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

Yao Chen[*] Felix Ward[*]

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Abstract

Current account reversals under the Gold Standard – a fixed exchange rate regime – were associated with few, if any, output costs. To understand why, we built and estimated an open economy model of the Gold Standard (1880-1913), which allows us to quantitatively assess the relative importance of three prominent channels of external adjustment: flexible prices, international migration, and monetary policy. Our first finding is that the output resilience of Gold Standard members that underwent external adjustment was primarily a consequence of flexible prices. Neither restrictions on migration, nor the elimination of countercyclical monetary policy would have given rise to substantially higher output-volatility. Our second finding is that price flexibility was predicated on a historical contingency: namely large primary sectors, whose flexibly priced products dominated the export booms that stabilized output during major external adjustments.

Keywords: External adjustment; Migration; Target Zone; Price Rigidity; DSGE; Bayesian estimation; Real effective exchange rate.
JEL Codes: N1, F2, E5.

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[*] Department of Macroeconomics and Econometrics, University of Bonn; (chen.yao@uni-bonn.de); (felix.ward@uni-bonn.de). The authors wish to thank, without implicating, Olivier Accominotti, Hakon Albers, Thilo Albers, Christian Bayer, Benjamin Born, Luis A. V. Catão, Alfredo Gigliobianco, David S. Jacks, Philip Jung, Keith Kuester, Dmitry Kuvshinov, Christopher M. Meissner, Matthias Morys, Gernot Müller, Moritz Schularick, Solomos N. Solomou, Ryland Thomas, Mathias Trabandt, Christoph Trebesch and Martin Wolf. We further acknowledge the financial support of the German Research Foundation (DFG) and the Federal Ministry of Education and Research (BMBF). This manuscript also benefited from helpful comments by participants of the fifth CEPR Economic History Symposium, the LMU Seminar for Macroeconomics, the EEA- and VfS-conferences, as well as two anonymous referees and an editor. All remaining errors are the sole responsibility of the authors.

1. Introduction

The pre-1914 Gold Standard was a global fixed exchange rate regime of colossal extent: By 1913 economies responsible for 67% of world GDP and 70% of world trade had relinquished flexible exchange rates as a means to unwind external imbalances. Yet external adjustments were associated with few, if any, output costs (see Meissner and Taylor, 2006; Adalet and Eichengreen, 2007). How did the Gold Standard (GS) equilibrate so smoothly despite inflexible exchange rates? There exist various competing, though not mutually exclusive explanations. First, prices were relatively flexible, allowing for a faster absorption of shocks (Backus and Kehoe, 1992; Basu and Taylor, 1999; Chernyshoff, Jacks and Taylor, 2009). Second, cyclical international migration helped to turn around the current account and took the pressure off of wages in depressed regions (e.g. Hatton, 1995; Khoudour-Castéras, 2005). Finally, central banks could smooth out temporary disturbances by running down their reserves (see Bazot, Bordo and Monnet, 2014; Eichengreen and Flandreau, 2014) or by making use of the considerable monetary policy independence that the Gold Standard, as a target zone regime, afforded in the short run (Krugman, 1991; Svensson, 1994; Bordo and MacDonald, 2005). The purpose of this paper is to provide a quantitative assessment of the relative importance of each of these channels. Can we determine which one reduced output volatility the most? Were they equally important – or were they most effective in combination?

In order to quantitatively assess the relative importance of flexible prices, international migration and monetary policy we built the first open-economy model of the Gold Standard that features international migration, various degrees of price flexibility and an elaborate monetary structure. We estimated the model with Bayesian methods and then studied the estimated model's behavior through counterfactual simulations: How would output volatility have looked had prices been less flexible? What if there had been no release through migration? How important was countercyclical monetary policy? The first main finding of this paper is that price flexibility was paramount for the benign adjustment experience under the Gold Standard. Neither restrictions on migration, nor the elimination of countercyclical monetary policy would have given rise to substantially higher output-volatility.

The second main finding of this paper is that price flexibility and benign external adjustment was predicated on production and trade concentrating in the primary sector: Agricultural products generally exhibit significantly more flexible prices than industrial or service goods. Prior to 1913 agricultural products still made up the majority of all merchandise exports, even among early industrializers. This fortunate coincidence of the nominally most flexible sector also being the most important tradable sector is the main explanation for the ease of external adjustment under the pre-1913 Gold Standard. On the basis of newly collected disaggregate export, price and production data we show that Gold Standard economies experienced a pronounced shift in sectoral structure in the face of a current account reversal. That is a shift, away from the production of non-tradables (primarily services) towards the production of tradable agricultural goods. This sectoral shift was brought about by quickly falling agricultural prices that directly translated into a boom in agricultural exports.

A study of external adjustment under the Gold Standard is particularly interesting in light of the often painful adjustment experiences in fixed exchange rate regimes today. Figure 1, for example, contrasts external adjustment under the Gold Standard with that in the euro area:[1] Under the Gold Standard as well as in the euro area the current account-to-GDP (CA/GDP) ratio on average decreased by about 5 percentage points in the 10 years prior to reversing sharply. However, while reversals were associated with

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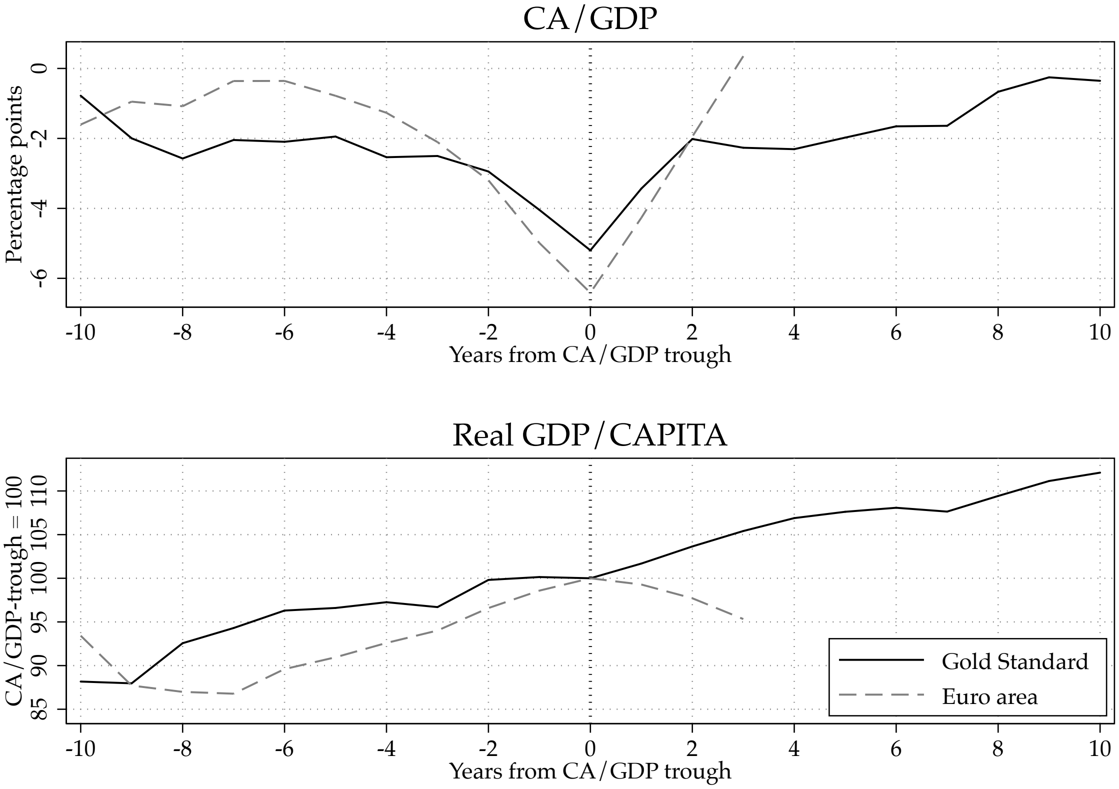
[1] CA/GDP troughs are defined according to a turning-point algorithm (see Bry and Boschan, 1971). CA/GDP-troughs are defined as the lowest CA/GDP-value in a ±10-year window. For the EZ a ±8-year window was chosen and border conditions were weakened because of the shorter sample length.

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



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

major recessions in the euro area, under the Gold Standard output continued to grow on trend. The Gold Standard thus also provides an auspicious historical contrast to more recent external adjustments where exchange rates are fixed. Additionally, the pre-1913 Gold Standard lasted longer than most international fixed exchange rate regimes and thus provides a unique opportunity to analyze external adjustment under fixed exchange rates for an unaltered set of countries over more than three decades.

The paper is structured as follows: The following section introduces the data. After that, Section 3 gives an empirical outline of the behavior of prices, migration and monetary policy during major external adjustment episodes under the Gold Standard. Here we show that: (i) a strong price-decline in regions facing a current account-reversal quickly increased their price-competitiveness, (ii) migration flows redistributed labor supply from deficit regions to surplus regions, and (iii) central banks made use of the short-run independence they enjoyed under the Gold Standard. Sections 4 and 5 presents the Gold Standard-model and its estimation. The relative importance of prices, migration and monetary policy are then analyzed on the basis of counterfactual model simulations in Section 6. Section 7 substantiates our findings from the model simulations with evidence from disaggregate price- and export data that suggests large primary sector shares and the dominance of primary products in international trade played a crucial role for external adjustment under the Gold Standard. Section 8 then concludes our analysis.

2. Data

The empirical foundation of our analysis is a new annual dataset for 14 countries that were members of the Gold Standard throughout the 1880-1913 period, namely Australia, Belgium, Canada, Denmark, Finland, France, Germany, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the U.K. and the U.S (`http://dx.doi.org/10.17632/wch3rbkxp7.2`). By focusing on a sample of 14 Gold Standard members whose commitment to gold was never seriously questioned in the period under consideration we exclude the topic of peg-credibility from our analysis. This allows us to squarely focus on the issue of external adjustment under inflexible exchange rates.

In many cases we were able to draw extensively from previous historical data collections by economic historians. In other cases new data had to be compiled from the historical publications of contemporary statistical offices, central banks and trade agencies. Particular effort went into the construction of a novel set of effective exchange rates, gold cover ratios and sectoral export- and price level data. The construction of these series is described in more detail in the following section.

All in all, our dataset covers the following annual time series: nominal GDP, real per capita GDP, consumer prices, the current account, imports and exports, the nominal exchange rate, immigration and emigration, population, discount rates, note circulation, nominal and real effective exchange rates, gold cover ratios, sectoral production shares, sectoral exports, sectoral price level data, terms of trade, and export prices. A detailed listing of all the sources is provided in Online Appendix I.1. Further data descriptions, as well as reliability and validation checks for the sectoral data and migration series can be found in Appendices I.2, I.3 and I.4.

2.1. Effective exchange rates

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

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

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

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

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

and Meissner (2008) and Mitchell (2013) as trade weights.[4] Trade weights $w_{i,j,t}$ equal the ratio of total bilateral trade to GDP, $(imports_{i,j,t} + exports_{i,j,t})/GDP_{i,t}$. In accordance with modern-day REER estimates, as provided for example by the ECB, we updated the bilateral trade-weights every three years. Note that we exclusively consider GS-member economies for the REER calculation. We do this in order to focus on competitiveness within the GS.[5] Along the same lines we constructed nominal effective exchange rates (NEER) and foreign effective consumer price indices as trade-weighted geometric averages. The final REER series are displayed in Figure I.3 in Online Appendix I.5.

2.2. *Gold cover ratios*

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

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

[5] This differentiates our REER series from those introduced by Catão and Solomou (2005), whose REER series are affected by fluctuations in the nominal exchange rate with respect to non-Gold Standard members. For our 14 country sample of long-term Gold Standard adherents an average of 75% of imports came from other countries in the sample and an average of 84% of exports went to other countries in the sample. Although there is some variation across countries and time in these within-GS trade shares, even the minimum intra-GS import share of 53% and the minimum intra-GS export share of 66% are sizeable.

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

exchange reserves to the numerator and central bank deposits to the denominator. This allowed us to select the cover ratio that comes closest to the legally defined one for each country. For example since 1877 the numerator of the cover ratio targeted by the National Bank of Belgium included foreign exchange reserves. Thus in our model estimation for Belgium we used the broad cover ratio series. The narrow and broad cover ratio series are displayed in Figures I.4 and I.5 in Online Appendix I.6.

