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# Rigid relations: External adjustment through prices, migration and monetary policy during the Gold Standard, 1880-1913\*

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### PRELIMINARY DRAFT - DO NOT CITE!

#### Abstract

External adjustment during the classical gold standard – a fixed exchange rate regime – was associated with few, if any, output costs. This paper analyzes the relative importance of flexible prices, migration and mildly countercyclical monetary policy for this relatively smooth adjustment experience. For this purpose we build and estimate a structural model of the classical gold standard. We find that the sustainability of the gold standard as a fixed exchange rate regime was primarily a consequence of flexible prices. Pre-1914 price flexibility is furthermore largely explicable by an historical contingency: large pre-1914 primary sector shares. The paper proceeds in an historical comparative fashion by relating the gold standard experience to that of another fixed-exchange rate regime – today's eurozone.

*Keywords:* Gold Standard; Eurozone; International adjustment; DSGE; Bayesian estimation; Real effective exchange rate.

JEL Codes: N1, F2, E5.

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### 1 Introduction

The classical gold standard (1880-1913) was a global fixed exchange rate regime of colossal extent. For more than three decades the world's largest economies had confined the movement of their exchange rates into narrow bands. Nevertheless external adjustments were associated with few, if any, output costs. How did the gold standard (GS) equilibrate so smoothly once exchange rates had entered such "rigid relations"? There exist various competing, though not mutually exclusive explanations. First, prices were relatively flexible (Gordon, 1990; Basu and Taylor, 1999; Obstfeld, 2007), which allowed for a faster absorption of shocks (Chernyshoff, Jacks and Taylor, 2009). Second, cyclical labor migration counteracted per capita output gaps and took off pressure from wages in depressed regions (e.g. Hatton, 1995; Khoudour-Castéras, 2005). Finally, central banks could smooth out the adjustment process by making use of the little room for maneuver the GS – a narrow exchange rate target zone regime (Krugman, 1991; Svensson, 1994; Bordo and MacDonald, 2005) – afforded them. The main purpose of this paper is to provide a comprehensive assessment of the relative importance of each of these channels. Can we say which one reduced output volatility most? Were they equally important – or were they most effective in combination?

The classical GS in the late 19th and early 20th century was pitted against a similar adjustment problem as the eurozone (EZ) is today: How can member economies digest a current account reversal or a misalignment in prices when nominal exchange rates are fixed, interregional fiscal transfers are few, and capital and labor are mobile? Furthermore, the average size of the adjustment problem faced by members of the GS in the 19th century and EZ-members today is comparable. Figure 1 shows the current account to GDP-ratio and the real effective exchange rate around the year they reach their turning point and

commence with a major reversal.<sup>1</sup> In the GS as well as in the EZ the current account to GDP ratio on average decreased by about 5 percentage points in the 10 years prior to a CA/GDP-reversal. For the REER, while the ascent and descent are steeper during the classical GS than in the EZ, the average REER-increase before a reversal is about 15% in both cases.<sup>2</sup> The GS thus constitutes an interesting historical analogy to the EZ, in that (i) the adjustment problems are similarly-sized, (ii) nominal exchange rate devaluations cannot bear the brunt of adjustment, (iii) interregional fiscal transfers are relatively small and (iv) goods, labor and capital can move relatively freely across borders. The paper thus at times uses the EZ as a yardstick against which to measure the GS and vice versa (also see Eichengreen and Temin, 2010; O'Rourke and Taylor, 2013). It also tries to critically assess where the GS experience has a bearing on external adjustments in today's EZ. The main focus of the paper however is on external adjustment under the GS, and neither EZ specific shocks (e.g. sovereign debt risk premia) nor transmission channels (e.g. fiscal transfers) will be discussed in any detail.<sup>3</sup>

The first part of the paper juxtaposes phases of major external adjustment in the GS and the EZ. Despite their magnitude, REER- and CA/GDP-adjustments under the classical GS were a relatively smooth affair that was associated with little, if any, losses

<sup>&</sup>lt;sup>1</sup>Here the real effective exchange rate is expressed in foreign units per domestic units. REER peaks (CA/GDP troughs) are defined according to a turning-point algorithm (see Bry and Boschan, 1971): CA/GDP-troughs (REER-peaks) are defined as the lowest CA/GDP-value (highest REER-value) in a  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length.

<sup>&</sup>lt;sup>2</sup>According to Adalet and Eichengreen (2007) current account reversals before WW1 were smaller than they are today. This however is due to their definition of a reversal as a sharp turnaround, which neglects smoother transitions.

<sup>&</sup>lt;sup>3</sup>Our exposition also abstracts from the zero lower bound constraint on monetary policy, which was not binding in any of the countries in our sample during the classical GS.





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 REER peak (CA/GDP trough) to the next. REER peaks (CA/GDP troughs) are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GDP-troughs (REER-peaks) are defined as the lowest CA/Y-value (highest REER-value) in a  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 9 CA/GDP troughs, 8 REER peaks. EZ: 7 CA/GDP troughs, 6 REER peaks. The REER is expressed in foreign units per domestic units.

in per capita output (see Meissner and Taylor, 2006; Adalet and Eichengreen, 2007). The average behavior of prices, migration and monetary policy indicates that during external adjustments all three channels became active: (i) A strong price-decline in regions with overvalued REERs and CA-deficits quickly increased their price-competitiveness, (ii) migration flows redistributed labor supply from overvalued deficit regions to undervalued surplus regions, and (iii) central banks made use of the little independence their narrow exchange rate target zone afforded them to conduct countercyclical discount rate policy. In contrast to this the average adjustment in today's EZ is characterized by slow price declines and severe output contractions. Average migratory activity however is more pronounced in EZ-adjustments than it was in GS-adjustments.

Against the backdrop of these empirical regularities the second part of the paper

addresses the following question: What was the relative importance of prices, migration and monetary policy for keeping output volatility in check during the classical GS? To investigate this question we build the first open-economy model of the classical GS that features international migration, various degrees of price flexibility and an elaborate monetary structure. We estimate the model for the U.K., Sweden and Belgium. The model-GS's behavior is then studied through counterfactual simulations: How would output volatility have looked like had prices been less flexible? What if there had been no release through migration? How important was the mildly countercyclical monetary policy? We find that price flexibility was paramount for the smooth adjustment in the classical GS. Neither restrictions to migration, nor the elimination of mildly countercyclical monetary policy would have given rise to a substantially higher output- or REER-volatility. The sustainability of the GS as a fixed exchange rate regime was thus primarily a consequence of flexible prices.

Flexible prices in turn are largely explicable by a historical contingency: large primary sector shares typically ranging from 10 to 50%. We collect disaggregate export data to see which product groups drove external adjustment under the GS. We find that the fast expenditure switching during major external adjustments was concentrated in the agricultural and raw material product groups. Industrial goods exports on the other hand reacted only sluggishly. Furthermore, during major external adjustments under the GS industrial sector shares declined by up to 2 percentage points, while primary sector shares rose by a corresponding amount. Large flex-price primary sectors thus acted as an absorbent for less adaptable industrial sectors. This is potentially bad news for the EZ, whose comparative forte – internal migration – did not substantially reduce the output costs of large external adjustments under the classical GS. In the absense of a return of pre-1914 levels of price flexibility the EZ's long-run sustainability thus will hinge upon finding other ways of rendering external adjustment less costly.

The paper is structured as follows: Section 2 discusses the behavior of prices, migration and monetary policy during the major current account- and REER- adjustments during the classical GS, and sets them against the current EZ experience. Section 3 presents the GS model and its estimation. The relative importance of prices, migration and monetary policy are then analyzed on the basis of counterfactual simulations for the estimated GS model in section 5. Section 6 offers an explanation for price flexibility in the pre-1914 era based on large pre-1914 agricultural sector shares. Section 7 concludes.

### 2 Stylized facts

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. This section discusses explanations for this phenomenon and empirically constrasts the external adjustment experience under the classical GS with that of the EZ.

To this end we identify peaks in the real effective exchange rate (REER) and troughs in the current account to GDP ratio (CA/GDP) through a Bry and Boschan (1971)-style algorithm: REER-peaks are defined as the highest REER-value in a  $\pm$ 10-year window. CA/GDP-troughs are defined analogously. For the period 1880-1913 we thus identify 9 CA/GDP troughs and 8 REER peaks (see figures 8 and 9 in Appendix B). CA/GDP troughs and REER peaks do not always coincide.<sup>4</sup> Generally however REER peaks often have a CA/GDP trough in their vicinity and vice versa.

We then look at how the average behavior of prices, migration and monetary policy

<sup>&</sup>lt;sup>4</sup>For Canada for example the turning point algorithm finds a REER-peak in the early 1880s, while the CA/GDP bottoms out only later in the decade. In other cases, such as Sweden, there are prolonged CA/GDP adjustments without a corresponding turning point in the REER.

after such major REER- or CA/GDP-reversals differs from their average behavior after non-reversal years. More formally we look at the sequence of differences

$$D_h(x_{i,t+h}, A_{i,t}) = E_{i,t}(x_{i,t+h} | A_{i,t} = 1) - E_{i,t}(x_{i,t+h} | A_{i,t} = 0), \quad h = 1, \dots, H$$
(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  $D_h(x_{i,t+h}, A_{i,t})$ , h = 1, ..., H stands for the different behavior of  $x_i$  after major external reversals relative to non-reversals.

Practially we turn to local projections (Jorda, 2005) to estimate the sequence of differences  $D_h(x_{i,t+h}, A_{i,t+h})$  through the following sequence of fixed effects models:

$$D_h(x_{i,t+h}, A_{i,t}) = \alpha_i + \beta_h A_{i,t} + u_{i,t}, \quad h = 1, ..., H$$
(2)

where  $\alpha_i$  are country-fixed effects,  $x_{i,t+h}$  are *h*-year growth rates of  $x_i$  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 REER-peak or CA/GDP-trough. This will provide us with a set of stylized facts on how EZ- and GS-member economies typically behave during major adjustment phases in contrast to their behavior during "normal" times. Note that for the sake of brevity we will only report the REER peak results. The CA/GDP trough results are very similar and can be found in the appendix.

### 2.1 Data

Our gold standard dataset consists of annual data for 14 countries that were on gold throughout the 1880-1913 period. We collected time series for the following macro variables from various secondary sources and contemporary statistical compendia (see Appendix A for the listing of sources): nominal GDP, real per capita GDP, consumer prices, the current account, imports and exports, the nominal exchange rate, immigration and emigration, population, discount rates and note circulation. Particular effort went into the construction of a novel set of real effective exchange rate series, gold cover ratios and disaggregated export data. While in some cases we were able to draw on collections of historical data by economic historians and central banks, in many cases we had to go back to the historical publications of contemporary statistical offices and trade agencies.

The real effective exchange rate of country *i* is calculated as the trade-weighted geometric average of the real exchange rates with respect to countries  $j \in 1, ..., J$ 

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

 $w_{i,j,t}$  is the bilateral trade weight. The real effective exchange rate is the product of the nominal exchange rate<sup>5</sup> and the ratio of consumer prices  $RER_{i,j,t} = NER_{i,j,t} \frac{CPI_{i,t}}{CPI_{j,t}}$ .<sup>6</sup> Our baseline *REER* estimate uses the bilateral trade flow data provided by López-Córdova and Meissner (2008) as trade weights.<sup>7</sup> Trade weights  $w_{i,j,t}$  equal the ratio of bilateral (*imports* + *exports*) to GDP. In accordance with today's REER estimates provided by the ECB, we update 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

<sup>&</sup>lt;sup>5</sup>Here the nominal exchange rate is written in quantity notation, i.e. foreign currency per domestic currency.

<sup>&</sup>lt;sup>6</sup> By using the weighted geometric average, the calculated REER becomes invariant to the choices of exchange rate quotation (price- or quantity notation) for the underlying individual exchange rates.

<sup>&</sup>lt;sup>7</sup>We linearly intrapolate the trade-weights and use the first and last observation of each country to fill in missing values at the beginning and end of the sample.

on within GS competitiveness.<sup>8</sup> Along the same lines nominal effective exchange rates (NEER) and foreign effective consumer price indices are constructed as trade-weighted geometric averages. The final REER series can be seen in figure 8 in Appendix B.

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 the cover ratio however differed across countries and time. For example in 1877 the National Bank of Belgium extended the definition of the numerator of its gold cover ratio to include foreign exchange reserves. For this reason 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 includes foreign exchange reserves into the numerator and central bank deposits into the denominator. The narrow and broad cover ratio series are displayed in figures 12 and 13 in Appendix C.

Finally, in order to see which sector drove external adjustment during the classical GS we collected data on disaggregate exports as well as primary sector shares. The export data are disaggregated into agricultural-, raw material- and industrial exports. While some sources provide data at this level of aggregation, in many cases we had to aggregate up from the more readily available product-level export data. Concerning the sectoral share data our main source is Buera and Kaboski (2012), who provide series on the

<sup>&</sup>lt;sup>8</sup>Note that about two thirds of the GS-members' trade was conducted within the GS itsself (see Catão and Solomou, 2005). For our 14 country sample an average of 68% of imports come from countries within the sample and an average of 89% of exports go to other countries in the sample. According to Eurostat the equivalent figure for the EU-28 is 60-70%. For our smaller sample of 12 EZ countries the equivalent percentage shares are 50% and 51%.

fraction of value-added in agriculture, industry and services. We supplement their series by agricultural employment shares, which we calculate from the sectoral employment data provided by Mitchell (2013).

In order to compare the major external adjustments of the GS-era with the recent external adjustments in the EZ we collect a corresponding set of macro variables for the EZ. Our EZ dataset comprises annual data for 12 countries (initial 1999 members + 2001 entry). It contains the following macro variables: real per capita GDP, consumer price indices, the current account, imports and exports, immigration and emigration and population levels. In addition we use the intra-EZ real effective exchange rate estimates provided by the ECB.<sup>9</sup> Intra-EZ bilateral imports and exports from the UN Comtrade database are used to construct foreign effective consumer prices. Where possible we collected data from 1994 onwards, by which time the exchange rates of most of the countries in our sample were already locked within the European Exchange Rate Mechanism. A detailed listing of all the sources is again provided in Appendix A

### 2.2 External adjustments

Figure 2 shows that the typical adjustment during the classical GS was a rather benign experience (black solid lines). A sharp increase in exports led to a quick turn-around in the current account. Imports remained stable. There were some output costs as measured by real per capita GDP in the case of CA/GDP-reversals, but not so much in the case of REER-reversals (Meissner and Taylor, 2006; Adalet and Eichengreen, 2007). This stands in sharp contrast to the recent EZ experience (grey dashed lines), which is characterized by external adjustment through expenditure reduction (also see Lane and Milesi-Ferretti,

<sup>&</sup>lt;sup>9</sup>In particular we use the Harmonized Competitiveness Indicators (HCI) vis-à-vis the other 19 euro area economies

# Figure 2: GDP per capita and external balance after major REER reversals relative to Non-reversals



Notes: Black solid – Gold Standard. Grey dashed – Eurozone. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one REER peak to the next. 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  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 8 REER peaks. EZ: 6 REER peaks.

