m	η^{m*}	η^x	η^{x*}	η^b	η^{b*}
At 1 year horizon												
Per capita output - H (y_t^p)	0.14	0.00	0.02	0.00	0.64	0.00	0.07	0.02	0.01	0.08	0.00	0.00
CPI inflation - H (Π_t)	0.30	0.03	0.01	0.00	0.06	0.02	0.18	0.08	0.02	0.29	0.00	0.00
REER ($E_{r,t}$)	0.71	0.04	0.00	0.00	0.21	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Trade balance/output - H (tb_t/y_t)	0.96	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
At 10 years horizon												
Per capita output - H (y_t^p)	0.21	0.04	0.02	0.00	0.59	0.00	0.05	0.02	0.01	0.06	0.00	0.00
CPI inflation - H (Π_t)	0.36	0.03	0.02	0.00	0.07	0.02	0.15	0.07	0.02	0.26	0.00	0.00
REER ($E_{r,t}$)	0.55	0.21	0.00	0.00	0.19	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Trade balance/output - H (tb_t/y_t)	0.92	0.06	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Unconditional												
Per capita output - H (y_t^p)	0.19	0.14	0.01	0.00	0.53	0.00	0.05	0.02	0.01	0.05	0.00	0.00
CPI inflation - H (Π_t)	0.36	0.03	0.02	0.00	0.07	0.02	0.15	0.07	0.02	0.26	0.00	0.00
REER ($E_{r,t}$)	0.49	0.30	0.00	0.00	0.16	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Trade balance/output - H (tb_t/y_t)	0.86	0.12	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00

Notes: One-year-, ten-year-, and unconditional FEVDs. η^a – technology shock, η^r – discount rate shock, η^g – markup shock, η^m – gold supply shock, η^x – money demand shock, η^b – risk premium shock.

Table 8: *Forecast error variance deomposition – Sweden*

	η^{a}	η^{a*}	η^{r}	η^{r*}	η^{g}	η^{g*}	η^{m}	η^{m*}	η^{x}	η^{x*}	η^{b}	η^{b*}
At 1 year horizon												
Per capita output - H (y_t^p)	0.02	0.00	0.01	0.01	0.82	0.00	0.03	0.02	0.01	0.07	0.00	0.01
CPI inflation - H (Π_t)	0.42	0.02	0.06	0.05	0.05	0.01	0.04	0.04	0.02	0.20	0.07	0.02
REER ($E_{r,t}$)	0.64	0.05	0.00	0.02	0.07	0.14	0.02	0.03	0.01	0.01	0.00	0.01
Trade balance/output - H (tb_t/y_t)	0.72	0.03	0.01	0.11	0.04	0.02	0.03	0.02	0.01	0.01	0.00	0.02
At 10 years horizon												
Per capita output - H (y_t^p)	0.15	0.08	0.01	0.01	0.68	0.00	0.02	0.01	0.01	0.05	0.00	0.00
CPI inflation - H (Π_t)	0.49	0.03	0.04	0.04	0.05	0.01	0.03	0.04	0.01	0.16	0.07	0.02
REER ($E_{r,t}$)	0.55	0.21	0.00	0.01	0.08	0.10	0.01	0.02	0.00	0.01	0.00	0.00
Trade balance/output - H (tb_t/y_t)	0.69	0.06	0.01	0.08	0.05	0.02	0.03	0.02	0.01	0.01	0.00	0.02
Unconditional												
Per capita output - H (y_t^p)	0.14	0.15	0.01	0.00	0.61	0.00	0.02	0.01	0.01	0.04	0.00	0.00
CPI inflation - H (Π_t)	0.47	0.03	0.05	0.04	0.05	0.01	0.03	0.04	0.01	0.15	0.08	0.02
REER ($E_{r,t}$)	0.52	0.23	0.00	0.01	0.08	0.11	0.02	0.02	0.00	0.01	0.00	0.00
Trade balance/output - H (tb_t/y_t)	0.52	0.19	0.01	0.09	0.06	0.03	0.03	0.03	0.01	0.02	0.00	0.02

Notes: One-year-, ten-year-, and unconditional FEVDs. η^a – technology shock, η^r – discount rate shock, η^g – markup shock, η^m – gold supply shock, η^x – money demand shock, η^b – risk premium shock.