2.3. *Sectoral shares, prices and exports*

In order to see which sector drove external adjustment during the GS we collected disaggregated price- and export data, as well as primary sector shares. The export data are disaggregated into agricultural-, raw material- and industrial exports. The sectoral price data features the same three categories as well as service prices. While some sources provide data at this level of aggregation, in many cases we had to aggregate up from more readily available product-level data. The sectoral data are described in more detail in Online Appendices I.2 and I.4. The sectoral value-added share data come from Buera and Kaboski (2012).

3. Stylized facts

In order to get a first impression of how prices, migration and monetary policy behaved during major external adjustments under the Gold Standard (GS) this section introduces a set of stylized facts. To this end we identify troughs in the current account to GDP ratio (CA/GDP) through a Bry and Boschan (1971)-style algorithm: CA/GDP-troughs are defined as the lowest CA/GDP-value in a ±10-year window. For the period between 1880-1913 we thus identify 9 CA/GDP troughs (see Figure II.1 in Online Appendix I.8).[7]

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[7] As a robustness check we have also considered an alternative set of CA/GDP-troughs. In particular we extended the selection to include any visually salient trough in the

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

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

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

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

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

where α_i are country-fixed effects and $u_{i,t}$ is an error term. The $\{\beta_h\}_{h=1,...,H}$ in expression 2 allow us to sketch out the average behavior of macroeconomic aggregates over the H years following a major CA/GDP-trough. This will provide us with a set of stylized facts on how GS-member economies typically behaved during major adjustment phases in contrast to their behavior during "normal" times.[8]

The first row of Figure 2 shows that the typical adjustment during the GS featured a sharp increase in exports that led to a quick turn-around in the current account. Lower import levels also temporarily contribute to the reversal. In general, however, external

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CA/GDP-ratio that was followed by a prolonged period of increasing CA/GDP-ratios. Results are generally robust to this alternative selection (see Online Appendix II.2).

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

adjustments under the GS were export-driven. How did prices, migration and monetary policy behave during these episodes? The second row in Figure 2 shows that domestic prices fell strongly and swiftly during adjustment phases. The brunt of the adjustment is furthermore born by domestic prices, with foreign prices remaining stable. As a consequence, the fall in domestic prices translates almost one-to-one to a gain in relative price competitiveness of around 6%.

How about migration? The third row of Figure 2 shows that about 5 years into the adjustment, the average GS economy's population was about 0.5% smaller due to the reduction in immigration and an increase in emigration.[9] This indicates that in the typical external adjustment under the GS migration played only a minor, albeit systematic role. However, for some economies migration flows could be more sizeable. Consider the case of Sweden in the 1880s, which for the best part of the decade lost close to 1% of its population per year. Assuming that at the end of such a decade the population level is only 5% lower than what it would have been without migration, a back-of-the-envelope calculation places the direct CA/GDP effect, stemming from emigrants lowering origin-country imports, in the +1 to +2 ppt range.[10] This constitutes a considerable contribution to external adjustment.

The same 5% population decline furthermore increases origin-country wages, and thus stabilizes incomes. For a Cobb-Douglas production function, that is parametrized to a labor share of income of around 66%, a 5% decrease in the labor supply thus implies a

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

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

non-negligible wage increase in the range of 1-2%.[11] Thus for Sweden, migration might have been more central to external adjustment than for other countries at the time.

Note, however, that the effect of migration on output is not unambiguously stabilizing. Destabilizing effects arise in the short-run when recessionary origin economies lose internal demand to already expanding host economies (see Farhi and Werning, forthcoming). When this channel is taken into account migration is less likely to have a stabilizing influence, because it now exerts opposing forces that can cancel each other out.[12]

Turning to the monetary side of external adjustment under the Gold Standard, the last row in Figure 2 displays the behavior of the central bank discount rate, gold cover ratio and the nominal effective exchange rate. In general, monetary policy turned accommodative during major external adjustments. Central bankers used their freedom to conduct independent discount rate policy within the target zone and, on average, lowered discount rates by 100 basis points. Some central banks made more extensive use of their freedom than others. To get an idea of how much discount rate independence a ±1% target zone regime allowed for, consider that a 1% depreciation of the exchange rate - that is expected to disappear within one quarter - allows a central bank to temporarily set its policy rate 4 ppts below world levels.[13] This can explain how in some years the discount rates set by several Scandinavian central banks deviated by up to 3 percentage

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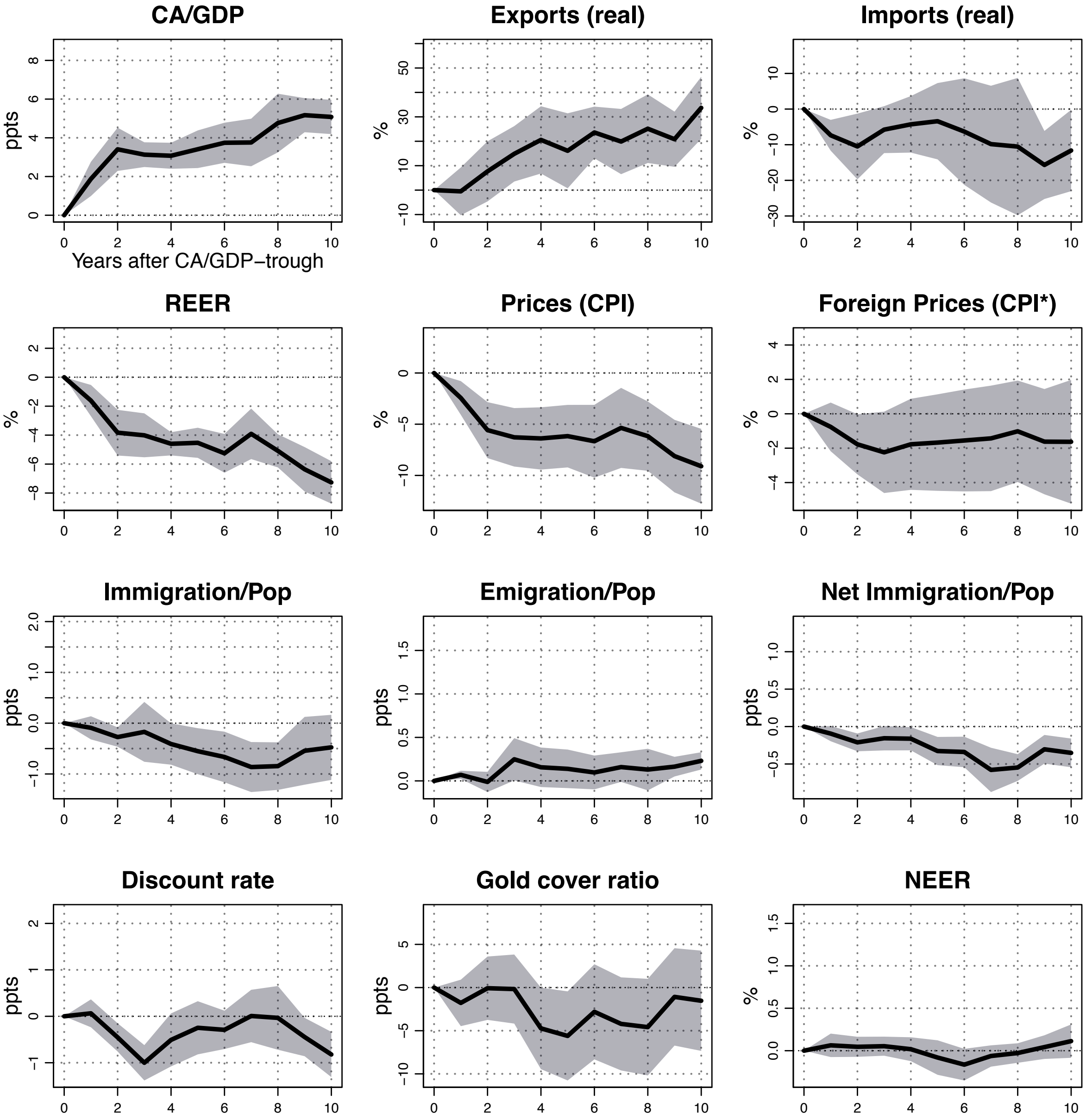
[11] Note that such wage effects will slightly dampen the direct CA/GDP effect of migration.

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

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

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



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

points from those set by the Bank of England.[14] In the short-run the GS left central bankers with considerable flexibility for setting their discount rates with a "concern for home trade" (Sayers (1976) vol I, p.44, Bordo and MacDonald (2005)). Beyond the limited monetary policy independence they enjoyed within the target zone, central bankers were furthermore willing to round the corners of the policy trilemma through active intervention in foreign exchange markets or through the passive accommodation of gold outflows. Figure 2 shows that during major external adjustments such policies resulted in a 5 ppt drop in gold cover ratios. The National Bank of Belgium and the Banque de France were particularly willing to let their gold cover ratios fluctuate in order to insulate the domestic economy from movements in world interest rates (Eichengreen and Flandreau, 2014; Bazot, Bordo and Monnet, 2014). Thus, the pre-1913 GS was in possession of several safety valves on the monetary side that could ease external adjustment.[15]

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

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

[15] The outlined relationship of prices, migration, and monetary policy with movements in the CA/GDP ratio is a robust characteristic of the GS data. It also shows up in within year correlations (see Table II.1 in Online Appendix II.1), as well as an alternative definition of CA/GDP troughs (see Figure II.2 in Online Appendix II.2).

4. A model of the Gold Standard

To quantitatively analyze the relative importance of prices, migration and monetary policy for the ease of external adjustment under the Gold Standard we need to be able to disentangle their individual impact. To this end, we introduce a two-region open economy model that features international migration flows, various degrees of price flexibility and a GS-specific monetary structure.[16]

In the following section, we will first shortly outline the model and thereby focus mainly on decision problems in one of the two regions – the H-region. The economy in the F-region is symmetric and we provide a more detailed description of the complete equation system that characterizes its state of equilibrium in Appendix A.1.

4.1. Households

There is a continuum of households $i \in [0, 1]$, with households $[0, n_t)$ living in H and $[n_t, 1]$ in F. Household i's period utility follows the Greenwood, Hercowitz and Huffman (1988) (GHH) form. The household maximizes its life time utility[17]

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

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[16] The 2-region model abstracts from those countries that were not part of the Gold Standard. As a robustness check we therefore also estimated a version of the model in which we treat one of the regions as a hybrid that includes all other gold, as well as non-gold countries. The presented results are robust to this alteration (see Online Appendix III.7.1).

[17] 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.

where β is the discount factor, l_t is hours worked and c_t is consumption, which is made up of H- and F-produced goods: $c_t = \left[(1-\alpha)^{\frac{1}{\epsilon}} c_{H,t}^{\frac{\epsilon-1}{\epsilon}} + \alpha^{\frac{1}{\epsilon}} c_{F,t}^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}$. The elasticity of substitution between these goods is ϵ and the openness parameter α reflects a home-bias in taste as well as trade frictions. The H and F goods themselves are CES bundles of differentiated goods that are produced by the n home- and $1-n$ foreign firms: $c_{H,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\mu}} \int_0^n c_{H,t}(j)^{\frac{\mu-1}{\mu}} \, \mathrm{d}\, j\right)^{\frac{\mu}{\mu-1}}$ and $c_{F,t} = \left(\left(\frac{1}{1-n}\right)^{\frac{1}{\mu}} \int_n^1 c_{F,t}(j)^{\frac{\mu-1}{\mu}} \, \mathrm{d}\, j\right)^{\frac{\mu}{\mu-1}}$, where j is the firm index and μ is the elasticity of substitution between goods produced in the same region. The price indices for the H- and F-produced goods bundles are $P_{H,t} = \left[\frac{1}{n} \int_0^n P_{H,t}(j)^{1-\mu} \, \mathrm{d}\, j\right]^{\frac{1}{1-\mu}}$ and $P_{F,t} = \left[\frac{1}{1-n} \int_n^1 P_{F,t}(j)^{1-\mu} \, \mathrm{d}\, j\right]^{\frac{1}{1-\mu}}$. The H consumer price index is then given by $P_t = \left[(1-\alpha)P_{H,t}^{1-\epsilon} + \alpha P_{F,t}^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$. We assume that the law of one price applies at the individual goods level so that $P_{F,t}(j)\, e_t = P_{F,t}^{*}(j)$, where F-variables are marked by an asterisk and e_t denotes the nominal exchange rate (domestic per foreign currency).[18] Note, however, that due to the existence of home bias in consumption LOP does not imply purchasing power parity (PPP).[19]

The households' budget constraint is

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

where F-variables are marked by an asterisk. $P_t w_t$ is the nominal wage households

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[18] While the law of one price (LOP) assumption is an exaggeration (see Persson, 2004), price differentials were generally declining over the 19th century, so that by the end of the century they had become a fraction of what they used to be at its beginning (see Klovland, 2005; Jacks, 2005).