2014). Imports contract along with per capita GDP, while exports stay put.<sup>10</sup> How can the comparatively smooth adjustment experience under the classical GS be explained?

<sup>&</sup>lt;sup>10</sup>For the EZ the turning point algorithm identifies 7 CA/GDP peaks and 6 REER troughs since 1999. Most of the consequent adjustment episodes are associated with the onset of the EZ crisis, when Greece, Ireland, Italy, Portugal and Spain experienced turn-arounds in their current account and/or REER. The Netherlands and Germany however start experiencing current account reversals around 2000 at the beginning of the sample period. Note that turning points were identified on a sample running from 1994 to 2013.

### 2.3 Nominal flexibility

The canonical starting point for explanations of how the GS equilibrated is Hume's pricespecie flow model (Hume, 1752): current account deficits, financed through gold outflows, decrease the domestic gold stock. Under the GS, when monetary conditions were tightly linked to the quantity of gold, gold outflows exert downward pressure on domestic prices and upward pressure on foreign prices. The resulting gains in price-competitiveness lead to a reversal of the current account.

Figure 3 shows that in accordance with the mechanism laid out by Hume domestic prices indeed fell strongly and swiftly during adjustments phases. The brunt of the adjustment is furthermore born by domestic prices, with foreign prices – here defined as a trade-weighted geometric average of foreign CPIs – remaining stable. As a consequence the fall in domestic prices translates almost one-to-one into a fall of the REER. By comparison, price adjustments within the EZ are small. The REER comparison indicates that 3 years into the adjustment the average EZ member has achieved only 1/3 of the REER-adjustment typical for a GS member.<sup>11</sup>

### 2.4 Monetary policy

In contrast to the EZ nominal exchange rates under the classical GS were not completely fixed, but could still fluctuate within a narrow 1 to 2% band (Officer, 1985; Giovannini, 1993; Canjels, Prakash-Canjels and Taylor, 2004; Coleman, 2007). By fixing the gold price of their currencies central banks effectively confined nominal exchange rates into a narrow target zone range whose upper and lower bound – the socalled gold points – were pinned down by the costs of arbitrage in international currency- and gold-markets.

<sup>&</sup>lt;sup>11</sup>Recall from figure 1 that this is not due to the average initial REER misalignement being smaller in the EZ than under the GS.





Notes: Black solid – Gold Standard. Grey dashed – Eurozone. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one REER peak to the next. 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  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 8 REER peaks. EZ: 6 REER peaks. REER is expressed in foreign units per domestic units.

Part of the smooth adjustment experience under the classical GS might be due to central banks making use of the little wiggling room within the gold points to conduct mildly countercylical monetary policies (Dutton, 1978, 1984; Pippenger, 1984; Davutyan and Parke, 1995; Bordo and MacDonald, 2005). A 1% deviation of the exchange rate from mint parity that was expected to dissappear within one year would imply a 1% annualized exchange rate appreciation. This gave central banks the freedom to temporarily set their policy rates 1ppt below what uncovered interest rate parity (UIP) in an absolutely fixed exchange rate regime would require. Frictions in international financial markets that allowed for limited deviations from UIP, such as portfolio adjustment costs, further increased central banks' wiggling room.<sup>12</sup> Figure 4 suggests that central banks indeed

<sup>&</sup>lt;sup>12</sup>Although the discount rate was not the only policy instrument available to central bankers at the time, it was the most important one. The discount rate was applied to bills of exchange, which lenders could swap for cash at the central bank's discount window. Morys (2011) documents that for many countries bills of exchange constituted between 60-85% of domestic assets. The discount rate was thus the most important





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made use of this freedom: Discount rates were on average 0.5 ppt lower during large external adjustments than usual (left panel). Consistent with UIP this was accompanied by the nominal exchange rate (NEER) lingering slightly below its normal level (right panel).<sup>13</sup>

policy rate for central banks during the late 19th and early 20th century. The Bank of England for example did make only infrequent use of open market operations before 1890, and even after that open market operations were only intended to "make Bank rate effective". Another policy tool were the so-called "gold devices" – most commonly constraints on the gold-convertibility of notes. Gold devices however played only a minor role for monetary policy in the European core (see Dutton (1984) on the Bank of England, and Eschweiler and Bordo (1994) on the Reichsbank). Only in the periphery, where discount rate policy was less effective in affecting gold flows (Morys, 2013), were "gold devices" given greater consideration (Reis, 2007; Ögren and Øksendal, 2011).

<sup>13</sup>The NEER was calculated as the trade-weighted geometric average of bilateral exchange rates. See Appendix A for details.

Several central banks, most notably the Banque de France and the National Bank of Belgium, further rounded the corners of the policy trilemma by using their reserves as a buffer stock (see Bazot, Bordo and Monnet, 2014; Eichengreen and Flandreau, 2014). When the exchange rate came under pressure these reserves could be used to actively intervene in foreign exchange markets or to passively accomodate gold outflows without having to resort to contractionary discount rate policy. Figure 4 shows that during major external adjustments such interventions were indeed sizeable: central bankers on average let the gold cover ratio slip by about 4 ppts.

### 2.5 Migration

A high degree of labor mobility can compensate for rigid exchange rates (Mundell, 1961), by redistributing labor supply and downward pressure on wages from overvalued deficitto undervalued surplus-regions. Migrants furthermore directly affect the external balance by carrying their consumption- and financing demands with them (see Kuznets, 1961; Fenoaltea, 1988). In this way migrants can contribute to a current account adjustment by decreasing the import demand of the origin country and increasing the import demand of the receiving country. The effect of migration however is not unambigously stabilizing. In particular, emigration constitutes a drag on demand in the origin country, potentially exacerbating a recession there (also see Farhi and Werning, 2014).

The late 19th century witnessed large-scale migration flows that varied with the economic conditions in origin- and receiving countries (Jerome, 1926; Thomas, 1941; Hatton, 1995). In the U.S. for instance net-immigration relative to population varied from 1ppt in the 1880s, to close to 0ppt in the 1890s, to again close to 1ppt in the early 20th century. Countries of origin, such as Sweden, experienced similarly sized outflows.

Figure 5 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 increase in





Notes: Black solid – Gold Standard. Grey dashed – Eurozone. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one REER peak to the next. 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  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 8 REER peaks. EZ: 6 REER peaks.

emigration. The grey dashed lines again convey an idea how this compares to recent developments within the EZ. The average migratory response for the EZ is even more pronounced: already 3 years into the adjustment net-immigration relative to population is down by 0.5 ppts compared to the non-reversal baseline. The wide 90% confidence bands however show that the EZ experience is more varied.

To sum up, between 1880 and 1913 many countries under the classical GS achieved large external adjustments that, in contrast to the current EZ experience, were not accompanied by severe output losses. The behavior of prices, monetary policy and migration during these adjustments is suggestive of substantial activity along all three channels. We now turn to evaluating their relative importance in explaining the smoothness of the pre-1914 external adjustment experience.

## 3 A model of the classical Gold Standard

What was the relative importance of prices, migration and monetary policy for keeping output volatility in check? To investigate this question we build a 2-region open-economy model of the classical GS that features international migration, various degrees of price flexibility and an elaborate monetary structure: Agents in the model can decide to take upon themselves the cost of migration in order to move to another region where they expect to be better off – e.g. because wages are higher.<sup>14</sup> The model's monetary structure ties together the major themes on monetary policy and international capital flows that the literature on the classical GS has highlighted: Central banks behave according to the "rules of the game" – i.e. they conduct interest rate policy such as to stabilize their gold cover ratio and/or the exchange rate (see Morys, 2011). They may however also deviate from the "rules of the game" (Bloomfield, 1959). Within the limits set by the gold exportand gold import-points central banks were free to set their policy rates with a "concern for home trade" (Sayers (1976) vol I, p.44, Bordo and MacDonald (2005)). In the long run, central banks' committment to convert the currency they issued into gold at a fixed parity was credible. The model thus features gold flows that are motivated by the arbitrage opportunities that arise when the market exchange rate of two currencies temporarily deviates from their relative gold parity – the socalled *mint ratio* (Giovannini, 1993; Canjels, Prakash-Canjels and Taylor, 2004).

<sup>&</sup>lt;sup>14</sup>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". In our annual model migration thus does not feature any intrinsic persistence.

### 3.1 Households

The model consists of a continuum of households  $i \in [0, 1]$ , with  $[0, n_t)$  of the households living in *H* and  $[n_t, 1]$  in *F*. Their lifetime utility is based on Greenwood, Hercowitz and Huffman (1988) (GHH) preferences<sup>15</sup>

$$V_{t}^{i} = \mathbb{E}_{t} \sum_{k \geq 0}^{\infty} \beta^{k} \frac{1}{1 - \sigma_{c}} \left( c_{t+k}^{i} - \frac{1}{1 + \sigma_{l}} l_{t+k}^{i}^{-1 + \sigma_{l}} \right)^{1 - \sigma_{c}},$$

where  $\beta$  is the discount factor,  $l_t$  is hours worked and  $c_t$  is consumption, which consists of a basket of H- and F-produced goods:  $c_t = \left[ (1 - \alpha)^{\frac{1}{c}} c_{H,t}^{\frac{c-1}{c}} + \alpha^{\frac{1}{c}} c_{E,t}^{\frac{c-1}{c}} \right]^{\frac{c}{c-1}}$ .  $\epsilon$  denotes the elasticity of substitution between domestic and foreign goods. The openness parameter  $\alpha$  reflects home-bias in taste as well as trade frictions. Home bias furthermore allows for realistic deviations from purchasing power parity. The H and F goods themselves are CES bundles of differentiated goods that are produced by the n home- and 1 - nforeign firms:  $c_{H,t} = \left( \left( \frac{1}{n} \right)^{\frac{1}{\mu}} \int_0^n c_{H,t}(j)^{\frac{\mu-1}{\mu}} dj \right)^{\frac{\mu}{\mu-1}}$  and  $c_{E,t} = \left( \left( \frac{1}{1-n} \right)^{\frac{1}{\mu}} \int_n^1 c_{E,t}(j)^{\frac{\mu-1}{\mu}} dj \right)^{\frac{\mu}{\mu-1}}$ , where j is the firm index and  $\mu$  is the elasticity of substitution between goods produced in the same region. The price indices for the H- and F-produced goods bundles are  $P_{H,t} = \left[ \frac{1}{n} \int_0^n P_{H,t}(j)^{1-\mu} dj \right]^{\frac{1}{1-\mu}}$  and  $P_{E,t} = \left[ \frac{1}{1-n} \int_n^1 P_{E,t}(j)^{1-\mu} dj \right]^{\frac{1}{1-\mu}}$ . The H consumer price index is then given by  $P_t = \left[ (1 - \alpha) P_{H,t}^{1-\epsilon} + \alpha P_{E,t}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$ . We assume that the law of one price applies at the individual goods level so that  $P_{E,t}(j) = P_{E,t}^*(j)e_t$ , with  $e_t$  denoting the nominal exchange rate.<sup>16</sup>

<sup>&</sup>lt;sup>15</sup>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.

<sup>&</sup>lt;sup>16</sup>The nominal exchange rate is defined as units of *H* currency per unit of *F* currency, so a depreciation of the *H* currency is associated with an increase in  $e_t$ .

The households' budget constraint is

$$B_{H,t-1}^{i}R_{t-1}^{e} + B_{F,t-1}^{i}R_{t-1}^{e*}e_{t} + TR_{t} + P_{t}w_{t}l_{t}^{i} + \Gamma_{t} + I_{t}^{\gamma}$$
$$= B_{H,t}^{i} + B_{F,t}^{i}e_{t} + P_{t}c_{t}^{i} + P_{t}\frac{K}{2}\left(\frac{B_{F,t}^{i}e_{t}}{P_{t}} - \bar{o}\right)^{2}$$

where  $P_t w_t$  is the nominal wage households receive for supplying their labor to local firms on competitive labor markets.  $B_{H,t}^i$  and  $B_{F,t}^i$  are houshold *i*'s holdings of two internationally traded one-period riskfree bonds, denominated in H- and F currency respectively.  $e_t$  denotes the nominal exchange rate; note that we switch to price notation here (domestic per foreign currency).  $R_t^e$  is the effective return, which is determined by the riskfree rate  $R_t$  and a risk premium shock  $\epsilon_t^b$  as  $R_t^e = R_t / \exp(\epsilon_t^b)$ . The adjustment of foreign real asset holdings is subject to a quadratic adjustment cost (see Benigno, 2009). Obstfeld and Taylor (2007) for example cite contemporary textbooks which estimate that such costs drove an annualized 75 basis point wedge between New York and London financial markets (e.g. Haupt, 1894; Margraff, 1908; Escher, 1917).<sup>17</sup> Portfolio adjustment costs and risk premium shocks allow for realistic deviations from strict uncovered interest parity (UIP). The portfolio adjustment expenditures of F households are transferred to *H* households in a lump-sum fashion:  $TR_t = e_t \frac{n_t^*}{n_t} P_t^* \frac{K^*}{2} \left( \frac{B_{H,t}^i}{P_t^* e_t} - \bar{o}^* \right)^2$ .  $\Gamma_t$ are local firms' nominal lump-sum dividends that are payed out to local households. The model knows four different agent types  $\tau$ : *H*- and *F*-agents that either stay or migrate  $\tau \in \{H \rightarrow H, H \rightarrow F, F \rightarrow H, F \rightarrow F\}$ . The type-specific and possibly negative payment  $I_t^{\tau}$  ensures that nominal asset holdings after migration are equalized across households within a region. Thus households within a region can be treated as identical.<sup>18</sup>

<sup>&</sup>lt;sup>17</sup>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 F).