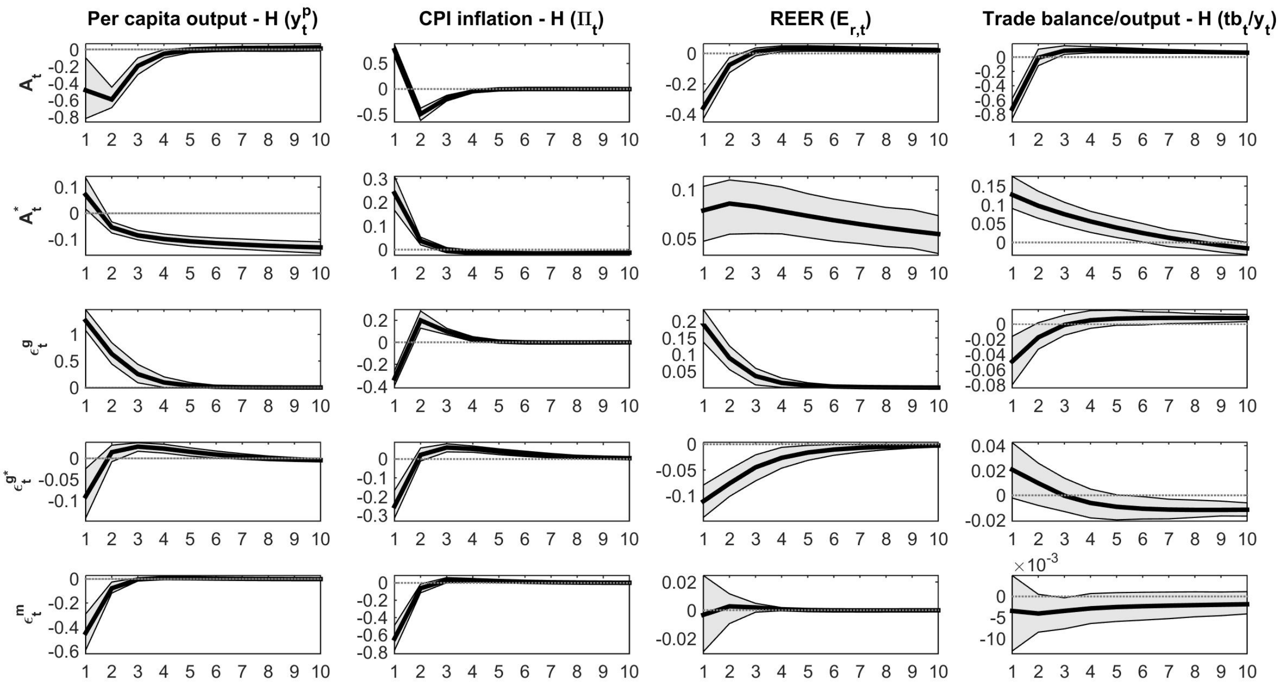
Table 9: *Forecast error variance deomposition – Belgium*