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

receive for supplying their labor to local firms on competitive labor markets. Γ_t are local firms' nominal lump-sum dividends that are payed out to local households. $B^i_{H,t}$ and $B^i_{F,t}$ are household i's holdings of two internationally traded one-period risk-free bonds, denominated in H- and F currency respectively. R^e_t is the effective return, which is determined by the risk-free rate R_t and a risk premium shock ϵ^b_t as $R^e_t = R_t/\exp(\epsilon^b_t)$. The adjustment of foreign real asset holdings is subject to a quadratic adjustment cost, which is the last term of the budget constraint equation.[20] When households in F adjust their portfolio holding of H bonds, the associated cost is transferred to H households in a lump-sum fashion: $TR_t = \frac{n^*_t}{n_t}\frac{P^*_t}{e_t}\frac{K^*}{2}\left(\frac{B^i{}_{H,t}e_t}{P^*_t} - \bar{o}^*\right)^2$. Portfolio adjustment costs and risk premium shocks allow for deviations from strict uncovered interest parity (UIP). Because of migrations, the model has four different household types - denoted by τ: H- and F-households that either stay or migrate $\tau \in \{H \rightarrow H, H \rightarrow F, F \rightarrow H, F \rightarrow F\}$, where $\rightarrow$ shows the direction of migration. The type-specific and possibly negative payment I^τ_t ensures that nominal asset holdings after migration are equalized across households within the region.

4.1.1 Endogenous migration

In our model households are free to migrate back and forth between the H and F regions.[21] At the beginning of each period, exogenous shocks realize and households choose whether to migrate ($\delta^i_t = 1$) or to stay ($\delta^i_t = 0$). The decision to migrate is based on

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[20] We assume the same functional form as Benigno (2009). The adjustment cost also pins down the steady state gross foreign asset position. The model's steady state for net foreign assets is determined even without the adjustment costs due to migration (see Appendix A.2).

[21] Kennan and Walker (2011) also develop an econometric and dynamic model of migration that features optimal location decisions over many alternative locations. They model individual decisions to migrate as a job search problem and focus on the partial equilibrium response of labor supply to wage differentials.

comparing the lifetime utilities of continuing to live in H (V_t^i) to that of moving to F. The utility of moving to F includes the utility of living there ($V_t^{i^*}$) minus the costs of moving. There exist two short-term costs of moving: One is a time-invariant, region specific migration cost κ_d, which reflects the various hindrances migrants have to overcome (e.g. travel costs). The other is a stochastic utility shock v_t^i that captures the cross-population idiosyncrasy and cross-time variation in a household's preference for leaving its current location.[22] The household i's migration decision is

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

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

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

After migrations have taken place, the type-specific transfers I_t^τ ensure that nominal asset holdings at the beginning of the period are the same across households within a region. They thus can be treated as identical and we drop the household index i.[23] As a consequence the population fraction that emigrates, $\widetilde{d}_t$, equals the emigration probability,

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[22] This ensures that not all households migrate at the same time.

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

d_t.[24] The aggregate population in H, therefore, evolves according to[25]

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

4.2. *Firms*

The model's production side consists of a continuum of monopolistic competitive firms $j \in [0,1]$ that maximize expected discounted profits. The n home firms and $1-n$ foreign firms produce with labor from H and F households respectively. The production technology is $y_t(j) = \exp(A_t) L_t(j)^\gamma$, where $y_t(j)$ is output, $L_t(j)$ is labor and A_t is the exogenous region-specific productivity level. γ parameterizes the curvature of the production function with respect to labor and thus determines the de- and reflationary effects of migration on wages in receiving and sending regions. As in Calvo (1983), firms face a nominal rigidity, where in each period only a random fraction $(1-\theta)$ of firms can reset their prices.[26] θ, together with γ and μ determine the slope of the Phillips curve according to $\widetilde{\kappa} = \frac{(1-\beta\theta)(1-\theta)}{\theta(1-\mu+\mu/\gamma)}$.[27]

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

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

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

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

4.3. Equilibrium

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

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

4.4. Monetary policy and gold flows

Different strands of the literature have characterized monetary policy under the classical GS as either a money-quantity rule or a discount rate rule. According to the money-quantity view central banks were supposed to expand and contract the money supply in proportion to gold in- and outflows, such as to keep the ratio of gold-to-money - the gold cover ratio - stable. Another part of the literature, however, focuses on the importance of central bank discount rates in stabilizing the exchange rate. Here we model monetary policy as a discount rate rule that targets the gold cover ratio γ_t. This formulation integrates the money quantity view and the discount rate view in that discount rate policy R_t contributes to a stable money-to-gold ratio in the long-run. At the same time in the short-run, within the target zone, the central bank is free to let the gold cover ratio fluctuate in order to stabilize the domestic output gap.

In contrast to strict money-quantity rules, this depiction of monetary policy under the GS is in line with the observed fluctuation in gold cover ratios (see Online Appendix I.6). Finally, we also allow central banks to directly target the nominal exchange rate e_t in order to accommodate the heterogeneity of discount rate policies that could be observed under the GS.[28] The discount rate rule is

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

where we allow for persistence in the discount rate, and Φ_y, Φ_γ and Φ_e denote the sensitivity of the discount rate reaction with respect to the output gap, the gold cover ratio and the exchange rate.[29]

Adherence to this discount rate rule implies deviations from a strict money-quantity rule. Money M_t varies with money demand according to a money demand function as in much of the earlier GS literature.[30] Money demand is assumed to be a fraction of the

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[28] 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.

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

[30] 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 foregoing of interest revenues.

nominal value of total production $n\,P_{H,t}\,y_t$ and depends on the discount rate R_t:

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

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

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

where gold moves between H and F according to deviations of the nominal exchange rate from the ratio of the two currencies' underlying gold parities – i.e. their mint ratio (Officer, 1985; Giovannini, 1993; Canjels, Prakash-Canjels and Taylor, 2004; Coleman, 2007). When H and F central banks commit to convert local currency into gold at a fixed parity, deviations of the nominal exchange rate from the mint parity makes shipping gold between regions profitable. ϵ^m_t indicates an exogenous gold shock.[31] Given money M_t and gold G_t the gold cover ratio γ_t is determined by the relation

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

where P_g is the legal gold parity.

Finally, note that in this setup the long-run credibility and sustainability of the peg is

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

never doubted. This allows us to focus on external adjustment when exchange rates are inflexible.

5. Bayesian Estimation

We loglinearize the model around its non-stochastic steady state (see Appendix A.3) and estimate it with Bayesian techniques for the U.K., Sweden and Belgium.[32] For each estimation, we chose the country in focus – the U.K., Sweden or Belgium – to be the *H* region, while all other GS members were aggregated into the *F* region.

We selected Sweden and Belgium with an eye on obtaining upper bound estimates for the effectiveness of the migration- and monetary policy-channels respectively. In the late 19th century, Sweden was one of the countries with the highest emigration rate, losing between 0.3% and 1.1% of its population per year through emigration. Previous research has already pointed out that Swedish net immigration followed a pronounced countercyclical pattern that might have aided external adjustment (see Khoudour-Castéras, 2005): Whenever the domestic economy went badly a sizeable fraction of the Swedish population headed for the New World, particularly the U.S.[33] For these reasons we expect Sweden to give us an upper bound estimate of how effective cyclical migration could be in easing external adjustment under the GS.

We select Belgium, because the National Bank of Belgium was renown for its willingness to let its gold cover ratio fluctuate in order to insulate the domestic economy from

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[32] The large number of parameters and the relative shortness of macroeconomic time series usually renders maximum likelihood estimation of medium-scale DSGE models infeasible.

[33] At that time, only Norway had a comparably high emigration rate with a similarly countercyclical pattern. Counterfactual simulation results for Norway are reported in Online Appendix III.7.3. The results are in line with the conclusions drawn on the basis of the other three countries' estimation results.

movements in world interest rates (Ugolini, 2012; Eichengreen and Flandreau, 2014). In fact, by the late 19th century Belgium was considered the prime example in this regard, due to the scale and scope of its foreign exchange market interventions (see Conant, 1910). The success of its policies in achieving a non-negligible degree of monetary autonomy within the GS did not escape international notice and even led to calls for emulation (see Palgrave, 1903; Schiltz, 2006). We thus expect that Belgium provides us with an upper bound estimate for the effectiveness of the monetary policy channel under the GS.[34]

Finally, we also estimate the model for the U.K. The U.K. was one of the earliest countries to abandon silver and switch to a purely gold-based monetary system already in the 18th century. As the first industrializer and subsequently the world's pre-eminent free-trader it motivated many trading partners to follow suit. The U.K. was in many ways the centerpiece of the Gold Standard (GS) – home to the world's largest financial center and hosting the most influential central bank of its time.

5.1. Observables

We estimate each model on the basis of 11 observables: domestic and foreign time series of per capita GDP; central bank discount rates and CPI-inflation; domestic time series for the ratio of net immigration to population[35]; the trade balance to GDP ratio; changes in the central bank notes in circulation; the gold cover ratio and the nominal effective exchange rate (NEER). The foreign time series are constructed as trade-weighted

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[34] The Banque de France is another central bank that pioneered an activist approach to reserve and portfolio management. Counterfactual simulation results for France are reported in Online Appendix III.7.4. These results lead to conclusions very similar to those we draw from the Belgian case.

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

geometric averages, analogously to the previously discussed REER series (see Section 3). The ratio of net immigration to population and the trade balance to GDP ratio are directly detrended by a one-sided HP-filter ($\lambda = 100$). All other variables are first logged before being detrended by the same one-sided HP-filter.

5.2. *Calibration*

Table 1: *Calibrated parameters*

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

Notes: GFA gross foreign assets. SST steady state.

Some parameters are calibrated, either because they are difficult to estimate (e.g. markups) or because their identification from observables is straightforward (e.g. discount factors) (see Table 1). We follow standard calibration strategies for the time discount factor β, the within-country intra-temporal elasticity of substitution μ, the curvature of the production function γ, the trade-openness parameters α and α^*, and the steady state gross foreign asset position $\bar{o}$. The time discount factor β is set to 0.9615, in order to match a sample average discount rate of 4%. The elasticity of substitution between the goods within a country μ is set to 11, implying a steady state price markup of 10%.[36] Given μ, we calibrate γ to target a steady state *labor income* to *GDP* ratio of 0.66 for the U.K. and 0.72 for all other countries (Sweden, Belgium and the F-regions).[37] The first value reflects the average labor share in the U.K. from 1880-1913 and the later is an approximation based on the average labor share in France and Germany during the same time period.[38] The trade openness parameters α and α^* are calibrated to target the historical average *import* to *GDP*-ratios (U.K.: 30%, Sweden: 25%, Belgium: 47%) and *export* to *GDP* ratios (U.K.: 29%, Sweden: 24%, Belgium: 37%) of the H region. The U.K.'s gross foreign asset holdings $\bar{o}$ are set to target a steady state *gross foreign asset* to *GDP* ratio of 1.33, which is consistent with the gross foreign asset estimates provided by Piketty and Zucman (2014) and Obstfeld and Taylor (2004).[39] Calibrating steady state gross foreign asset (GFA) positions for Sweden and Belgium is less straightforward due to the lack of historical data. We assume that in the steady state the F-region holds few Swedish or Belgian assets relative to its GDP, $GFA/GDP = 0.001$. Together with the steady state net foreign asset position, this pins down the steady state gross foreign asset holdings of Sweden and Belgium.[40]

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

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[36] This value is consistent with Jacks, Meissner and Novy (2010), who use an elasticity of substitution parameter of 11. A value of 11 implies a markup of 10% which nicely corresponds to the late 19th century markup estimate of 9.8% by Irwin (2003).

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

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

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

[40] The model's steady state for net foreign assets is determined due to migration (see Appendix A.2).