<sup>&</sup>lt;sup>18</sup>Type changing, or in our case migration, causes difficulties in tracking household's asset

#### 3.1.1 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 a comparison of the lifetime utilities of living in home  $V_t^i$  and in foreign  $V_t^{i*}$ . Emigration is subject to a one-time fixed migration cost  $\kappa_d$  ( $\kappa_d^*$  for *F*), which captures the various hindrances migrants have to overcome (e.g. traveling costs). A household living in *H* migrates when  $V_t^{i*} - V_t^i - \kappa_d$  is higher than an idiosyncratic i.i.d. utility shock  $v_t^i$ . The household *i*'s migration decision can therefore be written as:

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

We assume that  $v_t^i$  is logistically distributed with mean 0 and variance  $\sigma_v^2 = (\pi \psi)^2/3$ , where  $\psi$  is the logistic distribution's scale parameter. Using the property of the logistic distribution, we can write the ex ante migration probability of household *i* as (Anderson, De Palma and Thisse, 1992, ch.2)

$$d_t^i = \left[1 + \exp\left(\frac{V_t^i - V_t^{i^*} + \kappa_d}{\psi}\right)\right]^{-1}$$

As households within a region are identical, we drop the index for households,  $d_t^i = d_t$ . The *i.i.d.* assumption regarding  $v_t^i$  furthermore implies that the population fraction that emigrates  $\tilde{d}_t$  equals the emigration probability  $d_t$ . The aggregate population in *H* therefore

position. Cúrdia and Woodford (2010) constructs an insurance scheme for households that change types between saver and borrower 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, because of the endogenous migration probability. Here, we resort to the pooling assumption for the tractability of the model. A similar pooling assumption has been used in Corsetti et al. (2013, 2014).

evolves according to

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

where *F* variables are marked by an asterisk.

### 3.2 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- and 1 - n foreign firms produce with labor from H- and F- households respectively. Their production function is  $y_t(j) = \exp(A_t)L_t(j)^{\gamma}$ , where  $y_t(j)$  is output and  $A_t$  is the exogenous region-specific productivity level.  $\gamma$  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 each period only a random fraction  $(1 - \theta)$  of firms can reset their prices.<sup>19</sup>  $\theta$ , together with  $\gamma$  and  $\mu$  determine the slope of the Phillips curve according to  $\tilde{\kappa} = \frac{(1 - \beta \theta)(1 - \theta)}{\theta(1 - \mu + \mu/\gamma)}$ .

<sup>&</sup>lt;sup>19</sup>We do not model price (backward-)indexation as Benati et al. (2008) shows that during the classical GS inflation was mostly a purely forward-looking process.

### 3.3 Equilibrium

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

$$0 = n_t B_{H,t} + n_t^* B_{H,t}^*$$
  

$$0 = n_t B_{F,t} + n_t^* B_{F,t}^*$$
  

$$y_t(j) = n_t c_{H,t}(j) + n_t^* c_{H,t}^*(j), \quad j \in [0, n)$$
  

$$y_t^*(j) = n_t c_{F,t}(j) + n_t^* c_{F,t}^*(j), \quad j \in [n, 1]$$
  

$$n_t l_t = \int_0^n L_t(j) dj, \quad j \in [0, n)$$
  

$$n_t^* l_t^* = \int_n^1 L_t^*(j) dj, \quad j \in [n, 1]$$

### 3.4 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 moneyquantity 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 policy as a discount rate rule that targets the gold cover ratio  $\gamma_t$ . This formulation integrates the money-quantity- and the discount rate-views in that discount rate policy  $R_t$  contributes to a stable money-to-gold ratio in the long run, while in the short run – within the target zone – the central bank is free to deviate from the "rules of the game" in order to stabilize the domestic output gap, here defined as the deviation of real output  $y_t$  from its steady state  $\bar{y}$ .<sup>20</sup> We also allow central banks to directly target the nominal exchange rate  $e_t$  in order to accomodate the heterogeneity of discount rate policies that could be observed under the classical GS. 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. 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  $\rho$ , and  $\Phi_y$ ,  $\Phi_\gamma$  and  $\Phi_e$  denote the sensitivity of the discount rate reaction with respect to output, the gold cover ratio and the exchange rate.

Adherence to the discount rate rule implies deviations from a strict money-quantity rule. Money  $M_t$  therefore varies with money demand. We specify a money demand function as in much of the earlier GS literature.<sup>21</sup> Money demand is assumed to be a fraction of the nominal value of total production  $P_{H,t} n y_t$  and depends on the discount rate  $R_t$ :

<sup>&</sup>lt;sup>20</sup>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 set.

<sup>&</sup>lt;sup>21</sup>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 payments.

$$P_{H,t} n y_t = \exp(\chi_t) M_t k(R_t), \quad k(R_t) > 0, \quad v^r \coloneqq \frac{\partial k}{\partial R_t} \ge 0,$$

where  $\chi_t$  is an exogenous money demand shock.

Central bank gold stocks evolve according to

$$G_t = G_{t-1} + F(TB_t, n_t - n_{t-1}e_t) \exp(\epsilon_t^m),$$
  

$$F(\overline{TB}, \overline{e}, 0) = 0, \quad \epsilon^e \coloneqq \frac{\partial F}{\partial e_t} \le 0, \quad \epsilon^n \coloneqq \frac{\partial F}{\partial (n_t - n_{t-1})} \ge 0$$

where gold moves between *H* and *F* in one of three ways: First, as layed out in Hume's price-specie flow model gold can be used to settle a deficit in the trade balance  $TB_t$ . Second, migrants  $n_t - n_{t-1}$  carry gold across the border. Most importantly for the classical GS era however, gold flows across borders were motivated by arbitrage profits.<sup>22</sup> Since *H* and *F* central banks commit to convert local currency into gold at a fixed parity, deviations of the nominal exchange rate from mint parity makes shipping gold between regions profitable.  $\epsilon_t^m$  is an exogenous gold shock.

Given money  $M_t$  and gold  $G_t$  the gold cover ratio  $\gamma_t$  is implicit in

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

<sup>&</sup>lt;sup>22</sup>By the late 19th century only a small part of capital account transactions were goldbased, rendering the price-specie flow mechanism described by Hume in the 18th century less applicable. Also, Capie and Webber (1985) provide estimates on the amount of gold coins that U.K. emigrants carried with themselves. On average, the loss in gold coins due to net-emigration amounted to slightly below 1% of the annual change in the U.K. gold coin stock.

where  $P_g$  is the legal gold parity.<sup>23</sup>

In the short run the gold cover ratio  $\gamma_t$  fluctuates with money  $M_t$  and the gold stock  $G_t$ . A look at the data confirms that central banks indeed let their gold cover ratios fluctuate substantially (see Appendix C).

### **4** Bayesian Estimation

We loglinearize the model around its non-stochastic steady state (see appendix G) and estimate it with Bayesian techniques for the U.K., Sweden and Belgium. 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. We choose the U.K. because it was arguably the financial pivot of the GS. Sweden was an exemplar for pronounced cyclical emigration. Belgium is interesting because its central bank made extensive use of its balance sheet as a buffer stock to neutralize the impact of gold flows on the domestic money supply (Eichengreen and Flandreau, 2014); it thus is an exemplar of a central bank that made full use of the limited monetary policy independence the GS allowed for.

<sup>&</sup>lt;sup>23</sup>During the GS, the legal definition of the gold cover ratio varied considerably across central banks and time. For example, the numerator could include or exclude foreign exchange reserves, while the denominator could include or exclude various kinds of inside money. Bloomfield (1959) provides a summary of the main types of legal cover ratios. Here we define the gold cover ratio as gold reserves over central bank notes in circulation. We consider this definition to be the one which is most closely linked to central banks' underlying target of maintaining the (confidence in) the gold-convertibility of their notes.

### 4.1 Observables

We estimate each model on the basis of 11 observables: domestic and foreign time series of per capita output, central bank discount rates and CPI-inflation; domestic time series for the ratio of net immigration to population, the trade balance to GDP ratio, changes in the money stock, 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 2). The ratio of net immigration to population and the trade balance to GDP ratio are directly detrended by a one-sided HP-filter ( $\lambda = 100$ ). All other variables are first logged before they are detrended with the same one-sided HP-filter.

### 4.2 Calibration

Some parameters are calibrated (see Table 1), either because they are difficult to estimate (e.g. markups) or because their identification from observables is straightforward (e.g. discount rates). We follow relatively standard calibration strategies for the time discount factor  $\beta$ , the within-country intra-temporal elasticty of substitution  $\mu$ , the curvature of the production function  $\gamma$ , the trade-openness parameters  $\alpha$  and  $\alpha^*$ , and the steady state gross foreign asset position  $\bar{o}$ : The time discount factor  $\beta$  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  $\mu$  is set to 11. This is a common value in the literature (e.g. Eggertsson (2008)) that implies a steady state price markup of 10%. Given  $\mu$ , we calibrate  $\gamma$  to target a steady state *labor income* to *GDP* ratio of 0.66 for the U.K. and 0.72 for all other countries.<sup>24</sup> The first value reflects the average (1880-1913) labor share in the U.K. and

<sup>&</sup>lt;sup>24</sup>The model's steady state labor income share is  $\gamma(\mu - 1)/\mu$ 

Description		Value/Target			
$ \begin{array}{c} \beta \\ \mu \\ \overline{\mu - 1} \\ \gamma^* \\ \alpha \\ \alpha^* \end{array} $	Discount factor Markup Production function F Openness parameter H Openness parameter F	0.962 1.1 0.792 SST H import-to-GDP ratio SST H export-to-GDP ratio			
United Kingdom Y n d ō	Production function H SST population H SST emigration H Foreign portfolio H	0.726 0.160 0.0064 SST H GFA-to-GDP ratio = 1.33			
Sweden Y n đ ō*	Production function H SST population H SST emigration H Foreign portfolio F	0.792 0.020 0.0059 SST F GFA-to-GDP ratio = 0.001			
Belgium Y n đ ō*	Production function H SST population H SST emigration H Foreign portfolio F	0.792 0.027 0.0036 SST F GFA-to-GDP ratio = 0.001			

#### Table 1: CALIBRATED PARAMETERS

Notes: GFA gross foreign assets. SST steady state.

the later is an approximation based on the average labor share in France and Germany.<sup>25</sup> The trade openness parameters  $\alpha$  and  $\alpha^*$  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).<sup>26</sup> 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 steady state few Swedish or Belgian assets were held abroad,

<sup>&</sup>lt;sup>25</sup>According to the datasets provided by Hills, Thomas and Dimsdale (2015) and Piketty and Zucman (2014).

<sup>&</sup>lt;sup>26</sup>Since they also depend on estimated parameters,  $\bar{o}$  ( $\bar{o}^*$ ),  $\alpha$  and  $\alpha^*$  are re-calibrated during estimation for each draw from the prior distribution.

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.<sup>27</sup>

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  $\bar{d} n = \bar{d}^* n^*$ .

### 4.3 **Prior distribution**

The prior 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.<sup>28</sup>

The prior distributions for the estimated parameters are summarized in Table 2. We assume that the inverse elasticity of intertemporal substitution  $\sigma_c$  and the inverse Frisch elasticity  $\sigma_l$  are identical across regions. Their prior distribution follows the literature standard (e.g. De Walque and Wouters (2005) and Smets and Wouters (2007)).<sup>29</sup> For

<sup>&</sup>lt;sup>27</sup>The model's steady state for net foreign assets is determined due to migration (see appendix F).

<sup>&</sup>lt;sup>28</sup>As in Christiano, Trabandt and Walentin (2011), we use the actual sample as our *pre-sample*.

<sup>&</sup>lt;sup>29</sup>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

the trade elasticities  $\epsilon$  and  $\epsilon^*$  we choose a comparatively wide prior, reflecting the wide range of modern-day estimates for these parameters. The migration parameters  $\psi$  and  $\psi^*$ determine how sensitive migration is to differences in the utility level between regions: a small  $\psi$  implies a stronger migration reaction for any given utility difference, whereas a large  $\psi$  implies that migration is largely a random phenomenon.<sup>30</sup> In accordance with the previously cited evidence for the responsiveness of migrants to economic conditions we choose an inverse gamma distribution with a relatively small mean 0.05.

Nominal rigidity is characterized by the Calvo parameter  $\theta$ , which together with  $\gamma$ ,  $\beta$  and  $\mu$  determines the slope of the Phillips curve,  $\tilde{\kappa}$ , according to  $\tilde{\kappa} = (1 - \beta\theta)(1 - \theta)/[1/\theta(1 - \mu + \mu/\gamma)]$ . 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 [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 range [0.5, 0.8] imply an annualized Phillips curve slope between 0.04 and 0.52. Where can we expect the corresponding GS parameter to lie? The evidence on price flexibility during the classical GS is ambiguous: Although aggregate price indices appear to exhibit 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), the micro evidence based on product-group level prices indicates that prices have not become less flexible over time (Kackmeister, 2007;

likelihood comparison of the models with and without habit formation shows that the latter is favored by our 1880-1913 data.

<sup>&</sup>lt;sup>30</sup>Note that while  $\psi$  characterizes migration's sensitivity to cyclical fluctutations, the fixed migration cost  $\kappa_d$  determines the level of migration  $\bar{d}$ , which has already been calibrated in the previous section.

Knotek, 2008). This points towards a compositional effect. It is well known that pre-1913 price indices contain more flex-price items such as agricultural produce and raw materials than today's indices. For our macro model the aggregate price level evidence has more relevance. To be on the safe side however, we choose an uninformative beta-prior for  $\tilde{\kappa}$  and  $\tilde{\kappa}^*$ , 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 migration sensitivity of gold flows  $e^n$  Capie and Webber (1985) provide estimates on the amount of gold coins that U.K. emigrants carried with themselves. On average, in absolute values the loss in gold coins due to net-emigration amounted to slightly below 1% of the annual change in the U.K. gold coin stock. Hence, we choose an inverse gamma prior distribution for  $e^n$  with mean 0.01. Concerning the trade-balance sensitivity of gold flows  $e^{tb}$  we center the prior distribution around 0, because by the late 19th century only a minor part of capital account transactions were still gold-based. Finally, except for the sign we remain agnostic about the sensitivity of gold flows to the exchange rate  $e^e$  by selecting a wide [-15, 0] uniform prior distribution. In our prior choice for the portfolio adjustment cost parameter *K* we rely on Benigno (2009), by... [...EXTEND ARGUMENT...].