	η^a	η^{a*}	η^r	η^{r*}	η^g	η^{g*}	η^m	η^{m*}	η^x	η^{x*}	η^b	η^{b*}
At 1 year horizon												
Per capita output - H (y_t^p)	0.10	0.02	0.00	0.03	0.57	0.20	0.02	0.01	0.00	0.04	0.00	0.02
CPI inflation - H (Π_t)	0.48	0.10	0.10	0.02	0.10	0.00	0.05	0.01	0.00	0.09	0.03	0.02
REER ($E_{r,t}$)	0.59	0.02	0.00	0.03	0.13	0.13	0.01	0.01	0.00	0.04	0.00	0.02
Trade balance/output - H (tb_t/y_t)	0.08	0.14	0.01	0.10	0.46	0.09	0.01	0.01	0.00	0.07	0.00	0.04
At 10 years horizon												
Per capita output - H (y_t^p)	0.09	0.11	0.00	0.03	0.42	0.26	0.02	0.01	0.00	0.05	0.00	0.02
CPI inflation - H (Π_t)	0.48	0.12	0.06	0.02	0.12	0.01	0.05	0.01	0.00	0.09	0.04	0.02
REER ($E_{r,t}$)	0.58	0.06	0.00	0.02	0.10	0.17	0.01	0.01	0.00	0.03	0.00	0.01
Trade balance/output - H (tb_t/y_t)	0.16	0.17	0.01	0.07	0.33	0.11	0.01	0.01	0.00	0.10	0.00	0.03
Unconditional												
Per capita output - H (y_t^p)	0.09	0.11	0.00	0.03	0.34	0.25	0.03	0.01	0.00	0.12	0.00	0.03
CPI inflation - H (Π_t)	0.47	0.13	0.06	0.02	0.11	0.01	0.05	0.01	0.00	0.09	0.04	0.02
REER ($E_{r,t}$)	0.55	0.06	0.00	0.02	0.10	0.18	0.01	0.01	0.00	0.04	0.00	0.02
Trade balance/output - H (tb_t/y_t)	0.12	0.19	0.01	0.08	0.23	0.13	0.02	0.01	0.00	0.17	0.00	0.04

Notes: One-year-, ten-year-, and unconditional FEVDs. η^a – technology shock, η^r – discount rate shock, η^g – markup shock, η^m – gold supply shock, η^x – money demand shock, η^b – risk premium shock.