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

5.3. *Prior distribution*

The prior distribution is selected according to the *endogenous prior* method introduced by Christiano, Trabandt and Walentin (2011), who use observables' moments to adjust an initial prior choice. The endogenous prior approach is particularly attractive for our analysis because prior information on the model parameters for the GS era is relatively scarce. In particular, we use the second moments of the observables to form the endogenous prior. This helps to improve the model's fit of the observables' variances.[41]

The prior distributions for the estimated parameters are summarized in Table 2. We assume that the inverse elasticity of intertemporal substitution σ_c and the inverse Frisch elasticity σ_l are identical across regions. Their prior distribution follows the literature standard (e.g. De Walque and Wouters (2005) and Smets and Wouters (2007)). For the trade elasticities ϵ and ϵ^* we choose a comparatively wide prior, reflecting the wide range of modern-day estimates for these parameters. The migration parameters ψ and ψ^* determine how sensitive migration is to differences in the utility level between regions: a small ψ implies a stronger migration reaction for any given utility difference, whereas a large ψ implies that migration is largely a random phenomenon.[42] In accordance with the previously cited evidence for the responsiveness of migrants to economic conditions

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

[42] Note that while ψ characterizes migration's sensitivity to cyclical fluctuations, the fixed migration cost κ_d determines the level of migration $\bar{d}$.

we choose a normal distribution with a relatively small mean of 2. According to current best-practice estimates for the U.S. (Kennan and Walker, 2011) a persistent 1% increase in one state's wages implies a 0.5% larger state-population after 5 years. In our model's framework, a value of 2 for ψ implies a similar reactivity of migration.

Nominal rigidity is characterized by the Calvo parameter θ, which together with γ, β and μ determines the slope of the Phillips curve, $\tilde{\kappa}$, according to $\widetilde{\kappa} = (1-\beta\theta)(1-\theta)/[1/\theta(1-\mu+\mu/\gamma)]$. Instead of estimating the Calvo parameters we choose to directly estimate the the Phillips curve slopes. Many modern day quarterly Calvo parameter estimates lie in the range of $[0.5, 0.8]$, which corresponds to an average price duration of 2 to 5 quarters, or a quarterly Phillips curve slope between 0.01 and 0.13. Schmitt-Grohé and Uribe (2004) and Eggertsson (2008) convert the quarterly Phillips curve slope to an annual slope by multiplying the former by four. Thus today's Calvo parameter estimates in the $[0.5, 0.8]$-range imply an annualized Phillips curve slope between 0.04 and 0.52. Where can we expect the corresponding GS parameter to lie? Aggregate price indices exhibited substantially more flexibility (Gordon, 1990; Basu and Taylor, 1999; Obstfeld, 2007) and output responsiveness than today (Bayoumi and Eichengreen, 1996; Bordo, 2008; Chernyshoff, Jacks and Taylor, 2009).[43] We thus expect to find steeper Phillips curves for the GS era. To be on the safe side however, we chose a conservative beta-prior for $\widetilde{\kappa}$ and $\widetilde{\kappa}^*$, which gives almost equal prior weight to all but the most extreme values of the 0-1 range.

On the monetary side, following Benati et al. (2008) and Fagan, Lothian and McNelis (2013) we assume a prior mean of 0.1 for the interest-rate elasticity of money demand v^r

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[43] Note however that the micro evidence based on product-group level prices indicates that prices have not become less flexible over time (Kackmeister, 2007; Knotek, 2008). This points towards a compositional effect: it is well known that pre-1913 price indices contain more flex-price items such as agricultural produce and raw materials than today's indices. However, for our macro model calibration the aggregate price level evidence has more relevance.

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

For the discount rate rule, we use pre-sample data to inform our prior choice. We set the prior means of the discount rate coefficients close to the pooled regression coefficient estimates that we obtained for a sample of GS members for the years 1870-1879. We then chose wide prior standard deviations to reflect our uncertainty about these parameters. Consistent with historical accounts the regression results also show that the U.K. changed its discount rate much more frequently than the Swedish and Belgian central banks.[44] Accordingly, we estimate the discount rate rule for the U.K. without a persistence term. Furthermore, although foreign countries might have wanted to keep their nominal exchange rates stable vis-à-vis the U.K. (see Morys, 2011) there is little reason why they should directly target the nominal exchange rate vis-a-vis Sweden or 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.[45] Only the discount rate shock is not allowed to exhibit any persistence beyond that which is intrinsic to the discount rate rule. All persistence parameters are given a wide beta prior with a mean of 0.3.[46]

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

[45] 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.

[46] The 0.3 mean for our annual model corresponds to the conventional prior mean from

We allow for the region-specific technology shocks to be correlated. We chose a flat beta prior for the correlation σ_{aa^*}. The persistence and standard deviation of the gold shocks are assumed to be the same across regions.

Finally, we allow for measurement error in all trade-weighted observables (all *F*-aggregates and the NEER). We also allow for measurement error in the net immigration and *trade balance* to *GDP* ratio. Following Christiano, Trabandt and Walentin (2011) we calibrate the measurement errors' variance to 10% of the variance in the observables. As shown in Online Appendix III.1, the data without measurement error very closely follow the original data.

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the $[0.5, 0.85]$ range that is usually applied in quarterly models: $0.3 \approx 0.75^4$.

Table 2: *Prior distribution*

Description		Distribution	Mean	S.D.	Description		Distribution	Mean	S.D.
Utility parameters					*Shock parameters*				
σ_c	Inverse EIS	Normal	1.50	0.35	ρ^a	Persistence, technology (H)	Beta	0.30	0.15
σ_l	Inverse Frisch elasticity	Normal	2.00	0.75	ρ^{a*}	Persistence, technology (F)	Beta	0.30	0.15
ϵ	Trade elasticity (H)	Normal	1.50	1.50	ρ_g	Persistence, markup (H)	Beta	0.30	0.15
ϵ^*	Trade elasticity (F)	Normal	1.50	1.50	ρ^{g*}	Persistence, markup (F)	Beta	0.30	0.15
					ρ^x	Persistence, money demand (H)	Beta	0.30	0.15
Migration parameters					ρ^{x*}	Persistence, money demand (F)	Beta	0.30	0.15
ψ	Migration sensitivity (H)	Normal	2.00	1.00	ρ^b	Persistence, risk premium (H)	Beta	0.30	0.15
ψ^*	Migration sensitivity (F)	Normal	2.00	1.00	ρ^{b*}	Persistence, risk premium (F)	Beta	0.30	0.15
					ρ^m	Persistence, gold (H & F)	Beta	0.30	0.15
Price parameters					η^a	S.D., technology (H)	Inv. gamma	0.50	2.00
$\tilde{\kappa}$	Phillips curve slope (H)	Beta	0.50	0.28	η^{a*}	S.D., technology (F)	Inv. gamma	0.50	2.00
$\tilde{\kappa}^*$	Phillips curve slope (F)	Beta	0.50	0.28	η^g	S.D., markup (H)	Inv. gamma	0.50	2.00
					η^{g*}	S.D., markup (F)	Inv. gamma	0.50	2.00
Gold flow parameters					η^x	S.D., money demand (H)	Inv. gamma	0.50	2.00
ϵ^e	Gold flow due to exchange rate	Uniform	$[0,\ 15]$		η^{x*}	S.D., money demand (F)	Inv. gamma	0.50	2.00
$\frac{\bar{G}}{\bar{G}^*}$	Relative gold stock	Inv. gamma	$\frac{n}{1-n}$	1.00	η^b	S.D., risk premium (H)	Inv. gamma	0.50	2.00
					η^{b*}	S.D., risk premium (F)	Inv. gamma	0.50	2.00
Discount rate parameters					η^r	S.D., monetary policy (H)	Inv. gamma	0.10	2.00
ρ	Discount rate persistence (H)	Beta	0.30	0.15	η^{r*}	S.D., monetary policy (F)	Inv. gamma	0.10	2.00
Φ^y	Output coefficent (H)	Beta	1.00	0.56	η^m	S.D., gold (H & F)	Inv. gamma	0.50	2.00
Φ^e	Exchange rate coefficent (H)	Beta	1.00	0.56	σ_{aa^*}	Correlation, technology	Beta	0.50	0.28
Φ^g	Cover ratio coefficient (H)	Beta	1.00	0.56					
ρ^*	Discount rate persistence (F)	Beta	0.30	0.15					
Φ^{y*}	Output coefficent (F)	Beta	1.00	0.56					
Φ^{e*}	Exchange rate coefficent (F)	Beta	1.00	0.56					
Φ^{g*}	Cover ratio coefficient (F)	Beta	1.00	0.56					
Other parameters									
K	Foreign portfolio adjustment costs	Inv. gamma	0.04	2.00					
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 $\psi, \psi^*, \sigma_l, \epsilon$ and ϵ^* are truncated at zero. In case of the U.K., ρ is not estimated but set to zero. In the case of Sweden and Belgium, Φ^{e*} is not estimated but set to zero.

5.4. Posterior distribution

Table 3 summarizes the estimation results. Firstly, the posterior distributions for the Phillips curve parameters indicate that the price level was much more flexible in the time before 1914 than it is today. Annual Phillips curve (PC) slope estimates for the U.K., Sweden and Belgium are 0.34, 0.53 and 0.90 respectively, implying average price durations in the 1.5 to 2 quarter range. For comparison, estimates for the U.S. and the euro area today generally hint towards a much flatter Phillips curve. The Calvo parameter estimates obtained by De Walque and Wouters (2005) and Smets and Wouters (2003, 2007) for instance, imply annualized Phillips curve slopes in the [0.01-0.15]-range.

Secondly, consider the parameters ψ and ψ^* that pin down the sensitivity of migration to the business cycle. As expected, the comparatively small estimate for Sweden reflects that Swedish migrants were very responsive to economic fundamentals. Though less than in Sweden, U.K. migrants still responded strongly to cyclical differences in consumption and labor income. Given the U.K.'s ψ-estimate, a persistent 1% decrease in consumption in the U.K. relative to the F-region would result in a 4% decrease in the U.K.'s population after 5 years. By contrast, the comparatively high ψ-estimate for Belgium implies that Belgian migration flows were considerably less sensitive.[47]

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

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

These results reflect that the primary monetary policy targets at the time were stable gold cover ratios and nominal exchange rates. The autocorrelation of Swedish and Belgian discount rates is 0.42 and 0.44 respectively, implying that some interest rate smoothing took place. Furthermore Belgian discount rates reacted less to deviations of the exchange rate from its mint parity ($(1-\rho)\cdot\Phi^{e} = 0.34$) and fluctuations in the gold cover ratio ($(1-\rho)\cdot\Phi^{g} = 0.07$). In this sense the National Bank of Belgium made more use of the monetary policy independence that the Gold Standard allowed. Note, however, that it does not appear to have targeted the domestic output gap.

5.5. Model evaluation

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

Next, we compared the (auto-)correlations of the simulated data to that of the observed data. We did this for the six variables that we are most interested in – a total of 216 moments.[48] To obtain the simulated data we run the model with all parameters set to their posterior mean.[49] Figures III.4 to III.6 in Online Appendix III.2 show the correlations, including the 90% coverage percentiles for the stochastic simulations. The model fairly accurately represents the data's correlation structure.

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[48] 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.