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 we obtain for a sample of GS members for the years 1870-1879. We then choose 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. Accordingly, we estimate the discount rate rule for the U.K. without

persistence term.<sup>31</sup> 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 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.<sup>32</sup> Only the discount rate shock is not allowed to exhibit any persistence beyond that intrinsic to the discount rate rule. All persistence parameters are given a wide beta prior with mean 0.3.<sup>33</sup> We allow for the region-specific technology shocks to be correlated. We chose an uniformative beta prior for the correlation  $\sigma_{aa^*}$ . 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 obserables (all *F*-aggregates and the NEER), because trade-weights are updated only every third year. 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 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 H, the data

<sup>&</sup>lt;sup>31</sup>Discount rate decision at the Bank of England were made on a weekly basis (see Eichengreen, Watson and Grossman, 1985).

<sup>&</sup>lt;sup>32</sup>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.

<sup>&</sup>lt;sup>33</sup>The 0.3 mean for our annual model corresponds to the conventional prior mean from the [0.5, 0.85] range in quarterly models:  $0.3 \approx 0.75^4$ .

Table	2:	Prior	DISTRIBUTION
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Description		Distribution	Mean	S.D.	Descr	iption	Distribution	Mean	S.D.
1 Itilit	ı narameters			Shock narameters		narameters			
$\sigma_c$ Inverse EIS		Normal	1 50	0.35	0 <sup>a</sup>	Persistence technology (H)	Beta	0.30	0.15
$\sigma_1$	Inverse Frisch elasticity	Normal	2.00	0.75	$\rho^{a*}$	Persistence, technology (F)	Beta	0.30	0.15
ε	Trade elasticity (H)	Normal	1.50	1.50	r Øg	Persistence, markup (H)	Beta	0.30	0.15
$\epsilon^*$	Trade elasticity (F)	Normal	1.50	1.50	0 <sup>8</sup> *	Persistence, markup (F)	Beta	0.30	0.15
					$\rho^{x}$	Persistence, money demand (H)	Beta	0.30	0.15
Migra	tion parameters				$\rho^{x*}$	Persistence, money demand (F)	Beta	0.30	0.15
ψ <sup>3</sup>	, Migration sensitivity (H)	Inv. gamma	0.05	0.10	$\rho^b$	Persistence, risk premium (H)	Beta	0.30	0.15
10*	Migration sensitivity (F)	Inv. gamma	0.05	0.10	0 <sup>b</sup> *	Persistence, risk premium (F)	Beta	0.30	0.15
Ŧ	ingration benefit (1)	and gamma	0.00	0.10	$o^m$	Persistence, gold (H & F)	Beta	0.30	0.15
Price	parameters				$n^a$	S.D., technology (H)	Inv. gamma	0.50	2.00
ñ	Phillips curve slope (H)	Beta	0.50	0.28	$n^{a*}$	S.D., technology (F)	Inv. gamma	0.50	2.00
$\tilde{\kappa}^*$	Phillips curve slope (F)	Beta	0.50	0.28	ng	S.D., markup (H)	Inv. gamma	0.50	2.00
					n <sup>8*</sup>	S.D., markup (F)	Inv. gamma	0.50	2.00
Gold flow parameters					$\eta^x$	S.D., money demand (H)	Inv. gamma	0.50	2.00
$\epsilon^{e}$	Gold flow due to exchange rate	Uniform	[-15	, 0]	$\eta^{x*}$	S.D., money demand (F)	Inv. gamma	0.50	2.00
$\epsilon^{tb}$	Gold flow due to trade balance	Normal	0.00	1.00	$n^b$	S.D., risk premium (H)	Inv. gamma	0.50	2.00
$\epsilon^n$	Gold flow due to migration	Inv. gamma	0.01	0.03	$\eta^{b*}$	S.D., risk premium (F)	Inv. gamma	0.50	2.00
<u>Ē</u>	Relative gold stock	Inv gamma	<u>n</u>	1.00	$n^r$	S.D. monetary policy (H)	Inv gamma	0.10	2.00
$G^*$	Remarke gold block	nitti gunnitu	1-n	1.00	" n <sup>r</sup> *	S.D. monetary policy (F)	Inv. gamma	0.10	2.00
Discount rate narameters					" n <sup>m</sup>	SD gold (H & F)	Inv. gamma	0.10	2.00
0	Discount rate persistence (H)	Beta	0.30	0.15	'  <i>σ</i> *	Correlation technology	Beta	0.50	0.28
$\Phi^y$	Output coefficent (H)	Normal	0.00	0.50	° uu '	contention, technology	Deta	0.00	0.20
$\Phi^e$	Exchange rate coefficient (H)	Normal	0.50	0.50					
$\Phi^g$	Cover ratio coefficient (H)	Normal	0.10	0.50					
$\rho^*$	Discount rate persistence (F)	Beta	0.30	0.15					
$\Phi^{y*}$	Output coefficent (F)	Normal	0.00	0.50					
$\Phi^{e*}$	Exchange rate coefficent (F)	Normal	0.50	0.50					
$\Phi^{g*}$	Cover ratio coefficient (F)	Normal	0.10	0.50					
Other parameters									
K	Foreign portfolio adjustment costs	Inv. gamma	0.04	2.00					
$v^r$	Interest rate elasticity of money demand	Inv. gamma	0.10	0.03					

Notes: EIS elasticity of intertemporal substitution. S.D. standard deviation The prior distributions for  $\sigma_c$ ,  $\sigma_l$ ,  $\epsilon$  and  $\epsilon^*$  are truncated at zero. In case of UK,  $\rho$  is not estimated but set to zero. In case of Sweden and Belgium,  $\Phi^{e*}$  is not estimated but set to zero.

without measurement error very closely follow the original data.

### 4.4 **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 pre-1914 than today. Annual Phillips curve (PC) slope estimates for the U.K., Sweden and Belgium are 0.68, 0.44 and 0.93 respectively. For comparison, estimates for the EZ 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) for example imply annualized Phillips curve slopes of 0.0729 and 0.0079.<sup>34</sup> The counterfactual analysis in the next section will evaluate how this difference in PC slopes between the EZ- and GS-economies influences the external adjustment experience.

Secondly, consider the parameters  $\phi$  and  $\phi^*$  that pin down the sensitivity of migration movements to business cycle movements. The posterior mean estimates imply that migration was linked to the relative attractiveness of the two regions, but also that there was substantial idiosyncrasy in households' decision. The comparatively small estimate for Sweden reflects that Swedish migration was more responsive to fundamentals than that of the U.K. or Belgium. In particular the relatively high  $\phi$  estimate for Belgium implies that Belgian migration flows were relatively unresponsive to economic conditions. [...QUANTITATIVE EXAMPLE...]<sup>35</sup>

Finally, the monetary side is characterized by the following parameter estimates:

<sup>&</sup>lt;sup>34</sup>The slope estimates for *F* are lower than for *H*.

<sup>&</sup>lt;sup>35</sup>Between 1880 and 1913 Belgium itsself was a destination for many political refugees, which did not primarily migrate 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 coverd by our sample, 1880-1913.

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.<sup>36</sup> Also note that consistent with the exchange rate target the policy reaction to output is much less than what a modernday Taylor rule would suggest ( $\Phi^y = 0.5$ ). Thus, while monetary policy during the classical GS appears to have been a stabilizing force, we do not think that it is a crucial element for explaining stable output growth during major external adjustments. Gold flows appear to have been most sensitive with respect to exchange rate deviations in the U.K. ( $[1 + \overline{G}/\overline{G}^*][\overline{G}/\overline{G}^*] \cdot e^e = -85.8$ ). In accordance with Morys (2013) this implies that the Bank of England had considerable "pulling power", i.e. already small changes in the discount rate were effective in attracting and repelling international gold flows. In accordance with the historical record (e.g. Eichengreen and Flandreau, 2014), the National Bank of Belgium reacted least to fluctuations in the gold cover ratio ( $(1 - \rho)\phi^g = 0.045$ ).

### 4.5 Model evaluation

To see whether the estimated model gives a good description of the data we follow Surico and Benati (2009) in conducting an extensive comparison of observables' moments and moments based on simulated data that is obtained from stochastic simulations of the estimated model. In particular, we look at up to the 5th lag of correlations and auto-correlations for the six variables we are most interested in<sup>37</sup> – a total of 216 moments. To obtain the simulated data we run the model with all parameters set to their posterior mean, since these are the parameter values the subsequent counterfactual analysis is

<sup>&</sup>lt;sup>36</sup>We find no evidence for output stabilization in the *F*-regions ( $\phi^{y*} \approx 0$ ), while gold cover ratios and the GBP-exchange rate do show up as targets for *F* discount rate policy.

<sup>&</sup>lt;sup>37</sup>Per capita GDP, inflation, the discount rate, the nominal exchange rate, changes in the net-immigration/population ratio and changes in the trade-balance/GDP ratio.

			U.K.			Sweden			Belgium		
Description		Mean	90% HPDI		Mean	90% HPDI		Mean	90% HPDI		
Utilit	y parameters										
$\sigma_c$	Inverse EIS	1.3703	0.8858	1.8380	2.4222	1.9950	2.8321	2.2215	1.8549	2.5758	
$\sigma_l$	Inverse Frisch elasticity	2.4536	1.5077	3.3529	2.9985	2.0702	3.9463	3.5915	2.8020	4.3427	
e	Trade elasticity (H)	3.1698	1.1713	5.2429	1.4959	0.1052	2.6873	0.6327	0.0307	1.1585	
$\epsilon^*$	Trade elasticity (F)	3.5607	1.8171	5.3320	1.2927	0.2606	2.3497	0.4634	0.0265	0.8534	
Migra	ation parameters										
φ	Migration sensitivity (H)	0.2006	0.0455	0.3674	0.1701	0.0555	0.3035	2.2251	0.7908	3.9841	
$\phi^*$	Migration sensitivity (F)	0.2409	0.0444	0.4535	0.1703	0.0562	0.3030	1.9000	0.6311	3.5087	
Price	parameters										
ñ	Phillips curve slope (H)	0.6847	0.4350	0.9830	0.4373	0.2757	0.5955	0.9263	0.8440	1.0000	
$\tilde{\kappa}^*$	Phillips curve slope (F)	0.1161	0.0266	0.2179	0.4734	0.2421	0.6986	0.1953	0.0571	0.3498	
Gold	flow parameters										
$\epsilon^{e}$	Gold flow due to exchange rate	-3.3134	-4.6020	-1.9285	-2.9178	-3.9214	-1.8134	-0.7207	-1.0373	-0.4090	
$\epsilon^{tb}$	Gold flow due to trade balance	0.0050	0.0016	0.0086	-0.0001	-0.0017	0.0016	0.0073	-0.0001	0.0146	
$\epsilon^n$	Gold flow due to migration	0.0097	0.0023	0.0189	0.0097	0.0025	0.0179	0.0107	0.0023	0.0229	
$\frac{\bar{G}}{\bar{G}^*}$	Relative gold stock	0.0435	0.0313	0.0558	0.0418	0.0163	0.0658	0.0188	0.0099	0.0275	
Disco	unt rate parameters										
0	Discount rate persistence (H)	_	_	_	0.4882	0.2511	0.7377	0.4779	0.2978	0.6683	
$\Phi^y$	Output coefficent (H)	0.1373	0.0828	0.1956	0.2029	0.0062	0.4139	-0.0206	-0.1133	0.0742	
$\Phi^e$	Exchange rate coefficient (H)	0.5687	0.0993	1.0606	1.1525	0.3370	1.9472	0.5614	-0.0563	1.1514	
$\Phi^g$	Cover ratio coefficient (H)	0.0556	0.0414	0.0693	0.1534	0.0553	0.2639	0.0894	0.0432	0.1377	
$\rho^*$	Discount rate persistence (F)	0.2079	0.0370	0.3632	0.3406	0.1218	0.5671	0.2480	0.0553	0.4356	
$\Phi^{y*}$	Output coefficent (F)	-0.0766	-0.5324	0.3034	-0.1441	-0.4826	0.1722	-0.2166	-0.5147	0.0873	
$\Phi^{\ell*}$	Exchange rate coefficent (F)	1.3205	0.6293	2.0136	-	_	_	-	_	_	
$\Phi^{g*}$	Cover ratio coefficient (F)	0.5516	0.1856	0.8991	0.5953	0.2531	0.9107	0.4581	0.1588	0.7451	
Other	parameters										
K	Foreign portfolio adjustment costs	0.0213	0.0076	0.0369	0.1400	0.0154	0.3192	0.4890	0.2986	0.6637	
$v^r$	Interest rate elasticity of money demand	0.1012	0.0631	0.1365	0.1012	0.0638	0.1383	0.1035	0.0629	0.1428	