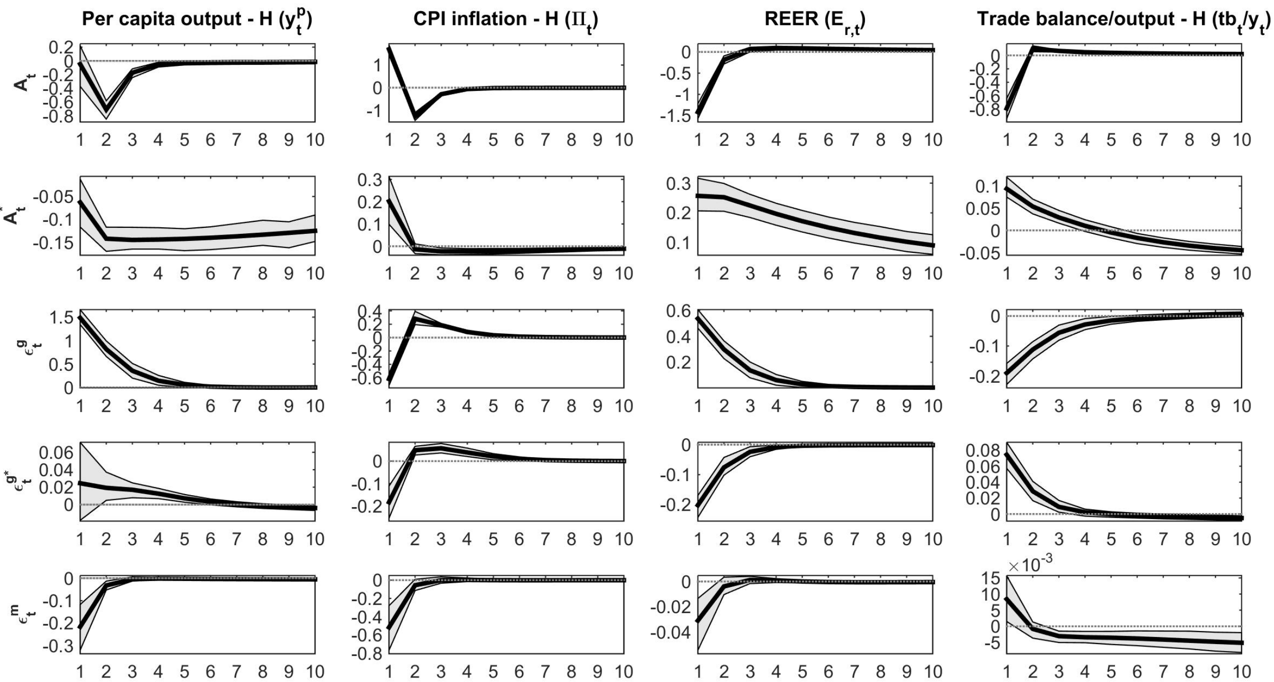
L. Bayesian Impulse Responses

Figure 17: *Bayesian IRF - U.K.*



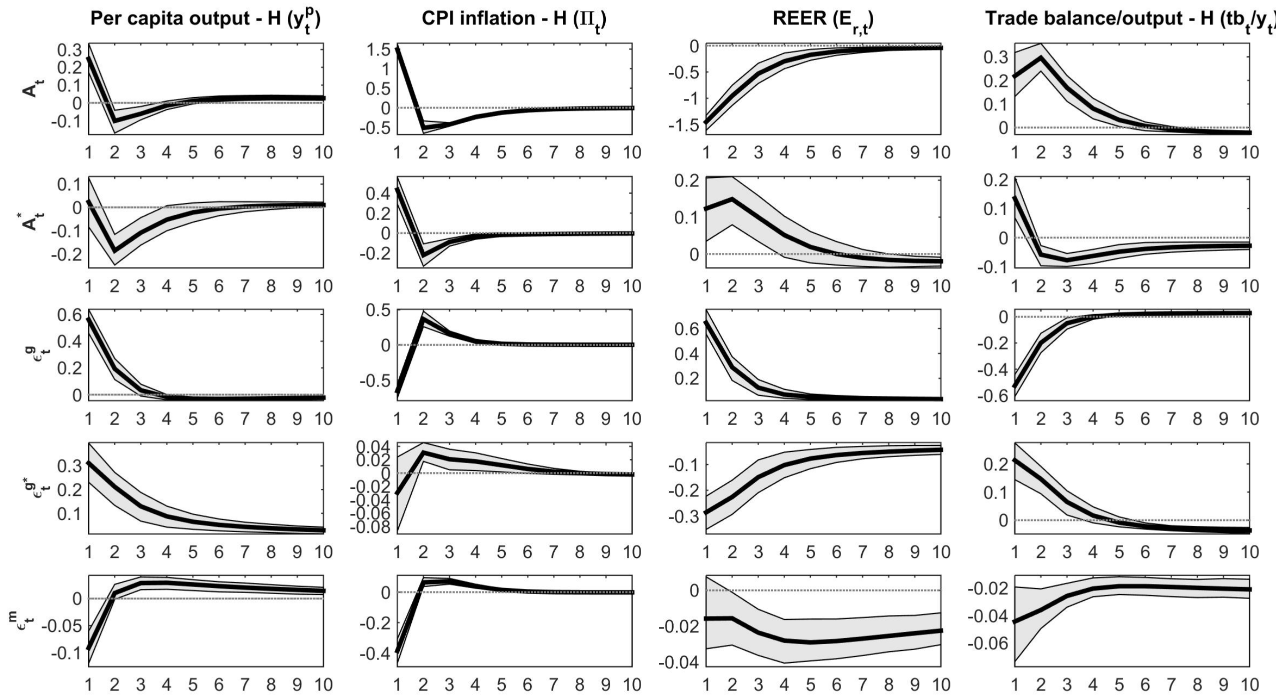
Notes: The graphic depicts Bayesian impulse responses to *negative* shocks. y_t^p, Π_t and $E_{r,t}$ are displayed as percentage deviations from steady state. tb_t/y_t is displayed in percentage point deviations from steady state. A_t – technology shock H, A_t^* – technology shock F, ϵ_t^g – markup shock H, $\epsilon_t^{g^*}$ – markup shock F, ϵ_t^m – gold shock.