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

Table 3: Posterior distribution

		U.K.			Sweden			Belgium		
Description		Mean	90% HPDI		Mean	90% HPDI		Mean	90% HPDI	
Utility parameters										
σ_c	Inverse EIS	1.57	1.11	2.03	2.50	2.07	2.93	2.10	1.77	2.41
σ_l	Inverse Frisch elasticity	2.65	1.67	3.60	2.85	1.94	3.79	3.36	2.57	4.13
ϵ	Trade elasticity (H)	2.81	0.71	4.72	1.44	0.09	2.60	0.64	0.03	1.17
ϵ^*	Trade elasticity (F)	3.20	1.57	4.80	1.26	0.26	2.27	0.47	0.00	0.84
Migration parameters										
ϕ	Migration sensitivity (H)	0.27	0.06	0.47	0.07	0.05	0.08	3.77	2.76	4.81
ϕ^*	Migration sensitivity (F)	1.98	0.33	3.39	2.03	0.44	3.52	3.44	2.42	4.40
Price parameters										
$\tilde{\kappa}$	Phillips curve slope (H)	0.34	0.16	0.54	0.53	0.33	0.75	0.90	0.79	1.00
$\tilde{\kappa}^*$	Phillips curve slope (F)	0.35	0.14	0.58	0.64	0.39	0.93	0.36	0.18	0.54
Gold flow parameters										
ϵ^e	Gold flow due to nom. exchange rate	2.33	3.29	1.35	1.85	2.90	0.78	0.54	0.75	0.31
$\frac{\bar{G}}{\bar{G}^*}$	Relative gold stock	0.05	0.04	0.07	0.03	0.01	0.06	0.02	0.01	0.03
Discount rate parameters										
ρ	Discount rate persistence (H)	–	–	–	0.42	0.18	0.65	0.44	0.28	0.59
Φ^y	Output coefficent (H)	0.14	0.09	0.19	0.18	0.01	0.34	0.02	0.00	0.04
Φ^e	Exchange rate coefficent (H)	0.72	0.13	1.27	1.68	1.29	2.00	0.61	0.14	1.07
Φ^g	Cover ratio coefficient (H)	0.05	0.04	0.06	0.14	0.07	0.22	0.12	0.08	0.15
ρ^*	Discount rate persistence (F)	0.25	0.06	0.42	0.42	0.17	0.66	0.13	0.02	0.24
Φ^{y*}	Output coefficent (F)	0.04	0.00	0.09	0.16	0.00	0.33	0.06	0.00	0.13
Φ^{e*}	Exchange rate coefficent (F)	1.63	1.23	2.00	–	–	–	–	–	–
Φ^{g*}	Cover ratio coefficient (F)	0.39	0.21	0.54	0.49	0.17	0.83	0.18	0.10	0.27
Other parameters										
K	Foreign portfolio adjustment costs	0.24	0.01	0.45	0.09	0.02	0.17	0.53	0.34	0.72
υ^r	Interest rate elasticity of money demand	0.10	0.06	0.13	0.10	0.06	0.14	0.10	0.06	0.14

Table 4: Posterior distribution (continued)

		U.K.			Sweden			Belgium		
Description		Mean	90% HPDI		Mean	90% HPDI		Mean	90% HPDI	
Shock parameters										
ρ^{a}	Persistence, technology (H)	0.18	0.06	0.29	0.05	0.01	0.09	0.49	0.39	0.59
ρ^{a*}	Persistence, technology (F)	0.93	0.90	0.96	0.86	0.82	0.90	0.46	0.29	0.64
ρ^{g}	Persistence, markup (H)	0.31	0.10	0.51	0.38	0.24	0.53	0.24	0.08	0.38
ρ^{g*}	Persistence, markup (F)	0.52	0.32	0.73	0.23	0.07	0.38	0.35	0.17	0.52
ρ^{x}	Persistence, money demand (H)	0.19	0.05	0.33	0.20	0.05	0.34	0.07	0.01	0.13
ρ^{x*}	Persistence, money demand (F)	0.54	0.39	0.69	0.36	0.16	0.56	0.55	0.35	0.74
ρ^{b}	Persistence, risk premium (H)	0.30	0.07	0.50	0.52	0.29	0.75	0.33	0.12	0.51
ρ^{b*}	Persistence, risk premium (F)	0.24	0.04	0.43	0.34	0.09	0.57	0.30	0.07	0.52
ρ^{m}	Persistence, gold (H & F)	0.21	0.04	0.38	0.30	0.12	0.49	0.14	0.03	0.26
η^{a}	S.D., technology (H)	1.52	1.26	1.77	2.05	1.77	2.32	1.62	1.43	1.82
η^{a*}	S.D., technology (F)	0.34	0.25	0.43	0.32	0.26	0.39	0.49	0.37	0.60
η^{g}	S.D., markup (H)	2.46	1.63	3.25	4.60	3.39	5.80	6.71	5.34	8.03
η^{g*}	S.D., markup (F)	1.34	0.77	1.91	2.11	1.32	2.85	1.51	0.75	2.24
η^{x}	S.D., money demand (H)	2.76	2.38	3.15	7.35	6.37	8.36	2.09	1.93	2.24
η^{x*}	S.D., money demand (F)	0.75	0.52	0.98	0.93	0.56	1.30	0.33	0.20	0.44
η^{b}	S.D., risk premium (H)	0.26	0.18	0.34	0.25	0.17	0.32	0.24	0.17	0.31
η^{b*}	S.D., risk premium (F)	0.20	0.13	0.27	0.21	0.13	0.28	0.19	0.13	0.26
η^{r}	S.D., monetary policy (H)	0.39	0.29	0.49	0.69	0.39	0.97	0.19	0.15	0.23
η^{r*}	S.D., monetary policy (F)	0.38	0.27	0.49	0.31	0.22	0.40	0.28	0.22	0.34
η^{m}	S.D., gold (H & F)	0.48	0.34	0.62	0.38	0.16	0.60	0.18	0.12	0.23
σ_{aa^*}	Correlation, technology	0.28	0.03	0.49	0.44	0.26	0.61	0.07	0.00	0.15

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

6. Counterfactual Analysis

In this section we conduct the horse-race between the price-, migration- and monetary policy-channels to explain why external adjustment under the Gold Standard (GS) was associated with few output costs. In order to quantitatively assess the channels' relative importance we present counterfactual output 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 ran 2000 simulations, each 34 periods long (corresponding to the length of our sample).[50] Columns 2 to 4 display the counterfactual standard deviations that result from conducting the same simulation with the respective counterfactual structural parameters.

First, for the price rigidity counterfactual we lower all Phillips curve slope parameters from our high GS estimates to a value which is representative of today's economies. In particular we set the average duration of price contracts to three quarters, implying annualized Phillips curve slopes of 0.13 for the U.K. and 0.17 for Sweden and Belgium. This comes close to what most price rigidity estimates for current advanced economies look like today (see Smets and Wouters, 2007; Schorfheide, 2008). In this scenario the counterfactual standard deviations for per capita output are substantially higher, increasing between 81.5% (for the U.K.) and 145.2% (for Belgium). According to these model simulations flexible prices were a major reason for the resilience of per capita incomes during the GS.

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

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

effect on output volatility. The exception is Belgium, where the standard deviation of output increases by a notable 3.8%. The counterfactual "no migration"-simulations for the U.K. and Belgium even resulted in slightly less volatile per capita incomes. This acts as a reminder that the stabilizing effects of migration on regional output do not necessarily outweigh the destabilizing effects that arise from the redistribution of aggregate demand away from the already recessionary origin-region.

For the monetary policy counterfactual we eliminated the freedom central banks enjoyed in setting their discount rates by assuming that H has to adjust its interest rate to ensure an absolutely fixed exchange rate, while F – a much larger region than H – sets its discount rate as estimated.[51] Column (4) in Table 5 shows that this "no independence" counterfactual has the most impact for the U.K. Here, the monetary policy independence that the GS allowed enabled the Bank of England to achieve a 3.2% lower per capita income volatility. A look at the counterfactual impulse response functions furthermore shows that particularly in the short-run monetary policy could exert a non-negligible stabilizing influence (see III.10 in the Online Appendix). Such short-run dynamics get played down in Table 5, which focuses on overall output volatility.[52] We find, however, no evidence that monetary policy substantially helped the adjustment experience of either Sweden or Belgium.

In the context of today's fixed exchange rate regimes an interesting question arises as to whether international migration can alleviate the external adjustment problem given that prices are rigid. To see if migration would be substantially more effective in reducing output and inflation volatility in a rigid price economy, we ran the corresponding counterfactual GS model simulation. The result displayed in column (3|2) of Table 5 does not support this supposition. Shutting down the migration channel in a rigid price

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[51] See Appendix A.3 for details.

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

Table 5: *Counterfactual per capita output volatilities*

		Counterfactuals				
	Baseline model (1)	Rigid prices (2)	No migration (3)	No independence (4)	No migration, given rigid prices (3∣2)	No indepen-dence, given rigid prices (4∣2)
United Kingdom	1.76	3.20	1.75	1.82	3.19	3.42
		(81.50%)	(-0.89%)	(3.19%)	(-0.16%)	(7.03%)
Sweden	1.88	4.26	1.87	1.90	4.28	4.38
		(126.77%)	(-0.20%)	(0.91%)	(0.46%)	(2.82%)
Belgium	0.94	2.29	0.97	0.93	2.29	2.29
		(145.15%)	(3.77%)	(-0.19%)	(-0.01%)	(-0.16%)

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

economy does not substantially impact output volatilities relative to the rigid price-only counterfactual. Rigid prices somewhat heighten the stabilizing effect that monetary policy has on output (see column (4∣2)), but the total effects still pale in comparison to the direct effects of price flexibility on output volatility .

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

7. Sectoral structure, price level flexibility and external adjustment

This section provides an in-depth analysis of price flexibility and external adjustment under the GS. Newly compiled disaggregate sectoral data allows us to address the following questions: Why was the aggregate price level so flexible under the GS? Which prices exactly adjusted by how much during external adjustments? Was it really an increase in the export of flex-price goods that turned around the current account?

7.1. Sectoral structure and price level flexibility

A notable feature of the Gold Standard-economies is their large primary sector shares, even among early industrializers. Primary sector products in turn generally exhibit much more flexible prices than industrial goods or services (Bordo, 1980; Han, Penson and Jansen, 1990; Jacks, O'Rourke and Williamson, 2011). Thus, the Gold Standard economies' sectoral structure is a likely reason for the flexibility of the overall price level.[53] Sectoral inflation variances within our 14-country sample line up accordingly: Table 6 shows that the growth rates of prices for agricultural goods (variance = 0.51) and raw materials (variance = 0.64) exhibit about twice the volatility of industrial price-growth rates (variance = 0.27) and more than five times the volatility of service prices (variance = 0.10).[54] To get an idea of the relative importance of primary sectors in the period from

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

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

1880 to 1913, consider that in our 14-country sample an average of 47% of employment is concentrated in primary sectors, and 30% of value added is generated in them (see Table 6). Even the U.K., the most industrialized country of its time, still employed between 10 and 20% of its labor force in agriculture and mining. Among internationally traded goods, agricultural products and raw materials made up an even larger fraction: Within our 14-country sample 67% of all merchandise exports were primary products.[55] Even among early industrializing North Western European countries, primary product exports equalled the amount of manufacture exports (see Lamartine Yates, 1959, pp. 226-32).

A look at disaggregated nominal prices and real (CPI-deflated) exports confirms the crucial role agriculture played for external adjustment under the GS (see Figure 3). Agricultural goods dominated the quick fall in domestic prices, and primary products generally dominated the export booms during major CA-reversals.[56] Four years into the adjustment agricultural and raw material exports were both up by 30%. At the same time industrial exports had increased by only 10%.[57] Agricultural exports in particular, dominated the early years of CA-reversals, with exports up by 20% after only two years.[58]

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long-term fixed contracts are more common (see Bordo, 1980; Sachs, 1980; Gordon, 1982).

[55] This comes very close to figures by Aparicio, Pinilla and Serrano (2009), according to which 63% of international trade between 1880 and 1939 consisted of primary products. Furthermore, the fraction of primary products in total trade remains surprisingly stable at around two thirds in the period from 1870 to 1913 (see Lewis, 1952).

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

[57] Note that while the sharp increase in agricultural exports is accompanied by an equally sharp fall in agricultural prices, this is not the case for raw materials. This possibly hints at differential price elasticities in the international demand for agricultural goods and raw materials.

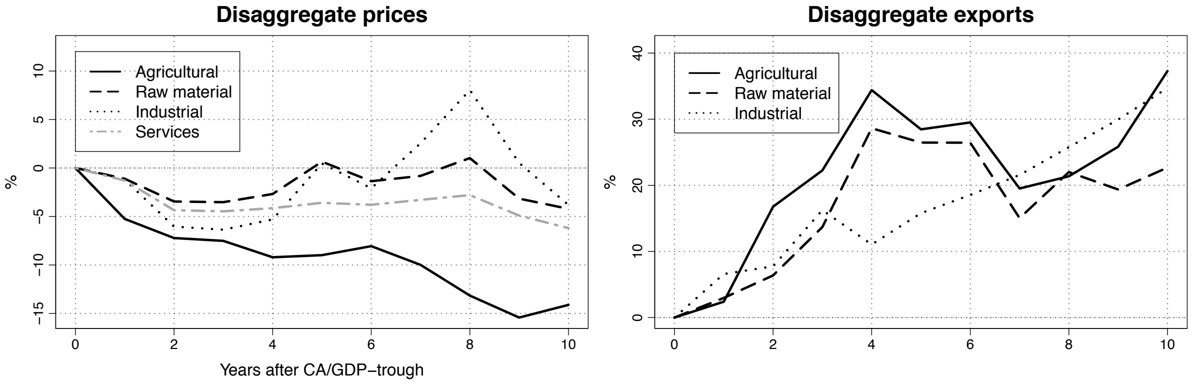
[58] This relationship between sectoral prices, sectoral exports and the CA/GDP ratio is not restricted to phases of major external adjustment. It also is present in within-year

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

	Mean	N.obs
Agriculture, value-added share (%)	30	428
Agriculture, employment share (%)	47	238
Agricultural exports, share of total merchandize exports (%)	36	551
Primary exports, share of total merchandize exports (%)	67	517
	Variance	**N.obs**
Agricultural prices, year-on-year change (%)	0.51	601
Raw material prices, year-on-year change (%)	0.64	578
Industrial prices, year-on-year change (%)	0.27	509
Service prices, year-on-year change (%)	0.10	436

Notes: The number of observations differs due to data availability and frequency. Agricultural employment share figures are commonly decennial data.