### Table 3: Posterior distribution

Notes: HPDI highest posterior density interval. For U.K.  $\rho$  is not estimated but set to zero. For Sweden and Belgium  $\Phi^{e*}$  is not estimated but set to zero.
Description		U.K.			Sweden			Belgium		
		Mean 90% HPDI		Mean	90% HPDI		Mean	90% HPDI		
Shock	parameters									
$\rho^a$	Persistence, technology (H)	0.1548	0.0417	0.2634	0.0529	0.0068	0.0952	0.4820	0.3800	0.5906
$\rho^{a*}$	Persistence, technology (F)	0.8786	0.8262	0.9309	0.8734	0.8389	0.9086	0.6045	0.3866	0.8258
$\rho_g$	Persistence, markup (H)	0.5513	0.3827	0.7166	0.3132	0.1621	0.4593	0.2709	0.1046	0.4273
$\rho^{g*}$	Persistence, markup (F)	0.2431	0.0309	0.4502	0.2770	0.1057	0.4365	0.5504	0.3535	0.7510
$\rho^x$	Persistence, money demand (H)	0.1392	0.0348	0.2375	0.2280	0.0694	0.3802	0.0690	0.0115	0.1229
$\rho^{x*}$	Persistence, money demand (F)	0.3853	0.1422	0.6254	0.3118	0.0743	0.5223	0.4698	0.2719	0.6674
$\rho^b$	Persistence, risk premium (H)	0.3216	0.0982	0.5471	0.4008	0.1381	0.6413	0.3045	0.0910	0.5096
$\rho^{b*}$	Persistence, risk premium (F)	0.2836	0.0513	0.5065	0.3434	0.1028	0.5841	0.3525	0.1190	0.5832
$\rho^m$	Persistence, gold (H & F)	0.4826	0.1926	0.8071	0.3140	0.1642	0.4597	0.2038	0.0295	0.3742
$\eta^a$	S.D., technology (H)	1.3266	1.1073	1.5437	2.0478	1.7736	2.3254	1.6042	1.4116	1.7876
$\eta^{a*}$	S.D., technology (F)	0.2815	0.2001	0.3570	0.3174	0.2544	0.3810	0.3178	0.2330	0.3990
$\eta^g$	S.D., markup (H)	3.5967	2.1904	4.9493	4.0272	2.9971	5.0438	6.0740	4.8427	7.3139
$\eta^{g*}$	S.D., markup (F)	0.7017	0.4443	0.9175	1.5026	0.8721	2.1031	0.8867	0.3108	1.5051
$\eta^x$	S.D., money demand (H)	1.9861	1.7967	2.1859	7.0538	6.0311	8.0013	2.0970	1.9353	2.2616
$\eta^{x*}$	S.D., money demand (F)	0.5972	0.2161	0.9493	0.4664	0.1451	0.7859	0.4175	0.2782	0.5586
$\eta^b$	S.D., risk premium (H)	0.3030	0.2219	0.3845	0.2201	0.1486	0.2887	0.1820	0.1236	0.2402
$n^{b*}$	S.D., risk premium (F)	0.2065	0.1320	0.2813	0.2225	0.1412	0.2997	0.2042	0.1389	0.2668
$\eta^r$	S.D., monetary policy (H)	0.4271	0.3123	0.5452	0.6618	0.3699	0.9524	0.4371	0.3216	0.5554
$\eta^{r*}$	S.D., monetary policy (F)	0.3575	0.2043	0.5130	0.3234	0.2176	0.4204	0.2869	0.1921	0.3767
$\eta^m$	S.D., gold (H & F)	0.4052	0.2396	0.5570	0.5933	0.3676	0.7885	0.2169	0.1378	0.2981
$\sigma_{aa^*}$	Correlation, technology									

### **Table 4:** Posterior distribution (continued)

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based on. We conduct 2000 simulations. Each simulation has 34 periods, corresponding to the length of our sample. To limit the result's dependence on the initial conditions, we run simulations for 134 periods and discard the first 100 observations. Figures 18 to 20 in Appendix I show the (auto-)correlation of the observables and those from the stochastic simulation together with the 90% coverage percentiles. The model does a rather good job at representing the data's correlation structure.

## 5 Counterfactual Analysis

In order to evaluate the relative importance of price flexibility, migration and monetary policy for an explanation of why external adjustment under the GS proceeded with few output costs, this section presents counterfactual output-, inflation-, REER-, and trade-balance volatilities. 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 run 2000 simulations, each 34 periods long (corresponding to the length of our sample).<sup>38</sup> 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 set the Phillips curve slope from our low GS estimates to a value which is representative of today's economies. In particular we set  $\tilde{\kappa} = \tilde{\kappa}^* = 0.05$ , which as discussed above, is within the range of estimated Phillips curve

<sup>&</sup>lt;sup>38</sup>To limit the result's dependence on the initial conditions, we run each simulation for 134 periods and discard the first 100 observations.

slopes for the EZ. The counterfactual standard deviations for output, the REER and the trade balance are substantially higher, with per capita output volatility increasing up to sixfold (for the U.K.). Flexible prices clearly helped to smooth out quantities during the classical GS.

In the second counterfactual, we shut down the migration channel. This has little effect on the standard deviations, except for Belgium, where output volatility increases by a notable 6.25%. Otherwise however even the sign of the effect is ambiguous, indicating that the stabilizing effects of migration do not necessarily outweight the destabilizing ones, that arise from migrants' procyclical effect on aggregate demand.

Finally, for the monetary policy counterfactual we eliminate the little freedom central banks had 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.<sup>39</sup> Column (4) in table 5 shows that this counterfactual would have had the most impact for the U.K. where per capita output volatility would have been almost 10% higher and inflation volatility 25% lower. This reflects our estimate that the BoE reacted more to output gaps than the other two countries' central banks. Besides this, there is little evidence that absolutely fixing the exchange rate would have substantially altered the adjustment experience under the classical GS.

In the context of the eurozone an interesting question is whether internal migration can alleviate the external adjustment problem given that prices are rigid. To get an idea about whether migration would be substantially more effective in reducing output and

$$\widehat{R}_{t}^{e} = \widehat{R}_{t}^{e*} - \frac{Kn}{n + \overline{E}_{r} (1 - n)} \left[ \overline{b}_{H} \left( \widehat{b}_{H,t} - \widehat{E}_{r,t} + \widehat{n}_{t} - \widehat{n}_{t}^{*} \right) + \overline{b}_{F} \overline{E}_{r} \left( \widehat{b}_{F,t} + \widehat{E}_{r,t} \right) \right] + \widetilde{\phi}_{e} \widehat{e}_{t},$$

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

 $<sup>\</sup>overline{^{39}}$ In *H*, the interest rate thus has to satisfy

		Baseline model (1)	Rigid prices (2)	No migration (3)	Fixed exchange rate (4)
United Kingdom					
$y_t^p$	Per capita output	1.6845	11.6500 (591 59%)	1.6885	1.8243 (8.30%)
$\Pi_t$	Inflation	1.3825	1.9131 (38.37%)	1.3823 (-0.02%)	1.0248 (-25.87%)
$E_{r,t}$	REER	0.4672	1.6677 (256.99%)	0.4614 (-1.23%)	0.4232 (-9.42%)
$tb_t/y_t$	Trade balance/GDP	0.7169	0.9644 (34.52%)	0.6952 (-3.03%)	0.7323 (2.15%)
Sweden					
$y_t^p$	Per capita output	1.8420	7.1330 (287.24%)	1.8354 (-0.36%)	1.8551 (0.71%)
$\Pi_t$	Inflation	2.3881	2.3717 (-0.69%)	2.3737 (-0.60%)	2.2293 (-6.65%)
$E_{r,t}$	REER	1.5575	2.6252 (68.55%)	1.5365 (-1.35%)	1.5593 (0.11%)
$tb_t/y_t$	Trade balance/GDP	0.8848	1.5213 (71.93%)	0.8654 (-2.19%)	0.8847 (-0.01%)
Belgium					
$y_t^p$	Per capita output	0.8814	3.7478 (325.20%)	0.9365 (6.25%)	0.8763 (-0.58%)
$\Pi_t$	Inflation	1.9848	2.8167 (41.91%)	1.9961 (0.57%)	2.0144 (1.49%)
$E_{r,t}$	REER	1.9435	4.2151 (116.88%)	1.9970 (2.75%)	1.9367 (-0.35%)
$tb_t/y_t$	Trade balance/GDP	0.8331	3.2790 (293.62%)	0.7940 (-4.69%)	0.8438 (1.29%)

#### Table 5: Counterfactual volatilities

Notes: Percentage change in counterfactual S.D. relative to baseline S.D. in parenthesis.

inflation volatility in a rigid price economy we run the corresponding counterfactual GS model simulation. The results displayed in table 9 in Appendix M do not suggest so. Shutting down the migration channel in a rigid price economy does not substantially impact output, inflation or REER volatilities. In fact migration has a marked impact only on the trade balance to GDP ratio, which in a rigid price world is about 10% less volatile in the no migration scenario. Migration's destabilizing effect on the denominator of the trade balance to GDP ratio thus appears to dominate its stabilizing effect on the numerator.<sup>40</sup>

<sup>&</sup>lt;sup>40</sup>Whether prices are rigid or flexible does not fundamentally change the impact of limited

In summary our findings for the most part discard migration- and monetary policybased explanations for the smoothness of external adjustment under the classical GS. Prices bore the brunt of adjustment.

### 6 Reasons for successful expenditure switching before 1914

Our analysis suggests that the low output cost of external adjustments under the classical GS was primarily a matter of expenditure switching brought about by a speedy adjustment in prices. Why did prices adjust much more quickly during the classical GS than subsequently? Over time, various explanations have been put forth: An increase in monopolistic power in goods- and labor markets (Galbraith, 1936; Hanes, 2000), changing inflation expectations (Cagan, 1975), the advent of countercyclical economic policies (Sachs, 1980) or the spread of long-term contracting (Sachs, 1980; Gordon, 1982).

An exhaustive investigation of the causes of the long run change in nominal rigidities is beyond the scope of this paper, but we would like to highlight one aspect which we think holds particular promise for explaining the ease of adjustment during the classical GS: The long-run change in the composition of output from primary products to finished goods, with the former generally exhibiting much more flexible prices (Cairnes, 1873; Bordo, 1980; Jacks, O'Rourke and Williamson, 2011). This compositional explanation of pre-1914 flexibility was already put forth by economists in the 1930s 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 19th century (Mills et al., 1927; Humphrey, 1937; Mason, 1938). In fact, studies based on disaggregate price data reaching

monetary policy independence on the counterfactual volatilities of output, inflation, the REER and the trade balance to GDP ratio (see table 9 in Appendix M).

even further back into the late 18th century indicated that over the long-run prices had if anything become more flexible (Bezanson et al., 1936; Tucker, 1938). To the best of our knowledge Humphrey (1937), Mason (1938) and Wood (1938) were among the first to suggest a sectoral change-based explanation to reconcile this seemingly contradictory doublet of evidence: while individual goods prices had gotten slightly more flexible over time, the fraction of flex-price goods the economy was producing was declining. The modern literature on price flexibility has extended this aggregation phenomenon into the 21th century. While studies based on micro-price datasets show that the frequency and size of price changes today are higher than they used to be in the late 19th- and early 20th century (Kackmeister, 2007; Knotek, 2008),<sup>41</sup> studies based on aggregate price indices show that the volatility (Gordon, 1990; Basu and Taylor, 1999; Obstfeld, 2007) and output-responsiveness (Bayoumi and Eichengreen, 1996; Bordo, 2008; Chernyshoff, Jacks and Taylor, 2009) of the aggregate price level prior to 1914 has never been reached since. The continued decline in the relative importance of the primary sector throughout the 20th century has again the potential to reconcile these two strands of the literature.<sup>42</sup> The following paragraphs show that the 20th century sectoral shift away from agriculture would indeed be quantitatively sufficient to explain most of the difference between the price rigidity estimates for today's EZ and our comparatively low price rigidity estimates for the GS.

In the late 19th century early industrializers such as France and Germany still em-

<sup>&</sup>lt;sup>41</sup>Also see Hatton (1988) and Allen (1992) for related evidence that wage rigidity in the U.K. and U.S. has changed little since the late 19th century. Hanes (1993) and Hanes and James (2003) however suggest that earlier in the 19th century U.S. wages indeed exhibited less downward nominal rigidity than subsequently.

<sup>&</sup>lt;sup>42</sup>Note however that part of the higher aggregate price level flexibility pre-1914 might be due to the underrepresentation of durable consumption goods as well as rent and housing.

ployed close to half of their labor force in agriculture and mining. Agriculture on its own was still responsible for 20-30% of total output in these economies. Even the U.K., the most industrialized country of its time, still employed between 10 and 20% of its labor force in the primary sector. For North Western Europe as a whole, primary product exports about equalled the amount of manufactures exports.<sup>43</sup> 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 merchandise exports.44 A back-of-the-envelope calculation can give some idea about what such a change in the sectoral composition of an economy implies for the rigidity of its aggregate price level. Estimates of the fraction of firms that can reset their price every quarter – the Calvo parameter – for today's eurozone ranges from 0.75 to 0.95 (Smets and Wouters, 2003; De Walque and Wouters, 2005). Assume for simplicity that the primary sector is characterized by 0 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 0.45 to 0.6. Our estimates of the annual Phillips curve slope imply a quarterly Calvo-parameter of 0.40, 0.53 and 0.40 for the U.K., Sweden and Belgium – all within the range suggested by the back-of-the-envelope calculation.<sup>45</sup> This suggests that an explanation of pre-1914 expenditure switching based on the sectoral composition of pre-1914 economies might go a long way in explaining the difference between the GS-

<sup>&</sup>lt;sup>43</sup>According to employment figures by Mitchell (2013), sectoral output shares by (Buera and Kaboski, 2012) and the export decomposition by Lamartine Yates (1959, pp. 226-32)
<sup>44</sup>Note however that today fuel – a flexible price commodity – can constitute a sizeable fraction of merchandise exports (see Worldbank (2016). World Development Indicators.). For many advanced economies however fuel exports constitute re-exports for which price movements do not translate into REER movements.

<sup>&</sup>lt;sup>45</sup>Note that different Phillips curve slope estimates for the U.K. and Belgium nevertheless result in the same Calvo parameter due to different production function curvatures  $\gamma$ 

#### Figure 6: DISAGGREGATED EXPORTS AND SECTORAL COMPOSITION AFTER MAJOR REER REVERSALS RELATIVE TO NON-REVERSALS



Notes: Agr – agricultural. Raw – raw material. Ind – industrial. LS – labor share. VA – value added share. Major adjustment periods are defined as the periods lasting from one REER peak to the next. REER peaks are defined according to a turning-point algorithm à la Bry and Boschan (1971): REER peaks are the highest REER-value in a  $\pm 10$ -year window. GS: 8 REER peaks.

and EZ-adjustment experiences.

To further explore this hypothesis we collected disaggregate export data which allows us to see which product groups drove the export boom and thus successful expenditure switching in the GS. The upper panel of figure 6 shows how agricultural, raw material and industrial exports behaved in the wake of a major REER reversal.<sup>46</sup> This is the

<sup>&</sup>lt;sup>46</sup>The following results are similar if we look at CA/GDP reversals instead of REER

sector-level equivalent to the aggregate export results presented in section 2 (see figure 2). The figure shows that fast pre-1914 expenditure switching was primarily due to the rapid increase of agricultural and raw material exports, which three years into the adjustment are up by 30%, while industrial exports have increased by only 10%. Thus primary sector exports are the reason why only three years into the adjustment aggregate exports are already up by almost 25% (see figure 2).

The lower panel of figure 6 shows that major external adjustments even left their mark on the sectoral structure of the economy. On average the fraction of value added in agriculture went up by 1 ppt and the agricultural labor share increased by 2 ppts. At the same time the industrial sector declined by a corresponding amount. This suggests that during major external adjustments the primary sector acted as an absorbent for the less adaptable industrial sector. Large flex-price primary sectors thus facilitated external adjustment under the GS.