Figure 18: *Bayesian IRF -Sweden*



Notes: The graphic depicts Bayesian impulse responses to *negative* shocks. y^p_t, Π_t and $E_{r,t}$ are displayed as percentage deviations from steady state. tb_t/y_t is displayed in percentage point deviations from steady state. A_t – technology shock H, A^*_t – technology shock F, ϵ^g_t – markup shock H, $\epsilon^{g^*}_t$ – markup shock F, ϵ^m_t – gold shock.

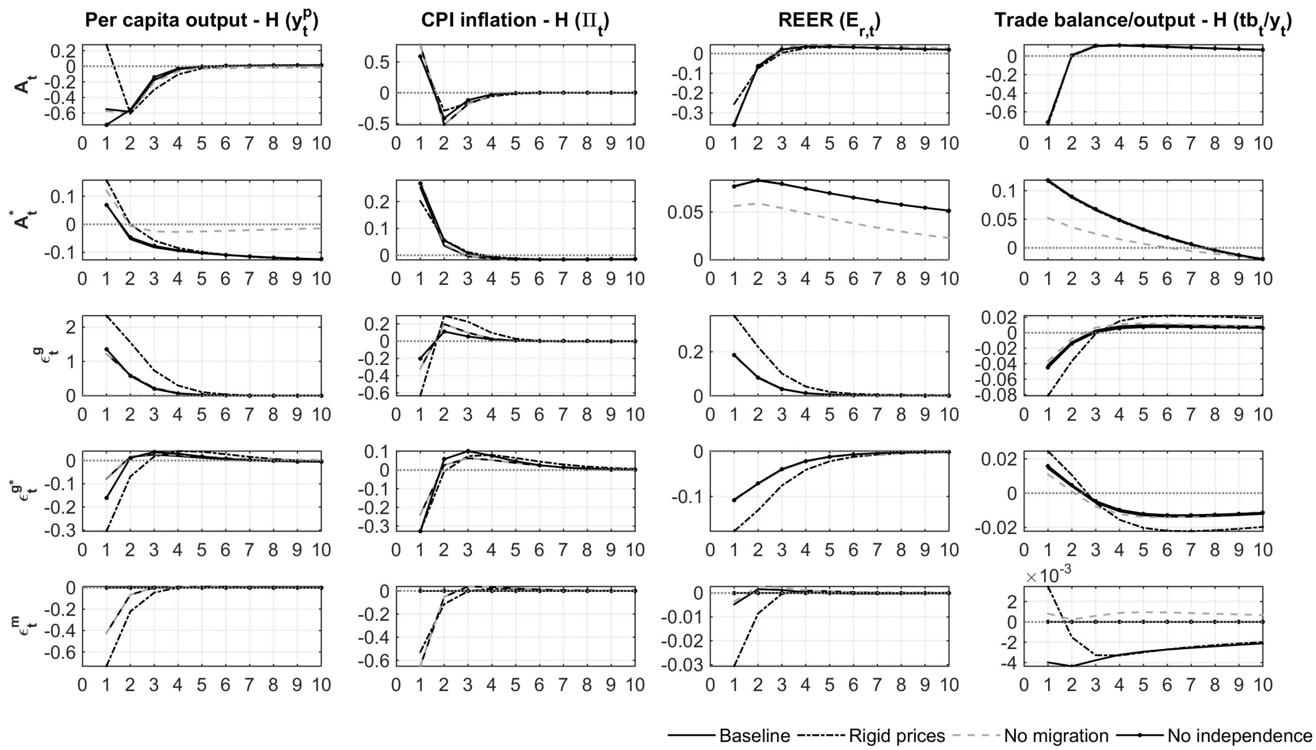
Figure 19: *Bayesian IRF -Belgium*



Notes: The graphic depicts Bayesian impulse responses to *negative* shocks. y_t^p, Π_t and $E_{r,t}$ are displayed as percentage deviations from steady state. tb_t/y_t is displayed in percentage point deviations from steady state. A_t – technology shock H, A_t^* – technology shock F, ϵ_t^g – markup shock H, $\epsilon_t^{g^*}$ – markup shock F, ϵ_t^m – gold shock.