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



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

Increasing primary good exports also left their mark on the adjusting economy's

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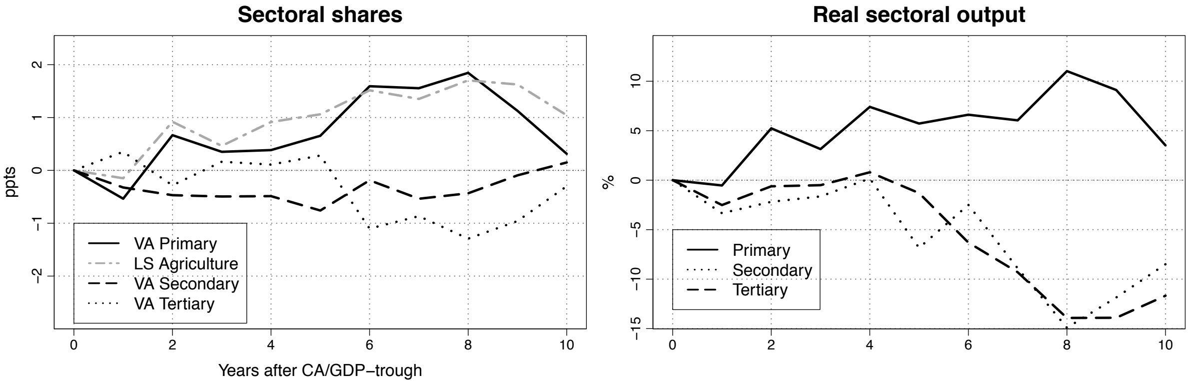
correlations (see Table II.2 in Online Appendix II.1).

Figure 4: *Sectoral adjustment after major reversals in the CA/GDP-ratio*



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

sectoral structure. Figure 4 depicts the sectoral adjustment that accompanied the export-led external adjustments of the GS economies. The value added (VA) share of the primary sector (predominantly tradable goods producing) increased by close to 2 ppts; so did the agricultural sector labor share (LS). At the same time, the VA shares of the tertiary sector (mostly non-tradable goods producing) tended to decrease by around 1 ppt. The VA share of the secondary sector, which here combines non-tradables (e.g. construction works) as well as tradables (e.g. raw materials and machines), falls by around 0.5 ppts. In terms of absolute real output, tertiary sector production fell up to 15% below trend during major CA-adjustments, while real primary sector production rose up to 10% above its trend level. Secondary sector production tends to closely follow the tertiary sector's path.[59]

In sum, the fortunate coincidence of the nominally most flexible sector – agriculture

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[59] This relationship is robust to an alternative definition of major CA/GDP troughs (see Figure II.5 in Online Appendix II.2). It also is present outside of major adjustment periods, in the contemporaneous correlations of changes in the CA/GDP ratio with changes in the sectoral shares (see Table II.4 in Online Appendix II.1).

– also being the most important tradable sector is the main explanation for the ease of external adjustment under the pre-1913 Gold Standard.[60] When hit by a shock that necessitated the reversal of the current account the agricultural sector produced more of its tradable output, which was readily absorbed by world markets.[61]

7.2. Terms of trade vs. local prices

While the local price level fell markedly, the terms of trade – the ratio of export prices to import prices as measured at the port – remained stable (Figure 5, left graph).[62] This generalizes the observations made by Viner (1924) and Angell (1926) for Canada, and by Wilson (1931) and Pope (1986, 1990) for Australia. They noted that the terms of trade moved little during external adjustments under the GS. How can this well known observation be reconciled with a price flexibility based explanation of external adjustment?

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[60] Note that large primary sector shares today are far less associated with benign external adjustments among developing economies (see Labys and Maizels, 1993; Kinda, Mlachila and Ouedraogo, 2016). One explanation may lie in the importance of primary product exports for fiscal revenue. Prior to 1913 government spending only made up a small fraction of GDP and revenue losses from lower-priced agricultural products would primarily be borne by private individuals.

[61] The sectoral adjustment, away from services and towards tradable primary goods, can be easier to accomplish against the backdrop of rapid industrialization. Instead of requiring a costly re-allocation of labor and capital away from the production of non-tradables towards the production of tradables, external adjustments under the GS simply required a temporary slow-down in the secular transition from agriculture (primarily tradable) to industry and services (primarily non-tradable).

[62] The same relationship between the terms of trade, the CPI, and the CA/GDP ratio extends to non-adjustment periods (see the within-year correlations in Table II.3 in Online Appendix II.1). It also is robust to using all visually salient CA/GDP troughs, instead of the lowest CA/GDP-value in a ±10-year window (see Figure II.4 in Online Appendix II.2).

Figure 5: *Terms of trade vs. local prices after major reversals in the CA/GDP-ratio*

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

To better understand how a stable terms of trade, together with domestic price deflation, can bring about external adjustment it is worth taking a look at the different price components that are involved. The terms of trade (ToT_t) equals export prices ($\tilde{P}^{\star}_{H,t}$) minus import prices ($\tilde{P}_{F,t}$) as measured at the port:

$$\widehat{ToT}_t = \hat{\tilde{P}}^{\star}_{H,t} - \hat{\tilde{P}}_{F,t},$$

where hatted variables denote logarithms.

The log CPI can be written as a weighted sum of non-tradable prices ($P_{N,t}$) and tradable prices ($P_{T,t}$). The latter can be further decomposed into the price of home tradables, as measured at home ($\tilde{P}_{H,t}$), and the price of foreign tradables, as measured at the port ($\tilde{P}_{F,t}$):

$$\begin{aligned} \hat{P}_t &= (1-\check{\gamma})\hat{P}_{N,t} + \check{\gamma}\hat{P}_{T,t} \qquad (5) \\ &= (1-\check{\gamma})\hat{P}_{N,t} + \check{\gamma}\left[\check{\alpha}\hat{\tilde{P}}_{H,t} + (1-\check{\alpha})\hat{\tilde{P}}_{F,t}\right], \end{aligned}$$

where $\check{\gamma}$ denotes the weight of non-tradables in the overall consumption basket, and $\check{\alpha}$ denotes the share of home tradables among all tradables. In this way, the *ToT* and CPI can be decomposed into four price components: $\tilde{P}^{\star}_{H,t}$, $\tilde{P}_{F,t}$, $P_{N,t}$ and $\tilde{P}_{H,t}$.

Table 7 summarizes the direction of movement of the four price components during major external adjustments. The table also shows the substitution effect associated with each of these price movements. These substitution effects have been derived from a straightforward extension of our GS model by a tradable and non-tradable sector (the full model description is provided in Appendix B).

The export price of H tradable goods ($\tilde{P}^{\star}_{H,t}$) and the import price of F tradable goods ($\tilde{P}_{F,t}$) both fall around 4% two years into the adjustment, resulting in a stable *ToT* (see Figure 5). Despite falling by an equal amount, however, the fall in export prices is likely to increase exports by more than the equivalent fall in import prices increases imports. This is because the rest of the world is large compared to the local economy.

Next, the local price of H tradable goods ($\tilde{P}_{H,t}$), as indicated by local agricultural prices, falls by a large amount – around 8% two years into the adjustment (see Figure 3). This is likely to induce a sizeable fall in imports, as domestic consumers substitute towards the cheaper domestic tradable good.

Also note that the local price of H non-tradable goods ($P_{N,t}$), as indicated by local service prices, falls around 4% (see Figure 3). This puts pressure on the CPI, and to the extent that non-tradable inputs enter tradable goods it is part of the explanation for why $\tilde{P}_{H,t}$ and $\tilde{P}^{\star}_{H,t}$ fall.

One loose end remains. Why does the local price of H tradables ($\tilde{P}_{H,t}$) fall by around twice as much as the export price of the very same tradables ($\tilde{P}^{\star}_{H,t}$)? This is consistent with distributional services driving a wedge between local prices and port prices. Consider that selling one ton of grain overseas is associated with more distribution costs (e.g. transportation, warehousing and finding overseas buyers) than selling the same ton of grain locally.[63] If the price for such distribution services is less flexible than the local price for grain, then the port price for grain – an aggregate of distribution service prices and local grain prices – will display fewer fluctuations than the local price for grain.

In sum, falling export prices induce a large increase in exports, while falling import prices and falling local prices have contravening effects on imports. The net result is a stable terms of trade, a sizeable decrease in the domestic price level and a sizeable increase in exports.

Table 7: *Local prices, terms of trade and the trade balance*

Price	Price change	Substitution effect
$P^{\star}_{H,t}$ (port price of H tradable good)	↓	exports ↑↑
$P_{F,t}$ (port price of F tradable good)	↓	imports ↑
$P_{H,t}$ (local price of H tradable good)	↓↓	imports ↓
Net effects	ToT stable, CPI ↓↓	exports ↑↑

7.3. *Engel decomposition*

Engel (1993) finds that most variation in the real exchange rate today is due to variation in tradable goods prices, as opposed to variation in non-tradable goods prices. How does this compare to the GS era? Engel (1993) decomposes the logarithm of the real exchange rate into a tradable price component (q_T), and a non-tradable price component (q_N):

$$\begin{aligned}
\widehat{REER}_t &= \widehat{CPI}_t + \widehat{NEER}_t - \widehat{CPI}^{\star}_t \\
&= \underbrace{\widehat{NEER}_t + \hat{P}_{T,t} - \hat{P}^{\star}_{T,t}}_{\equiv q_T} + (1-\check{\gamma})\underbrace{[(\hat{P}_{N,t} - \hat{P}_{T,t}) - (\hat{P}^{\star}_{N,t} - \hat{P}^{\star}_{T,t})]}_{\equiv q_N},
\end{aligned}$$

---

[63] Although by the late 19th century important trading centers and coastal cities were internationally well-integrated there was considerable market segmentation further inland (Uebele, 2011).

where we have used equation 5 to substitute for the CPI terms. $P_{T,t}$ denotes the price of locally consumed tradables, and $P_{N,t}$ denotes the price of local non-tradables. The F region's equivalents are denoted with an asterisk. $NEER_t$ denotes the nominal effective exchange rate and $\check{\gamma}$ denotes the weight of non-tradables in the overall consumption basket. All prices are in logs.[64]

Table 8 shows how the two components q_T and q_N correlate with the REER. When port prices are used for $P_{T,t}$ and $P^{\star}_{T,t}$ (as suggested by Burstein, Eichenbaum and Rebelo, 2005), the non-tradable price component, q_N, is positively correlated with the REER, while the tradable price component, q_T, is not. This is consistent with the earlier finding that external adjustment under the GS was based on local price deflation.[65]

When local prices, instead of port prices, are used to calculate q_T and q_N (see Engel, 1999), the tradable price component q_T starts to exhibit a significantly positive correlation with the REER. However, the correlation coefficient for the non-tradable price component, q_N, remains significantly positive.

In sum, the data indicate that variation in non-tradable prices played an important

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[64] We use local service prices as an indicator for local non-tradable prices $\hat{P}_{N,t}$. The F region's equivalent, $\hat{P}^{\star}_{N,t}$, is a trade-weighted average of the service prices of all other countries in the sample. With respect to the tradable price $\hat{P}_{T,t}$ two indicators have been used in the literature. First, port prices, as suggested by Burstein, Eichenbaum and Rebelo (2005). In this case, export prices are used as an indicator for the local tradable price $\hat{P}_{T,t}$, while import prices are used for $\widehat{NEER}_t - \hat{P}^{\star}_{T,t}$. Second, we use local tradable prices (see Engel, 1999). In this case we use a weighted average of local agricultural prices and local raw material prices (weighted by value-added sector shares) as our indicator for $\hat{P}_{T,t}$, whereas the F equivalent, $\hat{P}^{\star}_{T,t}$, is a trade-weighted average of the corresponding prices in all other countries.