In order to link the argument about the sectoral composition of the GS member economies back to the aggregate statistics shown in the beginning of this paper we want to look at how the aggregate price level and the trade balance/GDP ratio behave during major external adjustments conditional on an economy's agricultural sector share. In particular, we estimate the sequence of differences

$$\hat{D}_{h}(x_{i,t+h}, A_{i,t}, S_{i,t}) = \alpha_{i} + \beta_{h} A_{i,t} + \gamma_{h} S_{i,t} A_{i,t} + u_{i,t}, \quad h = 1, \dots, H,$$
(4)

where  $S_{i,t}$  is the value-added share of agriculture in total GDP. Otherwise all variables are defined as before in equation 2.  $A_{i,t}$  equals 1 if the economy *i* enters a major adjustment phase at time *t*, and 0 otherwise. *h* indicates the distance from the start of the adjustment phase.

reversals (see figures in Appendix N).

Figure 7: Price level and trade balance after major REER reversals relative to Non-reversals conditional on agricultural sector share



Notes: Major adjustment periods are defined as the periods lasting from one REER peak to the next. REER peaks are defined according to a turning-point algorithm à la Bry and Boschan (1971): REER peaks are the highest REER-value in a  $\pm$ 10-year window. GS: 8 REER peaks.

Figure 7 shows that during a prolonged REER reversal prices in a 50% agricultural economy (e.g. late 19th C. Finland) grew by about 15% less than usually. For a 30% agricultural economy the corresponding figure is 8%. For a largely non-agricultural economy with only 10% agricultural share these results indicate an only temporary deviation of prices from their average path. <sup>47</sup> The right panel of figure 7 shows that correspondingly the trade balance turned around faster for economies with a larger agricultural sector.

<sup>&</sup>lt;sup>47</sup>For prolonged CA-adjustments the difference in price adjustments is somewhat less, but larger agricultural shares are still associated with a larger relative price decline (see Appendix N).

## 7 Conclusion

How international adjustment could have worked so frictionlessly within the 19th century gold standard (GS) – a colossus defying most tenets of optimum currency area – has fascinated scholars of international economics ever since. The period from 1880 to 1913 did not lack in large international misalignments, during which on average the current account to GDP ratio troughed at -5% and the real effective exchange rate peaked after an almost 15% surge. In magnitude this is similar to the recent eurozone (EZ) experience.

In the average GS adjustment phase prices declined swiftly, exports rose sharply, domestic monetary policy turned mildly countercyclical and netemigration increased. To determine the relative importance of prices, monetary policy and migration for external adjustments from 1880 to 1913 this paper has introduced and estimated a structural model of the classical GS. Counterfactual simulations suggest that external adjustment under the GS was smooth mainly because flexible prices allowed for speedy expenditure switching. Monetary policy and migration at best played only minor supportive roles. Flexible prices in turn are largely explicable by an historical contingency: large primary sector shares ranging from 10-50%.

We interpret this as bad news for the EZ, which compared to the GS, displays a slightly more pronounced reaction along the rather ineffective migration channel. In the absense of a return of pre-1914 levels of price flexibility external adjustments within the EZ are unlikely to become substantially easier.

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# Appendix

### A Data

#### A.1 Gold Standard, 1880-1913

*Australia*: Nominal GDP: Mitchell (2013); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); nominal USD-exchange rate: Obstfeld and Taylor (2003); Immigration & emigration: Ferenczi (1929); Population: Maddison-Project (2013); Narrow and broad cover ratio: Jones and Obstfeld (2004) (gold) and Mitchell (2013) (notes and deposits); Notes in circulation: Mitchell (2013). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Coghlan (1901) (1880-1898), Statistical abstract for the several British colonies, possessions, and protectorates (1899-1900) and Official year book of the Commonwealth of Australia (1901-1912).

*Belgium*: Nominal GDP: Smits et al. (2009); Real per capita GDP: Barro and Ursúa (2010); CPI: National Bank of Belgium Services Statistiques Financières et Économiques (2012), Table: Indice des prix à la Consommation en Belgique; Current account: exports - imports; Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Schneider et al. (1991) (1870-1880) and Obstfeld and Taylor (2003) (1881-1913); Immigration & emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: National Bank of Belgium (1870-1879) and Flandreau and Zumer (2004) (1880-1913); Narrow and broad cover ratio: Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925); Notes in

circulation: Mitchell (2013). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Annuaire statistique de la Belgique.

*Canada*: Nominal GDP: Jones and Obstfeld (2004); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Schneider et al. (1991) (1870-1899 & 1909-1913) and Obstfeld and Taylor (2003) (1900-1908); Immigration & emigration: Mitchell (2013); Population: Maddison-Project (2013). Narrow and broad cover ratio: Leacy, Urquhart and Buckley (1983); Notes in circulation: Mitchell (2013). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical yearbook of Canada (1870-1904) and Canada yearbook (1905-1913).

*Denmark*: Nominal GDP: Mitchell (2013); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Denzel (2010) (1870-1880), Obstfeld and Taylor (2003) (1881-1912) and Officer (2015) (1913); Emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: Johansen (1985) (1870-1874) and Abildgren (2005) (1875-1913) ; Narrow and broad cover ratio: Johansen (1985); Notes in circulation: Johansen (1985). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries. (1884-1912) and Statistisk årbog (1913).

*Finland*: Nominal GDP: Hjerppe (1989); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Autio (1992) (1870-1880) and Obstfeld and Taylor (2003) (1881-1913); Immigration & emigration: Ferenczi (1929); Population: Maddison-Project (2013). Central bank discount rate: Autio (1996); Narrow cover ratio: Jones and Obstfeld (2004) (gold) and (Mitchell, 2013) (notes); Notes in circulation: Mitchell (2013). Agricultural share (value added): Hjerppe (1989). Agricultural share (labor share): Hjerppe (1989). Agricultural, raw material and industrial exports: Hjerppe (1989) (1875-1880) and Statistical yearbook of Finland (1877 & 1882-1913).

*France*: Nominal GDP: Mitchell (2013); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Denzel (2010) (1870-1880), Obstfeld and Taylor (2003) (1881-1912) and Officer (2015) (1913); Emigration: Mitchell (2013) (1870-1890) and Ferenczi (1929) (1891-1913); Population: Maddison-Project (2013). Central bank discount rate: Jong (1967) (1870-1879) and Flandreau and Zumer (2004) (1880-1913); Narrow and broad cover ratio: Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925); Notes in circulation: Mitchell (2013). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries.

*Germany*: Nominal GDP: Burhop and Wolff (2005); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Sensch (2009) (1872-1879) and Mitchell (2013) (1880-1913); Nominal USD-exchange rate: Denzel (2010) (1870-1886) and Statistisches Jahrbuch für das Deutsche Reich (various issues); Emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925) (1870-1879) and Flandreau and Zumer (2004) (1880-1913); Narrow and broad cover ratio: Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925); Notes in circulation: Mitchell (2013). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Sensch (2009).

*Netherlands*: Nominal GDP: Smits, Horlings and van Zanden (n.d.); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Smits, Horlings and van Zanden (n.d.); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Obstfeld and Taylor (2003); Immigration & emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: Jong (1967) (1870-1875), Vergle-ichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925) (1876-1879) and Flandreau and Zumer (2004) (1880-1913); Narrow cover ratio: Jong (1967) (1870-1875) and Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr Notenbanken, 1876-1913 (1925) (1876-1875) and Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925) (1870-1875) and Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925) (1870-1875) and Vergleichende Notenbankstatistik: Organisation und Geschäftsverkehr wichtiger europäischer Notenbanken, 1876-1913 (1925) (1876-1913); Broad cover ratio: Jong (1967); Notes in circulation: Jong (1967). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries.

*New Zealand*: Nominal GDP: Obstfeld and Taylor (2003); Real per capita GDP: Barro and Ursúa (2010); CPI: Reinhart and Rogoff (2010); Current account: exports - imports; Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Officer (2015) (GBP-USD exchange rate); Immigration & emigration: Ferenczi (1929); Population: Maddison-Project (2013). Notes in circulation: Mitchell (2013). Agricultural share (labor share): New Zealand Censuses (various issues 1871-1916). Agricultural, raw material and industrial exports: Statistics of the colony of New Zealand (1875-1907) and The New Zealand official yearbook (1908-1913).

*Norway*: Nominal GDP: Grytten (2004); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Obstfeld and Taylor (2003); Emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: Norges Bank Historical Monetary Statistics; Narrow and broad cover ratio: Norges Bank Historical Monetary Statistics; Notes in circulation: Norges Bank Historical Monetary Statistics. Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Statistics Aarbok (various issues). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries.

*Sweden*: Nominal GDP: Edvinsson (2004); Real per capita GDP: Barro and Ursúa (2010); CPI: Taylor (2002); Current account: Jones and Obstfeld (2004) (adjusted for monetary gold flows); Exports & imports: Mitchell (2013); Nominal USD-exchange rate: Denzel (2010) (1870-1880) and Obstfeld and Taylor (2003) (1881-1913); Immigration & emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: Edvinsson, Jacobson and Waldenström (2010); Narrow and broad cover ratio: Swedish Riksbank Historical Monetary Statistics of Sweden; Notes in circulation: Swedish Riksbank Historical Monetary Statistics of Sweden. Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries.

Switzerland: Nominal GDP: Ritzmann-Blickenstorfer (1996); Real per capita GDP:

Barro and Ursúa (2010); CPI: Taylor (2002); Exports & imports: Ritzmann-Blickenstorfer (1996) (1870-1884) and Mitchell (2013) (1885-1913); Nominal USD-exchange rate: Denzel (2010) (1870-1880) and Obstfeld and Taylor (2003) (1881-1913); Emigration: Mitchell (2013); Population: Maddison-Project (2013). Central bank discount rate: Swiss National Bank (SNB): average of discount rates in Geneva, Basel, Zurich and St Gallen (1870-1893), Flandreau and Zumer (2004) (1894-1906) and SNB central bank discount rate (1907-1913); Broad cover ratio: Swiss National Bank; Notes in circulation: Swiss National Bank. Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the principal and other foreign countries.

*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; Notes in circulation: Bank of England Historical Balance Sheet; Notes in circulation: Bank of England Historical Balance Sheet; Notes in circulation: Bank of England Historical Balance Sheet; Notes in circulation: Bank of England Historical Balance Sheet; Notes in circulation: Bank of England Historical Balance Sheet; Notes in circulation: Bank of England Historical Balance Sheet: Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (labor share): Mitchell (2013). Agricultural, raw material and industrial exports: Statistical abstract for the United Kingdom

*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). Agricultural share (value added): Buera and Kaboski (2012). Agricultural share (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).

#### A.2 Eurozone economies, 1994-2015

*Austria*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Belgium*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Finland*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*France*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: OECD Statistics (Immigration, 1994-2005), UN (Immigration, 2006-2013 and Emigration); Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Germany*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Greece*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

Ireland: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook;

Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Italy*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Luxembourg*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Netherlands*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database. *Portugal*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

*Spain*: Real per capita GDP: World Economic Outlook; CPI: World Economic Outlook; Current account: World Economic Outlook; Imports & exports: IMF International Financial Statistics; Immigration & emigration: UN; Population: World Economic Outlook; Real effective exchange rate: ECB's CPI-based harmonized competitiveness indicator (HCI) vis-à-vis the other 19 euro area countries. Bilateral imports and exports: UN Comtrade Database.

# **B** Adjustment periods



Figure 8: REERs within the Gold Standard

Notes: Grey - not on Gold Standard. Vertical bar - REER peak. REER is expressed in foreign units per domestic units.



Figure 9: CA/GDP within the Gold Standard

Notes: Grey – not on Gold Standard. Vertical bar – CA/GDP trough.



Figure 10: REERs within the Eurozone

Notes: Grey - not in eurozone. Vertical bar - REER peak. REER is expressed in foreign units per domestic units.



Figure 11: CA/GDP within the Eurozone

Notes: Grey – not in eurozone. Vertical bar – CA/GDP trough.
# C Gold cover ratios



Figure 12: Gold cover ratios, narrow

Notes: The figure depicts narrowly defined gold cover ratios: Gold cover ratio = Gold divided by central bank notes in circulation.



Figure 13: Gold cover ratios, broad

Notes: The figure depicts broadly defined gold cover ratios: Gold cover ratio = Metal reserves + foreign exchange reserves divided by central bank notes in circulation + central bank deposits.

## **D** Primary sector shares



Figure 14: 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 inter- and extrapolated values.