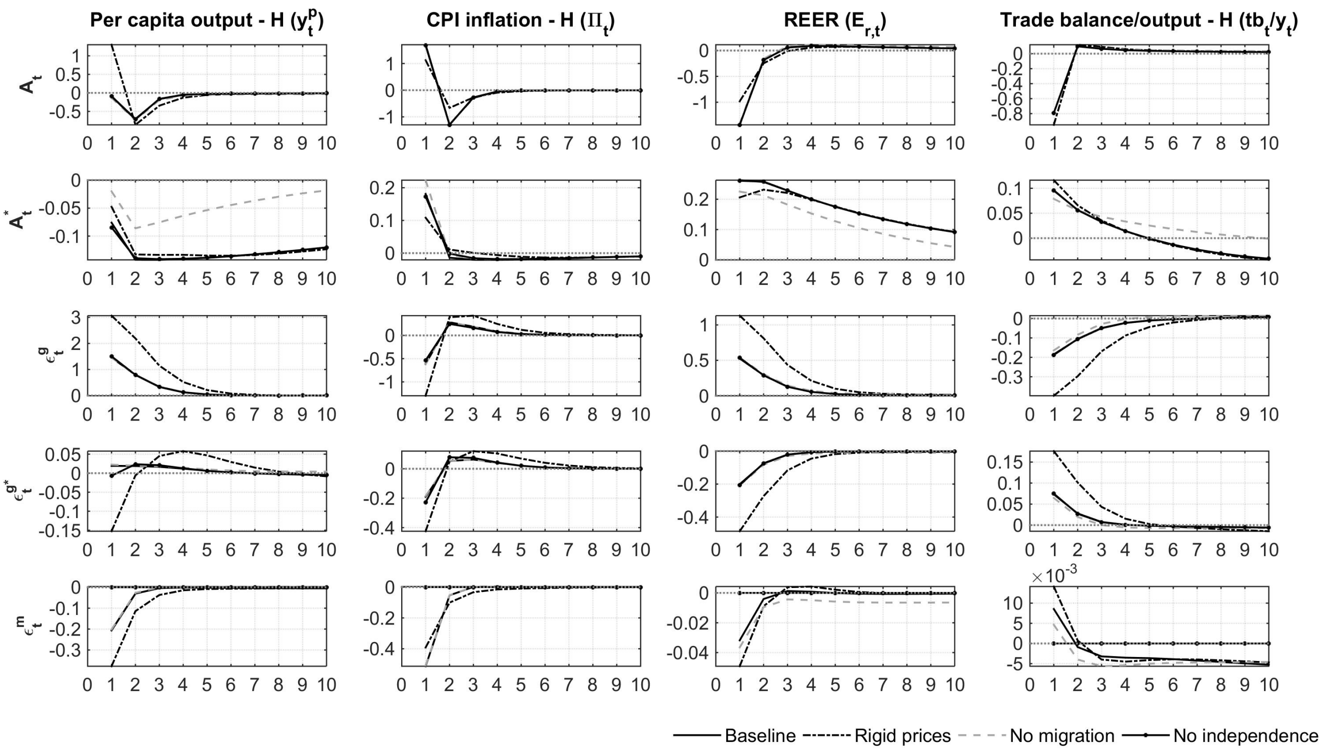
M. Baseline and counterfactual Impulse Responses