[65] This finding is also consistent with the finding by Burstein, Eichenbaum and Rebelo (2005) that during several large devaluations in the 1990s and 2000s, variation in q_N accounted for most of the variation in real exchange rates, if port prices are used as the traded goods price.

Table 8: *Engel decomposition*

	Port prices:				*Local prices:*		
	Δ REER				Δ REER		
	ρ	p	N		ρ	p	N
Δq_T	0.019	0.68	456	Δq_T	0.170***	0.00	287
Δq_N	0.162***	0.00	399	Δq_N	0.107*	0.08	277

Notes: * 0.10 ** 0.05 *** 0.01. ρ: Pearson correlation coefficients. p: p-values. N: number of observations.

role in overall REER variation under the GS. This stands in contrast to the findings for floating exchange rate economies today, where most variation in the real exchange rate can be attributed to variation in tradable prices q_T, instead of non-tradable prices q_N Engel (1993, 1999).

There exist several plausible explanations for this shift in the composition of real exchange rate movements: First, non-tradable price variation might be more important for economies whose exchange rate is fixed. This conforms with recent findings by Berka, Devereux and Engel (forthcoming), who show that among euro area members, variation in non-tradable prices plays a more important role for overall REER variation. Second, the finding that tradable price variation was less important under the GS than today is also consistent with the fact that tradable goods under the GS (i.e. primary goods) were more homogeneous than tradable goods today. This would be consistent with the finding by Engel (1993), that for very homogeneous tradable goods (e.g. bananas) q_T explains less real exchange rate variation than q_N. In this way, the 20th century shift away from primary goods production may have changed the nature of real exchange rate adjustments. Finally, to the extent that services are labor intensive and wages were less rigid in the late 19th century than they are today, the larger role of non-tradable prices in adjusting the real exchange rate under the GS can be partly attributed to more flexible wages.

8. Conclusion

How international adjustment worked so smoothly during the 19th century Gold Standard, a colossus defying most tenets of optimum currency area, has continually fascinated scholars of international economics. The contribution of the present paper towards a better understanding of this benign adjustment experience is twofold. First, we built and estimated a structural model of the Gold Standard. On the basis of the estimated model we quantitatively assessed the relative importance of three prominent adjustment channels: flexible prices, international migration, and monetary policy. Counterfactual simulations suggest that the ease of external adjustment under the Gold Standard was primarily due to flexible prices allowing for speedy expenditure switching.

Second, we find that price flexibility, and thus benign external adjustments, were predicated on a historical contingency: large agricultural sectors and the dominance of primary products among merchandise exports. As still is the case today, agricultural products and raw materials exhibited much more flexible prices than industrial or service goods. At the same time agricultural products made up a large part of all merchandise exports, even among early industrializers. This fortunate coincidence of the nominally most flexible sector simultaneously being the most important tradable sector is the main explanation for the ease of external adjustment under the pre-1913 Gold Standard.

Our findings raise an interesting question with respect to the malfunctioning of the Gold Standard after World War 1 and its fall in the 1930s, which is often attributed to the rise of rigid wages (see Bordo, Erceg and Evans, 2000). A sectoral composition-based explanation for why the 19th century Gold Standard worked well, however, suggests that staying on gold was becoming increasingly difficult as primary sector shares continued their decline. According to this line of reasoning the classical Gold Standard had been approaching its date of expiry independently of the rise of wage rigidity and the unfolding of the tumultuous events after 1913 (see Means, 1936).

Our result also touches upon current problems in the euro area. The pre-1914 Gold Standard is a prime historical example for a functioning fixed exchange rate regime among fiscally independent nation states. In this regard the Gold Standard served as a historical precedent that could be alluded to when the design of the euro area was questioned in principle. To the extent that our findings attribute its functioning to a fortunate historical contingency the Gold Standard loses its role as an exemplar in this regard.

9. References

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A. Model appendix

A.1. 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:

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

The second stage decision is

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

The budget constraint for a F household is:

$$\begin{aligned} & B^{i*}_{H,t-1} R^{e}_{t-1}\, e_t + B^{i*}_{F,t-1} R^{e*}_{t-1} + TR^{e*}_t + P^*_t w^*_t\, l^{i*}_t + \Gamma^*_t + I^{\tau}_t \\ & = B^{i*}_{H,t}\, e_t + B^{i*}_{F,t} + P^*_t\, c^{i*}_t + P^*_t\, \frac{K}{2}\, \left(\frac{B^{i*}_{H,t}\, e_t}{P^*_t} - \bar{o}^* \right)^2 \end{aligned}$$

where the nominal exchange rate e_t is expressed in quantity notation, i.e. foreign currency per domestic 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 $E_{r,t} = P_t\, e_t / P^*_t$ the first order conditions imply

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

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

$$\lambda_t = \beta\, R^e_t\, \mathbb{E}_t \left(\frac{(1-d_{t+1})\ \lambda_{t+1}}{\Pi_{t+1}} + \frac{d_{t+1}\, \lambda^*_{t+1} E_{r,t+1}}{\Pi_{t+1}} \right) \tag{A.3}$$

$$\lambda^*_t = \beta\, R^{e*}_t\, \mathbb{E}_t \left(\frac{(1-d^*_{t+1})\ \lambda^*_{t+1}}{\Pi^*_{t+1}} + \frac{d^*_{t+1}\, \lambda_{t+1}}{\Pi^*_{t+1} E_{r,t+1}} \right) \tag{A.4}$$

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

$$\lambda^*_t = \beta\, R^e_t\, \frac{1}{1 + \mathsf{K}\ \left(b^*_{H,t}\, E_{r,t} - \bar{o}^* \right)}\, \frac{e_{t+1}}{e_t} \mathbb{E}_t \left(\frac{(1-d^*_{t+1})\ \lambda^*_{t+1}}{\Pi^*_{t+1}} + \frac{d^*_{t+1}\, \lambda_{t+1}}{\Pi^*_{t+1} E_{r,t+1}} \right) \tag{A.6}$$

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

$$l_t^{*\sigma_l} = w^*_t \tag{A.8}$$

The population evolves according to

$$n_t = n_{t-1}\ (1 - d_t) + d^*_t\, n^*_{t-1} \tag{A.9}$$

$$n^*_t = 1 - n_t \tag{A.10}$$

Firm j's optimization problem is

$$\begin{aligned} \max_{P_{H,t}(j)} \quad & \mathbb{E}_t \sum_{k=0}^{\infty} \left\{ (\beta\theta)^k \, \frac{\lambda_{t+k}}{\lambda_t} \frac{P_t}{P_{t+k}} \left[P_{H,t}(j) y_t(j) - w_{t+k} P_{t+k} l_{t+k}(j) \right] \right\} && \text{(A.11)} \\ \text{s.t. } \; y_{t+k}(j) \; &= \; \left(\frac{P_{H,t}(j)}{P_{H,t+k}} \right)^{-\mu} y_{t+k} && \text{(A.12)} \\ y_{t+k}(j) \; &= \; A_{t+k} l_{t+k}^{\gamma} && \text{(A.13)} \end{aligned}$$

The first order condition leads to

$$\begin{aligned} F_t \; &= \; \lambda_t \, y_t \, \left(\frac{P_{H,t}}{P_t} \right) \left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)^{1-\mu} + \beta \, \theta \, \mathbb{E}_t \left(\frac{\left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)}{\left(\frac{P_{H,t+1}^{opt}}{P_{H,t+1}} \right)} \frac{1}{\Pi_{H,t+1}} \right)^{1-\mu} F_{t+1} && \text{(A.14)} \\ K_t \; &= \; w_t \, \frac{\lambda_t}{\gamma} \, \frac{\mu}{\mu - 1} \, \left(\frac{y_t}{A_t} \right)^{\frac{1}{\gamma}} \left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)^{\frac{-\mu}{\gamma}} + \beta \, \theta \, \mathbb{E}_t \left(\frac{\left(\frac{P_{H,t}^{opt}}{P_{H,t}} \right)}{\left(\frac{P_{H,t+1}^{opt}}{P_{H,t+1}} \right)} \frac{1}{\Pi_{H,t+1}} \right)^{\frac{-\mu}{\gamma}} K_{t+1} && \text{(A.15)} \\ K_t \; &= \; F_t && \text{(A.16)} \end{aligned}$$

The price dynamics are described by

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

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

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

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

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

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

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

The market clearing conditions are

$$y_t \, n = (1-\alpha) \left(\frac{P_{H,t}}{P_t}\right)^{-\epsilon} c_t \, n_t + \alpha^* \left(\frac{P^{\star}_{H,t}}{P^{\star}_t}\right)^{-\epsilon^{\star}} c_t^* \, n_t^* \tag{A.23}$$

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

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

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

Auxiliary variables:

$$ToT_t = \frac{P^{\star}_{H,t}}{P_{F,t}} \tag{A.27}$$

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

$$\Pi_{H,t} = \frac{P_{H,t}}{P_{H,t-1}} \tag{A.29}$$

$$TB_t = n^*_t c^*_{H,t} P_{H,t} - n_t c_{F,t} P_{F,t} \tag{A.30}$$

$$c_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\epsilon} c_t \tag{A.31}$$

$$c^*_{H,t} = \alpha^*\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\epsilon^*} c^*_t \tag{A.32}$$

$$c_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\epsilon} c_t \tag{A.33}$$

$$c^*_{F,t} = (1-\alpha^*)\left(\frac{P^*_{F,t}}{P^*_t}\right)^{-\epsilon^*} c^*_t \tag{A.34}$$

A.2. 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 (A.4) and (A.6) it follows that $\bar{R} = \bar{R}^*$. Using (A.4) and (A.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

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

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

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

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

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

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

The steady state labor supply satisfies

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

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

At the steady state, the asset pooling assumption gives us

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

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

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

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

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

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

$$
\begin{aligned}
\bar{y}\,\bar{n} &= (1-\alpha)\left(\frac{\bar{P}_H}{\bar{P}}\right)^{-\epsilon}\bar{c}\,\bar{n} + \alpha^{*}\left(\frac{\bar{P}_H\bar{E}_r}{\bar{P}}\right)^{-\epsilon^{\star}}\bar{c}^{*}\,(1-\bar{n}) && \text{(A.9)}\\
\bar{y}^{*}\,(1-\bar{n}) &= \alpha\left(\frac{\bar{P}_F^{*}}{\bar{P}^{*}E_r}\right)^{-\epsilon^{\star}}\bar{c}\,\bar{n} + (1-\alpha^{*})\left(\frac{\bar{P}_F^{*}}{\bar{P}^{*}}\right)^{-\epsilon^{\star}}(1-\bar{n})\,\bar{c}^{*} && \text{(A.10)}\\
\bar{y} &= \bar{A}\,\bar{l}^{\gamma} && \text{(A.11)}\\
\bar{y}^{*} &= \bar{A}^{*}\,(\bar{l}^{*})^{\gamma} && \text{(A.12)}
\end{aligned}
$$

Prices in the steady state satisfy

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

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 (A.1) - (A.13).