## E 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:

$$\begin{aligned} \mathbf{Y}_{t}^{i} &= \max_{\{\text{stay, migrate}\}} \{ V_{t}^{i}, \quad V_{t}^{i^{*}} + v_{t}^{i} - \kappa_{d} \}, \text{ with } v_{t}^{i} \stackrel{iid}{\sim} Logistic\left(0, \frac{(\pi\psi)^{2}}{3}\right) \\ d_{t}^{i} &= \text{Prob}\left(V_{t}^{i} \leq V_{t}^{i^{*}} + v_{t}^{i} - \kappa_{d}\right) \\ \Rightarrow \mathbf{Y}_{t}^{i} &= \psi \ln\left(\exp\left(\frac{V_{t}^{i}}{\psi}\right) + \exp\left(\frac{V_{t}^{i^{*}} - \kappa_{d}}{\psi}\right)\right), \quad d_{t}^{i} = \left[1 + \exp\left(\frac{V_{t}^{i} - V_{t}^{i^{*}} + \kappa_{d}}{\psi}\right)\right]^{-1} \end{aligned}$$

The second state decision is

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

The budget constraint for a F household is:

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

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

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

$$\lambda_{t}^{*} = \left(c_{t}^{*} - \frac{(l_{t}^{*})^{1+\sigma_{l}}}{1+\sigma_{l}}\right)^{-\sigma_{c}}$$
(E.2)

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

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

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

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

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

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

The population evolves according to

$$n_t = n_{t-1} (1 - d_t) + d_t^* n_{t-1}^*$$
(E.9)

$$n_t^* = 1 - n_t$$
 (E.10)

Firm *j*'s optimization problem is

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

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

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

The first order condition leads to

$$F_{t} = \lambda_{t} y_{t} \left(\frac{P_{H,t}}{P_{t}}\right) \left(\frac{P_{H,t}^{opt}}{P_{H,t}}\right)^{1-\mu} + \beta \theta \mathbb{E}_{t} \left(\frac{\left(\frac{P_{H,t}^{opt}}{P_{H,t+1}}\right)}{\left(\frac{P_{H,t+1}^{opt}}{P_{H,t+1}}\right)} \frac{1}{\Pi_{H,t+1}}\right)^{1-\mu} F_{t+1} \qquad (E.14)$$

$$K_{t} = w_{t} \frac{\lambda_{t}}{\gamma} \frac{\mu}{\mu-1} \left(\frac{y_{t}}{A_{t}}\right)^{\frac{1}{\gamma}} \left(\frac{P_{H,t}^{opt}}{P_{H,t}}\right)^{\frac{-\mu}{\gamma}} + \beta \theta \mathbb{E}_{t} \left(\frac{\left(\frac{P_{H,t}^{opt}}{P_{H,t+1}}\right)}{\left(\frac{P_{H,t+1}^{opt}}{P_{H,t+1}}\right)} \frac{1}{\Pi_{H,t+1}}\right)^{\frac{-\mu}{\gamma}} K_{t+1} \quad (E.15)$$

$$K_{t} = F_{t} \qquad (E.16)$$

The price dynamics are described by

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

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

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

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

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

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

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

The market clearing conditions are

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

$$\Delta_t^P n y_t^{\frac{1}{\gamma}} = l_t n_t A_t^{\frac{1}{\gamma}}$$
(E.24)

$$0 = n_t B_{H,t} + n_t^* B_{H,t}^*$$
(E.25)

$$0 = n_t B_{F,t} + n_t^* B_{F,t}^*$$
(E.26)

Auxiliary variables:

$$ToT_t = \frac{P_{F,t}}{P_{H,t}}$$
(E.27)

$$\Pi_t = \frac{P_t}{P_{t-1}} \tag{E.28}$$

$$\Pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}}$$
(E.29)

$$y_t^p = \frac{n y_t}{n_t} \tag{E.30}$$

$$TB_t = n_t^* c_{H,t}^* P_{H,t} - n_t c_{F,t} P_{F,t}$$
(E.31)

$$c_{H,t} = (1-\alpha) \left(\frac{P_{H,t}}{P_t}\right)^{-\epsilon} c_t$$
(E.32)

$$c_{H,t}^{*} = \alpha^{*} \left(\frac{P_{H,t}^{*}}{P_{t}^{*}}\right)^{-\epsilon^{*}} c_{t}^{*}$$
 (E.33)

$$c_{F,t} = \alpha \left(\frac{P_{F,t}}{P_t}\right)^{-\epsilon} c_t \tag{E.34}$$

$$c_{F,t}^{*} = (1 - \alpha^{*}) \left(\frac{P_{F,t}^{*}}{P_{t}^{*}}\right)^{-\epsilon^{*}} c_{t}^{*}$$
 (E.35)

#### F 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 (E.4) and (E.6) it follows that  $\bar{R} = \bar{R}^*$ . Using (E.4) and (E.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

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

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

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

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

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

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

The steady state labor supply satisfies

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

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

At the steady state, the asset pooling assumption gives us

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

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

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

$$\bar{n}\,\bar{b} = \bar{R}\,(1-\bar{d}-\bar{d}^*)\,\bar{\Omega}\bar{n}$$

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

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

$$\bar{n}\,\frac{\bar{P}_{H}}{\bar{P}}\bar{y} + (1-\bar{n})\,\frac{\bar{P}_{F}^{*}}{\bar{P}^{*}}\bar{y}^{*}\bar{E}_{r} = \bar{n}\,\bar{c} + (1-\bar{n})\,\bar{c}^{*}\,\bar{E}_{r}$$
(F.8)

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

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

$$\bar{y}^{*}(1-\bar{n}) = \left(\frac{\bar{P}_{F}^{*}}{\bar{P}^{*}}\right)^{-\epsilon} \left(\alpha \, \bar{c} \, \bar{n} / \bar{E}_{r}^{\epsilon} + (1-\alpha^{*}) \left(1-\bar{n}\right) \bar{c}^{*}\right)$$
(F.10)

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

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

Prices in the steady state satisfy

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

### G 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,  $\hat{x} = \log(\frac{x}{\bar{x}})$ ).  $\Delta$  indicates the first difference ( $\Delta \hat{x}_t = \hat{x}_t - \hat{x}_{t-1}$ ).  $\tilde{\kappa}$  denotes the slope of the Phillips curve, which is related to the structural parameters  $\beta$ ,  $\gamma$ ,  $\mu$  and  $\theta$  according to  $\tilde{\kappa} = (1 - \beta \theta)(1 - \theta)/[1/\theta(1 - \mu + \mu/\gamma)]$ .

$$\hat{\lambda}_{t} = \frac{(-\sigma_{\bar{c}})}{\bar{c} (1-h) - \frac{1}{1+\sigma_{l}} (\bar{l})^{1+\sigma_{l}}} \left( \bar{c} \, \hat{c}_{t} - (\bar{l})^{1+\sigma_{l}} \, \hat{l}_{t} \right) \tag{G.1}$$

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

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

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

$$\hat{R}_{t}^{e} = \hat{R}_{t}^{e*} + \mathbb{E}_{t}\hat{e}_{t+1} - \hat{e}_{t} - \frac{\mathsf{K}\,n}{n + \bar{E}_{r}\,(1-n)}\,\left(\widehat{\Omega}_{t} + \left(\bar{E}_{r}\,\bar{b}_{F} - \bar{b}_{H}\right)\,\widehat{E}_{rt} + \bar{b}_{H}\,\left(\hat{n}_{t} - \hat{n}_{t}^{*}\right)\right) \tag{G.5}$$

$$\bar{b}\left(\hat{n}_{t-1} + \frac{1}{\bar{E}_{r}\,\bar{b}_{F} + \bar{b}_{H}}\left(\widehat{\Omega}_{t-1} + \bar{b}_{H}\,\left(\hat{R}_{t-1} - \hat{\Pi}_{t}\right) + \bar{E}_{r}\,\bar{b}_{F}\,\left(\hat{E}_{rt} + \hat{R}_{t-1}^{*} - \hat{\Pi}_{t}^{*}\right)\right) \\
- \frac{1}{1 - \bar{d} - \bar{d}^{*}}\left(\bar{d}\,\hat{d}_{t} + \bar{d}^{*}\,\hat{d}_{t}^{*}\right)\right) = \widehat{\Omega}_{t} - \bar{y}\,\frac{\bar{P}_{H}}{\bar{P}}\left(\hat{y}_{t} - \alpha\,\left(\frac{\bar{P}_{F}}{\bar{P}}\right)^{1-\epsilon}\,\widehat{ToT}_{t}\right) \\
+ \hat{n}_{t}\,\left(\bar{c} + \bar{E}_{r}\,\bar{b}_{F} + \bar{b}_{H}\right) + \bar{E}_{r}\,\bar{b}_{F}\,\hat{E}_{rt} + \bar{c}\,\hat{c}_{t}$$
(G.6)

$$\hat{d}_{t} = \left(1 - \bar{d} - \bar{d}^{*}\right) \beta \mathbb{E}_{t} \hat{d}_{t+1} + \frac{1 - \bar{d}}{\psi} \left( \left( \bar{c}^{*} \left( \hat{c}^{*}_{t} - h \, \hat{c}^{*}_{t-1} \right) - \left( \bar{l}^{*} \right)^{1 + \sigma_{l}} \hat{l}^{*}_{t} \right) \bar{\lambda}^{*} - \left( \bar{c} \left( \hat{c}_{t} - h \, \hat{c}_{t-1} \right) - \left( \bar{l} \right)^{1 + \sigma_{l}} \hat{l}_{t} \right) \bar{\lambda} \right)$$

$$(G.7)$$

$$\hat{d}_{t}^{*} = (1 - \bar{d} - \bar{d}^{*}) \ \beta \mathbb{E}_{t} \hat{d}_{t+1}^{*} \\
- \left( \left( \bar{c}^{*} \ \left( \hat{c}_{t}^{*} - h \ \hat{c}_{t-1}^{*} \right) - (\bar{l}^{*})^{1 + \sigma_{l}} \ \hat{l}_{t}^{*} \right) \ \bar{\lambda}^{*} - \left( \bar{c} \ \left( \hat{c}_{t} - h \ \hat{c}_{t-1} \right) - (\bar{l})^{1 + \sigma_{l}} \ \hat{l}_{t} \right) \ \bar{\lambda} \right) \ \frac{1 - \bar{d}^{*}}{\psi^{*}} \quad (G.8)$$

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

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

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

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

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

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

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

$$\begin{split} \hat{y}_{t} &= \frac{\bar{c}}{\bar{y}} \left(1 - \alpha\right) \frac{\bar{P}_{H}}{\bar{p}}^{-\epsilon} \left(\hat{c}_{t} + \hat{n}_{t}\right) + \frac{\frac{(1 - n)\bar{c}^{*}\frac{\bar{P}_{H}}{\bar{p}}^{-\epsilon}}{\bar{y}} \alpha^{*} \bar{E}_{r}^{\epsilon} \left(\hat{c}_{t}^{*} + \hat{n}_{t}^{*} + \hat{E}_{rt} \epsilon\right) \\ &+ \widehat{ToT}_{t} \frac{\alpha \left(\frac{\bar{P}_{E}}{\bar{p}}\right)^{1 - \epsilon}}{\bar{y}} \left(\frac{\bar{P}_{H}}{\bar{p}}^{-\epsilon} \left(1 - \alpha\right) n \bar{c} \epsilon + \bar{E}_{r}^{\epsilon} \alpha^{*} \left(1 - n\right) \frac{\bar{P}_{H}}{\bar{p}}^{-\epsilon} \bar{c}^{*} \epsilon\right) \end{split}$$
(G.16)

$$\hat{y}_{t}^{*} = (\hat{c}_{t}^{*} + \hat{n}_{t}^{*}) \frac{\bar{c}^{*}}{\bar{y}^{*}} (1 - \alpha^{*}) \frac{\bar{P}_{F}^{*} - \epsilon}{\bar{P}^{*}} + \frac{\bar{P}_{F}^{*} - \epsilon}{\bar{P}^{*}} \frac{\alpha \frac{\frac{\epsilon}{1 - n}}{\bar{y}^{*}}}{\bar{E}_{r}^{\epsilon}} (\hat{c}_{t} + \hat{n}_{t} - \hat{E}_{rt} \epsilon)$$

$$- \widehat{ToT}_{t} \frac{\alpha^{*} \left(\frac{\bar{P}_{H}^{*}}{\bar{P}^{*}}\right)^{1 - \epsilon^{*}}}{\bar{y}^{*}} \left(\frac{\bar{P}_{F}^{*} - \epsilon}{\bar{P}^{*}} (1 - \alpha^{*}) (1 - n) \bar{c}^{*} \epsilon + \frac{\bar{P}_{F}^{*} - \epsilon}{\bar{P}^{*}} \frac{\alpha n \bar{c} \epsilon}{\bar{E}_{r}^{\epsilon}}\right)$$
(G.17)

$$\hat{R}_t = \hat{R}_{t-1}\rho^R + \hat{y}_t \left(1 - \rho^R\right)\Phi^y + \hat{e}_t \left(1 - \rho^R\right)\Phi^e + \left(1 - \rho^R\right)\left(-\Phi^g\right)\hat{\gamma}_t + \epsilon_t^r \qquad (G.18)$$

$$\hat{R}_{t}^{*} = \hat{R}_{t-1}^{*} \rho^{R^{*}} + \hat{y}_{t}^{*} \left(1 - \rho^{R^{*}}\right) \Phi^{y^{*}} + \left(1 - \rho^{R^{*}}\right) \Phi^{e^{*}} \left(-\hat{e}_{t}\right) + \left(1 - \rho^{R^{*}}\right) \left(-\Phi^{g^{*}}\right) \hat{\gamma}_{t}^{*} + \epsilon_{t}^{r^{*}} \quad (G.19)$$

$$\hat{R}_t^e = \hat{R}_t + \epsilon_t^b \tag{G.20}$$

$$\hat{R}_t^{e*} = \hat{R}_t^* + \epsilon_t^{b*} \tag{G.21}$$

$$\Delta \hat{G}_t \frac{\frac{\bar{G}}{\bar{G}^*}}{1 + \frac{\bar{G}}{\bar{G}^*}} = \hat{e}_t \,\epsilon^e + \epsilon^{ca} \,\hat{c}a_t + n \,\epsilon^n (\hat{n}_t - \hat{n}_{t-1}) + \epsilon_t^m \tag{G.22}$$

$$\Delta \hat{G}^*_t \frac{1}{1 + \frac{\bar{G}}{\bar{G}^*}} = \hat{e}_t (-\epsilon^e) - \epsilon^{ca} \hat{c}a_t + (1 - n) \epsilon^n (\hat{n}^*_t - \hat{n}^*_{t-1}) + \epsilon^{m*}_t$$
(G.23)

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

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

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

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

$$\hat{y}_t^p = \hat{y}_t - \widehat{ToT}_t \alpha \left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon} - \hat{n}_t \tag{G.28}$$

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

$$\hat{E}_{r,t} = \hat{\Pi}_t^* + \hat{e}_t + \hat{E}_{rt-1} - \hat{e}_{t-1} - \hat{\Pi}_t$$
(G.30)

$$\hat{t}b_t \, \bar{t}\bar{b} = \left(\hat{y}_t - \widehat{ToT}_t \, \alpha \left(\frac{\bar{P}_F}{\bar{P}}\right)^{1-\epsilon}\right) \, n \, \bar{y} \, \frac{\bar{P}_H}{\bar{P}} - (\hat{c}_t + \hat{n}_t) \, \bar{c} \, n \tag{G.31}$$

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

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

$$\hat{w}_t = \sigma_l \, \hat{l}_t \tag{G.34}$$

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

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

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

$$\hat{l}_{t}^{*} = \frac{1}{\gamma} \left( \hat{y}_{t}^{*} - \hat{A}_{t}^{*} \right) - \hat{n}_{t}^{*}$$
(G.38)

$$\hat{A}_{t} = \rho^{a} \, \hat{A}_{t-1} - \eta^{A}_{t} \tag{G.39}$$

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

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

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

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

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

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

$$\epsilon_t^{m*} = \rho_m^*, \epsilon_{t-1}^{m*} - \eta_t^{m*}$$
 (G.46)

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

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

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



# H History and smoothed data

**Figure 15:** U.K. - Historical observation with measurement errors and smoothed variables without measurement errors. For variables without no measurement errors, the two series are identical.