Figure 20: *IRF baseline and counterfactual - U.K.*



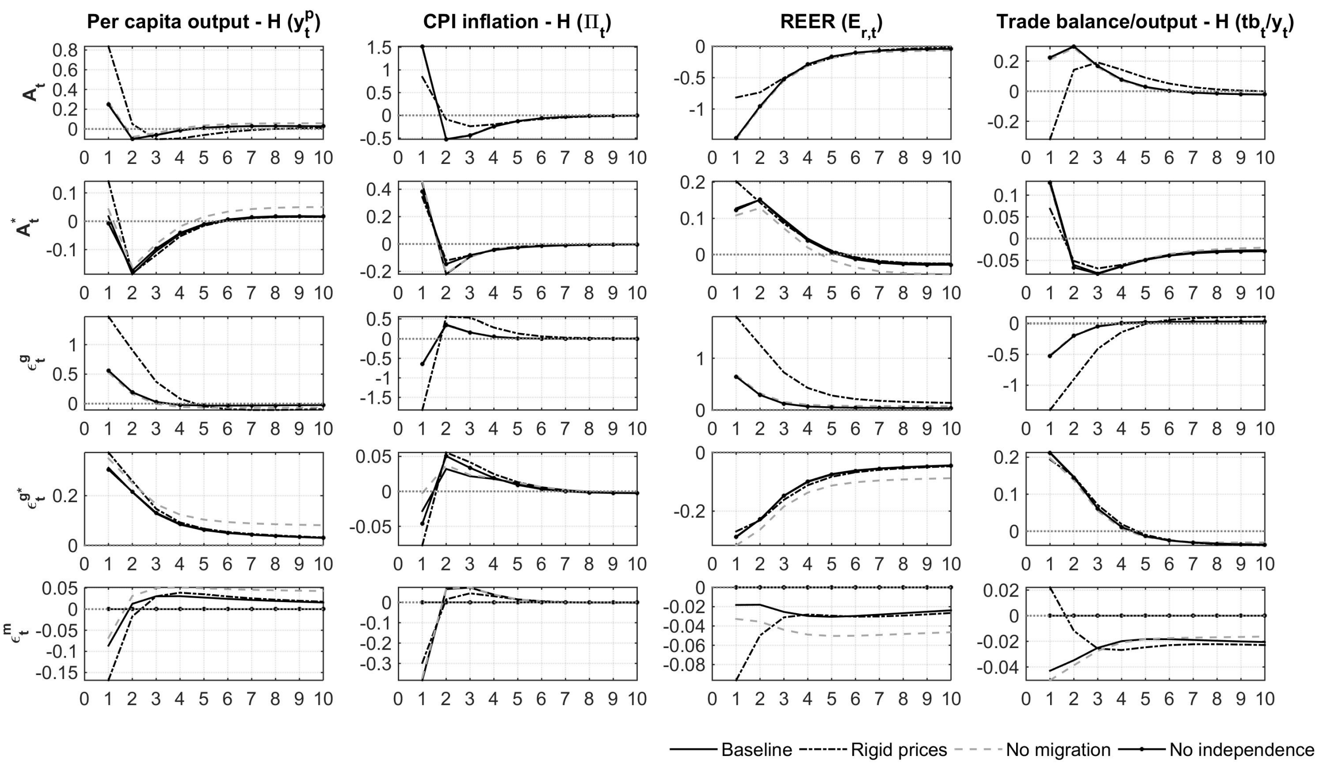
Notes: The graphic depicts the impulse responses to *negative* one standard deviation shocks. y_t^p, Π_t and $E_{r,t}$ are displayed as percentage deviations from steady state. tb_t/y_t is displayed in percentage point deviations from steady state. A_t – technology shock H, A_t^* – technology shock F, ϵ_t^g – markup shock H, $\epsilon_t^{g^*}$ – markup shock F, ϵ_t^m – gold shock.

Figure 21: *IRF baseline and counterfactual - Sweden*



Notes: The graphic depicts the impulse responses to *negative* one standard deviation shocks. y_t^p, Π_t and $E_{r,t}$ are displayed as percentage deviations from steady state. tb_t/y_t is displayed in percentage point deviations from steady state. A_t – technology shock H, A_t^* – technology shock F, ϵ_t^g – markup shock H, $\epsilon_t^{g^*}$ – markup shock F, ϵ_t^m – gold shock.

Figure 22: *IRF baseline and counterfactual - Beglium*



Notes: The graphic depicts the impulse responses to *negative* one standard deviation shocks. y_t^p, Π_t and $E_{r,t}$ are displayed as percentage deviations from steady state. tb_t/y_t is displayed in percentage point deviations from steady state. A_t – technology shock H, A_t^* – technology shock F, ϵ_t^g – markup shock H, $\epsilon_t^{g^*}$ – markup shock F, ϵ_t^m – gold shock.

N. Counterfactual analysis

Table 10: *Counterfactual volatilities*

		Baseline model (1)	Rigid prices (2)	No migration (3)	No independence (4)	No migration, given rigid prices (3∣2)	No independence, given rigid prices (4∣2)
United Kingdom							
y_t^p	Per capita output	1.7715	3.2318	1.7596	1.8649	3.2291	3.5374
			(82.44%)	(-0.67%)	(5.27%)	(-0.08%)	(9.45%)
Π_t	Inflation	1.7075	1.5505	1.7059	1.4341	1.5501	1.3273
			(-9.19%)	(-0.09%)	(-16.01%)	(-0.02%)	(-14.40%)
$E_{r,t}$	REER	0.4725	0.5820	0.4560	0.4768	0.5709	0.6046
			(23.19%)	(-3.49%)	(0.93%)	(-1.90%)	(3.88%)
tb_t/y_t	Trade balance/output	0.8019	0.8327	0.7648	0.8006	0.7944	0.8303
			(3.84%)	(-4.63%)	(-0.15%)	(-4.60%)	(-0.29%)
Sweden							
y_t^p	Per capita output	1.8846	4.2275	1.8811	1.9093	4.2465	4.3813
			(124.32%)	(-0.19%)	(1.31%)	(0.45%)	(3.64%)
Π_t	Inflation	2.6189	2.2674	2.6031	2.5317	2.2640	2.1679
			(-13.42%)	(-0.60%)	(-3.33%)	(-0.15%)	(-4.39%)
$E_{r,t}$	REER	1.6611	1.8817	1.6427	1.6644	1.8860	1.8958
			(13.28%)	(-1.11%)	(0.19%)	(0.23%)	(0.75%)
tb_t/y_t	Trade balance/output	0.8710	1.1686	0.8452	0.8713	1.0886	1.1761
			(34.16%)	(-2.96%)	(0.03%)	(-6.85%)	(0.64%)
Belgium							
y_t^p	Per capita output	0.8870	2.1028	0.9437	0.8891	2.1020	2.1097
			(137.08%)	(6.39%)	(0.25%)	(-0.04%)	(0.33%)
Π_t	Inflation	2.0767	2.3436	2.0843	2.0428	2.3735	2.3152
			(12.85%)	(0.36%)	(-1.63%)	(1.28%)	(-1.21%)
$E_{r,t}$	REER	1.9428	2.5414	1.9956	1.9404	2.6332	2.5371
			(30.81%)	(2.71%)	(-0.13%)	(3.61%)	(-0.17%)
tb_t/y_t	Trade balance/output	0.8431	1.8544	0.8070	0.8423	1.7297	1.8566
			(119.94%)	(-4.29%)	(-0.10%)	(-6.73%)	(0.12%)

Notes: Percentage change in counterfactual S.D. relative to baseline S.D. in parenthesis. Rigid prices – model with rigid prices. No migration – model without migration. No independence – model without policy independence for central bank.