----- observed data ---- smoothed data

**Figure 16:** Sweden - Historical observation with measurement errors and smoothed variables without measurement errors. For variables without no measurement errors, the two series are identical.



----- observed data ---- smoothed data

**Figure 17:** Belgium - Historical observation with measurement errors and smoothed variables without measurement errors. For variables without no measurement errors, the two series are identical.

#### I Autocorrelation - observed vs. simulated data



**Figure 18:** (*Auto-*)correlation - U.K.: data sample autocorrelation matrix, and medians and 90 percent coverage percentiles of the distribution of the autocorrelation matrix of the simulated data with measurement errors based on 2000 times simulation conditional on posterior mean. The rows depicts the reference variables, and columns variables between whom and the reference variable the (auto-) correlation is calculated.



**Figure 19:** (*Auto-*)correlation - Sweden: data sample autocorrelation matrix, and medians and 90 percent coverage percentiles of the distribution of the autocorrelation matrix of the simulated data with measurement errors based on 2000 times simulation conditional on posterior mean. The rows depicts the reference variables, and columns variables between whom and the reference variable the (auto-) correlation is calculated.

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**Figure 20:** (*Auto-*)correlation - Belgium: data sample autocorrelation matrix, and medians and 90 percent coverage percentiles of the distribution of the autocorrelation matrix of the simulated data with measurement errors based on 2000 times simulation conditional on posterior mean. The rows depicts the reference variables, and columns variables between whom and the reference variable the (auto-) correlation is calculated.

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# J Forecast Error Variance Decomposition

	$\eta^a$	$\eta^{a*}$	$\eta^r$	$\eta^{r*}$	$\eta^g$	$\eta^{g*}$	$\eta^m$	$\eta^{m*}$	$\eta^x$	$\eta^{x*}$	$\eta^b$	$\eta^{b*}$
					τ	J.K.						
At 1 year horizon												
$y_t^p$	0.18	0.00	0.00	0.01	0.77	0.00	0.02	0.01	0.00	0.01	0.00	0.00
$\Pi_t$	0.28	0.00	0.01	0.02	0.09	0.09	0.20	0.11	0.01	0.19	0.00	0.00
$E_{r,t}$	0.56	0.01	0.00	0.02	0.31	0.06	0.01	0.01	0.00	0.02	0.00	0.00
$tb_t/y_t$	0.92	0.04	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
At 10 years horizon												
$y_t^p$	0.14	0.01	0.00	0.01	0.81	0.00	0.01	0.00	0.00	0.01	0.00	0.00
$\Pi_t$	0.32	0.00	0.01	0.02	0.09	0.08	0.17	0.11	0.00	0.18	0.01	0.00
$E_{r,t}$	0.44	0.06	0.00	0.02	0.36	0.07	0.02	0.01	0.00	0.02	0.00	0.00
$tb_t/y_t$	0.86	0.08	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.01	0.00	0.00
Unconditional												
$y_t^p$	0.14	0.03	0.00	0.01	0.79	0.00	0.01	0.00	0.00	0.01	0.00	0.00
$\Pi_t$	0.32	0.00	0.01	0.02	0.09	0.08	0.17	0.11	0.00	0.18	0.01	0.00
$E_{r,t}$	0.44	0.07	0.00	0.01	0.35	0.07	0.02	0.01	0.00	0.02	0.00	0.00
$tb_t/y_t$	0.77	0.13	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.01	0.00	0.00

**Table 6:** Forecast error variance decomposition - U.K.: at 1 year / 10 years horizon and unconditional.

 Highlighted are the two shocks with the largest contribution to the forecast error variance.

	$\eta^a$	$\eta^{a*}$	$\eta^r$	$\eta^{r*}$	$\eta^g$	$\eta^{g*}$	$\eta^m$	$\eta^{m*}$	$\eta^x$	$\eta^{x*}$	$\eta^b$	$\eta^{b*}$
					Sw	veden						
At 1 year horizon												
$y_t^p$	0.02	0.01	0.01	0.01	0.85	0.00	0.05	0.03	0.01	0.01	0.00	0.01
$\Pi_t$	0.05	0.02	0.23	0.18	0.03	0.02	0.01	0.07	0.00	0.02	0.29	0.07
$E_{r,t}$	0.01	0.07	0.01	0.07	0.00	0.55	0.10	0.11	0.02	0.03	0.00	0.03
$tb_t/y_t$	0.04	0.05	0.04	0.45	0.00	0.04	0.13	0.10	0.03	0.03	0.00	0.09
At 10 years horizon												
$y_t^p$	0.14	0.05	0.00	0.01	0.72	0.00	0.03	0.02	0.01	0.01	0.00	0.00
$\Pi_t$	0.04	0.08	0.16	0.16	0.03	0.03	0.01	0.07	0.00	0.03	0.31	0.06
$E_{r,t}$	0.05	0.35	0.00	0.04	0.00	0.38	0.06	0.07	0.01	0.02	0.00	0.02
$tb_t/y_t$	0.04	0.12	0.04	0.36	0.01	0.06	0.13	0.10	0.02	0.04	0.00	0.08
Unconditional												
$y_t^p$	0.14	0.11	0.00	0.01	0.67	0.00	0.03	0.02	0.01	0.01	0.00	0.00
$\Pi_t$	0.04	0.09	0.16	0.16	0.03	0.03	0.01	0.07	0.00	0.03	0.31	0.06
$E_{r,t}$	0.06	0.37	0.00	0.04	0.00	0.36	0.06	0.06	0.01	0.02	0.00	0.02
$tb_t/y_t$	0.04	0.13	0.04	0.35	0.01	0.06	0.13	0.10	0.02	0.04	0.00	0.08

**Table 7:** Forecast error variance decomposition - Sweden: at 1 year / 10 years horizon and unconditional. Highlighted are the two shocks with the largest contribution to the forecast error variance.

	$\eta^a$	$\eta^{a*}$	$\eta^r$	$\eta^{r*}$	$\eta^g$	$\eta^{g*}$	$\eta^m$	$\eta^{m*}$	$\eta^x$	$\eta^{x*}$	$\eta^b$	$\eta^{b*}$
Belgium												
At 1 year horizon												
$y_t^p$	0.10	0.02	0.01	0.03	0.57	0.17	0.02	0.01	0.00	0.03	0.00	0.03
$\Pi_t$	0.04	0.16	0.40	0.06	0.01	0.00	0.06	0.01	0.00	0.05	0.15	0.04
$E_{r,t}$	0.00	0.07	0.01	0.11	0.00	0.42	0.06	0.05	0.00	0.17	0.00	0.10
$tb_t/y_t$	0.00	0.39	0.03	0.34	0.00	0.01	0.01	0.01	0.00	0.10	0.00	0.10
At 10 years horizon												
$y_t^p$	0.09	0.11	0.01	0.03	0.42	0.26	0.02	0.01	0.00	0.04	0.00	0.03
$\Pi_t$	0.05	0.24	0.25	0.05	0.01	0.02	0.07	0.01	0.00	0.10	0.15	0.05
$E_{r,t}$	0.00	0.18	0.01	0.06	0.00	0.52	0.04	0.03	0.00	0.11	0.00	0.06
$tb_t/y_t$	0.01	0.47	0.03	0.24	0.00	0.04	0.01	0.01	0.00	0.12	0.00	0.08
Unconditional												
$y_t^p$	0.09	0.13	0.01	0.03	0.34	0.24	0.03	0.02	0.00	0.08	0.00	0.03
$\Pi_t$	0.06	0.23	0.23	0.05	0.02	0.03	0.06	0.01	0.00	0.11	0.14	0.05
$E_{r,t}$	0.00	0.18	0.01	0.06	0.00	0.52	0.04	0.03	0.00	0.11	0.00	0.06
$tb_t/y_t$	0.01	0.47	0.03	0.24	0.00	0.04	0.01	0.01	0.00	0.12	0.00	0.08

**Table 8:** Forecast error variance decomposition - Belgium: at 1 year / 10 years horizon and<br/>unconditional.Highlighted are the two shocks with the largest contribution to the forecast error<br/>variance.

# **K** Bayesian Impulse Responses



Figure 21: Bayesian IRF - U.K.

Notes: The graphic depicts the Bayesian impulse responses to *negative* shocks.  $y_t^p$ ,  $\Pi_t$  and  $E_{r,t}$  are shown as (relative) percentage deviation (in percentage points) from steady state.  $tb_t/y_t$  is depicted as absolute deviation (in percentage point) from steady state.





Notes: The graphic depicts the Bayesian impulse responses to *negative* shocks.  $y_t^p$ ,  $\Pi_t$  and  $E_{r,t}$  are shown as (relative) percentage deviation (in percentage points) from steady state.  $tb_t/y_t$  is depicted as absolute deviation (in percentage point) from steady state.

#### Figure 23: Bayesian IRF -Belgium



Notes: The graphic depicts the Bayesian impulse responses to *negative* shocks.  $y_t^p$ ,  $\Pi_t$  and  $E_{r,t}$  are shown as (relative) percentage deviation (in percentage points) from steady state.  $tb_t/y_t$  is depicted as absolute deviation (in percentage point) from steady state.

# L Baseline and counterfactual Impulse Responses - Sweden and Belgium



Figure 24: IRF baseline and counterfactual - Sweden

Notes: The graphic depicts the impulse responses to *negative* shocks with sizes equal to one standard deviation.  $y_t^p$ ,  $\Pi_t$  and  $E_{r,t}$  are shown as (relative) percentage deviation (in percentage points) from steady state.  $tb_t/y_t$  is depicted as absolute deviation (in percentage point) from steady state.



Figure 25: IRF baseline and counterfactual - Beglium

Notes: The graphic depicts the impulse responses to *negative* shocks with sizes equal to one standard deviation.  $y_t^p$ ,  $\Pi_t$  and  $E_{r,t}$  are shown as (relative) percentage deviation (in percentage points) from steady state.  $tb_t/y_t$  is depicted as absolute deviation (in percentage point) from steady state.

# M Counterfactual analysis

		Rigid prices	and no migration	and fixed exchange rate						
United Kingdom										
, p	Por conito output	11 6500	11 7694	12 4402						
$y_t$	rer capita output	11.6300	(1.02%)	12.4495 (6.86%)						
П	Inflation	1 9131	1 9243	1 6310						
11	muton	1.9101	(0.59%)	(-14.74%)						
Er t	REER	1.6677	1.6598	1.6936						
.,.			(-0.48%)	(1.55%)						
$tb_t/y_t$	Trade balance/GDP	0.9644	0.8532	0.9595						
			(-11.54%)	(-0.51%)						
Sweden										
n										
$y_t^p$	Per capita output	7.1330	7.1553	7.6008						
п	T	0.0717	(0.31%)	(6.56%)						
$11_t$	milation	2.3/1/	(0.22%)	(7.45%)						
F.,	REER	2 6252	2 6451	2 6559						
Lr,t	KLEK	2.0252	(0.76%)	(1 17%)						
tb+/v+	Trade balance/GDP	1.5213	1.3668	1.5348						
			(-10.15%)	(0.89%)						
Belgium	!									
$y_t^p$	Per capita output	3.7478	3.6862	3.4521						
			(-1.64%)	(-7.89%)						
$\Pi_t$	Inflation	2.8167	2.8875	3.0500						
	DEED	4 04 54	(2.52%)	(8.28%)						
$E_{r,t}$	KEEK	4.2151	4.3653	4.0641						
11. /		2 2700	(3.56%)	(-3.58%)						
$t v_t / y_t$	Irade balance/GDP	3.2790	2.9067	3.2388						
			(-11.35%)	(-1.23%)						

#### Table 9: Counterfactual volatilities conditional on rigid prices

Notes: Percentage change in counterfactual S.D. relative to rigid price S.D. in parenthesis.

### N Current account to GDP-ratio peaks

Figure 26: GDP PER CAPITA AND EXTERNAL BALANCE DURING MAJOR ADJUSTMENT PERIODS RELATIVE TO NON-ADJUSTMENT PERIODS



Notes: Black solid – Gold Standard. Grey dashed – Eurozone. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one CA/GPD trough to the next. CA/GPD troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GPD troughs are the lowest CA/GDP-value in a  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 9 CA/GPD troughs. EZ: 7 CA/GPD trough.





Notes: Black solid – Gold Standard. Grey dashed – Eurozone. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one CA/GPD trough to the next. CA/GPD troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GPD troughs are the lowest CA/GDP-value in a  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 9 CA/GPD troughs. EZ: 7 CA/GPD trough.



Figure 28: MIGRATION AFTER MAJOR CA/GDP REVERSALS RELATIVE TO NON-REVERSALS



Notes: Agr – agricultural. Raw – raw material. Ind – industrial. LS – labor share. VA – value added share. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one CA/GPD trough to the next. CA/GPD troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GPD troughs are the lowest CA/GDP-value in a  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 9 CA/GPD troughs. EZ: 7 CA/GPD trough.



Figure 29: MONETARY POLICY AFTER MAJOR CA/GDP REVERSALS RELATIVE TO NON-REVERSALS

Notes: Black solid – Gold Standard. Grey dashed – Eurozone. Shaded areas – 90% confidence bands. Major adjustment periods are defined as the periods lasting from one CA/GPD trough to the next. CA/GPD troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GPD troughs are the lowest CA/GDP-value in a  $\pm$ 10-year window. For the EZ a  $\pm$ 8-year window was chosen and border conditions were weakened because of the shorter sample length. GS: 9 CA/GPD troughs. EZ: 7 CA/GPD trough.

# Figure 30: Price level and trade balance after major CA/GDP reversals relative to NON-REVERSALS



Notes: Major adjustment periods are defined as the periods lasting from one CA/GPD trough to the next. CA/GPD troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GPD troughs are the lowest CA/GDP-value in a  $\pm 10$ -year window. GS: 9 CA/GPD troughs.

Figure 31: DISAGGREGATED EXPORTS AND SECTORAL COMPOSITION AFTER MAJOR CA/GDP REVERSALS RELATIVE TO NON-REVERSALS



Notes: Agr – agricultural. Raw – raw material. Ind – industrial. LS – labor share. VA – value added share. Major adjustment periods are defined as the periods lasting from one CA/GPD trough to the next. CA/GPD troughs are defined according to a turning-point algorithm à la Bry and Boschan (1971): CA/GPD troughs are the lowest CA/GDP-value in a  $\pm$ 10-year window. GS: 9 CA/GPD troughs.