A.3. Log-linearized Model

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\hat{E}_{r,t} = \hat{\Pi}^{*}_{t} - \hat{e}_{t} - \hat{E}_{r\,t-1} + \hat{e}_{t-1} - \hat{\Pi}_{t} \tag{A.28}$$

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

$$\hat{n}_{t} - \hat{n}_{t-1} = \bar{d} \, \left(\hat{d}^{*}_{t} + \hat{n}^{*}_{t-1} - \hat{d}_{t} - \hat{n}_{t-1}\right) \tag{A.30}$$

$$\hat{n}^{*}_{t} - \hat{n}^{*}_{t-1} = \bar{d}^{*} \, \left(\hat{n}_{t-1} + \hat{d}_{t} + \left(-\hat{d}^{*}_{t}\right) - \hat{n}^{*}_{t-1}\right) \tag{A.31}$$

$$\hat{w}_{t} = \sigma_{l} \, \hat{l}_{t} \tag{A.32}$$

$$\hat{w}^{*}_{t} = \sigma_{l} \, \hat{l}^{*}_{t} \tag{A.33}$$

$$\hat{l}_{t} = \frac{1}{\gamma} \, \left(\hat{y}_{t} - \hat{A}_{t}\right) - \hat{n}_{t} \tag{A.34}$$

$$\hat{l}^{*}_{t} = \frac{1}{\gamma} \, \left(\hat{y}^{*}_{t} - \hat{A}^{*}_{t}\right) - \hat{n}^{*}_{t} \tag{A.35}$$

$$\hat{A}_t = \rho^{a}\, \hat{A}_{t-1} - \eta_t^{A} \tag{A.36}$$

$$\hat{A}^*_t = \rho^{a^*}\, \hat{A}^*_{t-1} - \eta_t^{A^*} \tag{A.37}$$

$$\epsilon^r_t = \rho^{\epsilon^R}\, \epsilon^r_{t-1} - \eta_t^{R} \tag{A.38}$$

$$\epsilon^{r*}_t = \rho^{\epsilon^{R*}}\, \epsilon^{r*}_{t-1} - \eta_t^{R^*} \tag{A.39}$$

$$\epsilon^g_t = \rho^{g}\, \epsilon^g_{t-1} - \eta_t^{g} \tag{A.40}$$

$$\epsilon^{g*}_t = \rho^{g^*}\, \epsilon^{g*}_{t-1} - \eta_t^{g^*} \tag{A.41}$$

$$\epsilon^m_t = \rho_m\, \epsilon^m_{t-1} - \eta_t^{m} \tag{A.42}$$

$$\epsilon^{m*}_t = \rho^*_{m},\epsilon^{m*}_{t-1} - \eta_t^{m*} \tag{A.43}$$

$$\epsilon^\chi_t = \rho^{x}\, \epsilon^\chi_{t-1} - \eta_t^{x} \tag{A.44}$$

$$\epsilon^{\chi*}_t = \rho^{x*}\, \epsilon^{\chi*}_{t-1} - \eta_t^{x*} \tag{A.45}$$

For the monetary policy counterfactual (*no independence*) we eliminated the freedom central banks enjoyed in setting their discount rates by assuming that H has to adjust its interest rate to ensure an absolutely fixed exchange rate, while F – a much larger region than H – sets its discount rate as estimated. In particular, we substitute the monetary policy equation in the baseline model (equation A.18) by the following equation

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

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

B. An extended model with sectoral structure

This section presents an extended GS model that explicitly models a tradable and non-tradable goods producing sector. The model throws light on two salient features of external adjustment under the GS: First, external adjustment under the GS was closely intertwined with its sectoral structure. Second, the terms of trade remained relatively stable during external adjustments under the GS, while the domestic price level deflated. This section shows how both of these features are naturally accommodated by a two-sector model with distribution services.[66] Finally, counterfactual simulations based on an estimated version of the extended model also constitute a robustness check for the papers main result (see Online Appendix III.7.2).

To keep the model description short, it focuses on the H region where possible. F equations are analogs to the H ones, and foreign variables are denoted by an asterisk. Small letters denote real variables, defined as $x = X/P$ and $x^* = X^*/P^*$.

The extension mainly affects the households' decision regarding the allocation of expenses on different consumption bundles, as well as the price dynamics and the market clearing conditions. The H-households' consumption c_t consists of non-tradable goods and retail tradable goods. The retail tradable goods themselves are composed of wholesale tradable goods and non-tradable services – e.g. local retail services. Here, for simplicity, we model the final goods directly as a CES composite of wholesale tradable goods $c_{T,t}$ and non-tradable goods $c_{N,t}$: $c_t = \left[\tilde{\gamma}^{\frac{1}{\tilde{\lambda}}} c_{T,t}^{\frac{\tilde{\lambda}-1}{\tilde{\lambda}}} + (1-\tilde{\gamma})^{\frac{1}{\tilde{\lambda}}} c_{N,t}^{\frac{\tilde{\lambda}-1}{\tilde{\lambda}}}\right]^{\frac{\tilde{\lambda}}{\tilde{\lambda}-1}}$. $\tilde{\lambda}$ is the elasticity of substitution between tradable and non-tradable goods, and $\tilde{\gamma}$ reflects the households' relative preference.

The tradable goods bundle itself is a CES bundle of home produced goods $c_{H,t}$ and imported goods $c_{F,t}$: $c_{T,t} = \left[\tilde{\alpha}^{\frac{1}{\tilde{\epsilon}}} c_{H,t}^{\frac{\tilde{\epsilon}-1}{\tilde{\epsilon}}} + (1-\tilde{\alpha})^{\frac{1}{\tilde{\epsilon}}} c_{F,t}^{\frac{\tilde{\epsilon}-1}{\tilde{\epsilon}}}\right]^{\frac{\tilde{\epsilon}}{\tilde{\epsilon}-1}}$. $\tilde{\epsilon}$ denotes the elasticity of substitution between domestic and foreign goods. If $\tilde{\alpha} > n$, the household exhibits home bias.

H produced wholesale tradable goods are a combination of H produced tradable inputs $I_{H,t}$ and H produced non-tradable inputs $V_{H,t}$: $c_{H,t} = \left[\tilde{\phi}^{\frac{1}{\tilde{\psi}}} I_{H,t}^{\frac{\tilde{\psi}-1}{\tilde{\psi}}} + (1-\tilde{\phi})^{\frac{1}{\tilde{\psi}}} V_{H,t}^{\frac{\tilde{\psi}-1}{\tilde{\psi}}}\right]^{\frac{\tilde{\psi}}{\tilde{\psi}-1}}$ with $\tilde{\phi}$ denoting the

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[66] The extension is an adapted version of the model developed in Berka, Devereux and Engel (forthcoming).

weight of tradable inputs, and $\tilde{\psi}$ denoting the elasticity of substitution between tradable and non-tradable inputs. To illustrate, locally sold agricultural goods are composed of the agricultural product itsself (e.g. grain) and local services (e.g. utility and financial services).

The home consumption of imported goods is defined as $c_{F,t} = \left[\check{\phi}^{\frac{1}{\tilde{\psi}^{\star}}} I_{F,t}^{\frac{\tilde{\psi}^{\star}-1}{\tilde{\psi}^{\star}}} + (1-\check{\phi})^{\frac{1}{\tilde{\psi}^{\star}}} V_{F,t}^{\frac{\tilde{\psi}^{\star}-1}{\tilde{\psi}^{\star}}} \right]^{\frac{\tilde{\psi}^{\star}}{\tilde{\psi}^{\star}-1}}$, with $\check{\phi} \leq \tilde{\phi}$ reflecting that imported goods require more distribution services already in the region of origin. For example, selling one ton of grain locally involves less services than selling the same ton of grain overseas, because selling overseas requires finding overseas buyers through export companies, as well as more transportation services.

The tradable goods and non-tradable goods themselves are bundles of differentiated goods that are produced by the n home- and $1-n$ foreign firms: $I_{H,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\mu}} \int_0^n I_{H,t}(j)^{\frac{\mu-1}{\mu}} \,\mathrm{d}j \right)^{\frac{\mu}{\mu-1}}$, $I_{F,t} = \left(\left(\frac{1}{1-n}\right)^{\frac{1}{\mu}} \int_n^1 I_{F,t}(j)^{\frac{\mu-1}{\mu}} \,\mathrm{d}j \right)^{\frac{\mu}{\mu-1}}$, $V_{H,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\mu}} \int_0^n V_{H,t}(j)^{\frac{\mu-1}{\mu}} \,\mathrm{d}j \right)^{\frac{\mu}{\mu-1}}$, $V_{F,t} = \left(\left(\frac{1}{1-n}\right)^{\frac{1}{\mu}} \int_n^1 V_{F,t}(j)^{\frac{\mu-1}{\mu}} \,\mathrm{d}j \right)^{\frac{\mu}{\mu-1}}$, where j is the firm index and μ is the elasticity of substitution between goods produced in the same region. Direct consumption of non-tradable goods is defined in the same way: $c_{N,t} = \left(\left(\frac{1}{n}\right)^{\frac{1}{\mu}} \int_0^n c_{N,t}(j)^{\frac{\mu-1}{\mu}} \,\mathrm{d}j \right)^{\frac{\mu}{\mu-1}}$, $c_{N,t} = \left(\left(\frac{1}{1-n}\right)^{\frac{1}{\mu}} \int_n^1 c_{N,t}(j)^{\frac{\mu-1}{\mu}} \,\mathrm{d}j \right)^{\frac{\mu}{\mu-1}}$.

The H consumer price index is then given by $P_t = \left[\tilde{\gamma} P_{T,t}^{1-\tilde{\lambda}} + (1-\tilde{\gamma}) P_{N,t}^{1-\tilde{\lambda}} \right]^{\frac{1}{1-\tilde{\lambda}}}$. $P_{T,t}$ is the local wholesale price of tradable consumption goods $c_{T,t}$: $P_{T,t} = \left[\tilde{\alpha} \tilde{P}_{H,t}^{1-\tilde{\epsilon}} + (1-\tilde{\alpha}) \tilde{P}_{F,t}^{1-\tilde{\epsilon}} \right]^{\frac{1}{1-\tilde{\epsilon}}}$, where $\tilde{P}_{H,t}$ and $\tilde{P}_{F,t}$ are the prices for H-produced and imported goods, inclusive of prices for the tradable inputs $P_{H,t}$, $P^{*}_{F,t}$, as well as the prices for the non-tradable inputs $P_{N,t}$, $P^{*}_{N,t}$.

We have $\tilde{P}_{H,t} = \left[\tilde{\phi} P_{H,t}^{1-\tilde{\psi}} + (1-\tilde{\phi}) P_{N,t}^{1-\tilde{\psi}} \right]^{\frac{1}{1-\tilde{\psi}}}$ and $\tilde{P}_{F,t} = \left[\check{\phi} (P^{*}_{F,t}/e_t)^{1-\tilde{\psi}} + (1-\check{\phi}) (P^{*}_{N,t}/e_t)^{1-\tilde{\psi}} \right]^{\frac{1}{1-\tilde{\psi}}}$. The prices for the H- and F-produced goods bundles are $P_{H,t} = \left[\frac{1}{n} \int_0^n P_{H,t}(j)^{1-\mu} \,\mathrm{d}j \right]^{\frac{1}{1-\mu}}$ and $P^{*}_{F,t} = \left[\frac{1}{1-n} \int_n^1 P^{*}_{F,t}(j)^{1-\mu} \,\mathrm{d}j \right]^{\frac{1}{1-\mu}}$ respectively. The prices of H- and F-produced non-tradable goods are $P_{N,t} = \left[\frac{1}{n} \int_0^n P_{N,t}(j)^{1-\mu} \,\mathrm{d}j \right]^{\frac{1}{1-\mu}}$ and $P^{*}_{N,t} = \left[\frac{1}{1-n} \int_n^1 P^{*}_{N,t}(j)^{1-\mu} \,\mathrm{d}j \right]^{\frac{1}{1-\mu}}$. It is worth pointing out that the law of one price does not hold due to distribution service costs.

On the production side, firms' optimization problem is only slightly affected by the extension. It is assumed that there exist sector-specific technology shocks – A_t for the tradable sector and $A_{N,t}$

for the non-tradable sector. Depending on whether the firm is operating in the tradable goods or the non-tradable goods sector, it has the chance to reset its price with probability $(1-\theta_T)$ or $(1-\theta_N)$. When it can change prices, it optimizes over $P_{H,t}(j)$ or $P_{N,t}(j)$ while taking into account its demand schedule and production function. Thus, firm j's optimization problem in the tradable sector is

$$\max_{P_{H,t}(j)} \quad \mathbb{E}_t \sum_{k=0}^{\infty} \left\{ (\beta\theta_T)^k \, \frac{\lambda_{t+k}}{\lambda_t} \, \frac{P_t}{P_{t+k}} \left[P_{H,t}(j) y_{T,t+k}(j) - w_{t+k} P_{t+k} l_{T,t+k}(j) \right] \right\} \tag{B.1}$$

$$\text{s.t.} \;\; y_{T,t+k}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t+k}} \right)^{-\mu} y_{T,t+k} \tag{B.2}$$

$$y_{T,t+k}(j) = A_{t+k} l^{\gamma}_{T,t+k}(j) \tag{B.3}$$

where l_T and y_T denote H primary sector employment and average output. The resulting first order conditions and price dynamics are very similar to those of the model without the sectoral structure. The optimization of a firm in the non-tradable sector is analogous.

The labor market clearing conditions now include the labor employed in the tradable and the non-tradable sector:

$$\Delta^P_{T,t}\, n\, y_{T,t}^{\frac{1}{\gamma}} = l_{T,t}\, n_t\, A_t^{\frac{1}{\gamma}} \tag{B.4}$$

$$\Delta^P_{N,t}\, n\, y_{N,t}^{\frac{1}{\gamma}} = l_{N,t}\, n_t\, A_{N,t}^{\frac{1}{\gamma}} \tag{B.5}$$

$$l_t = l_{T,t} + l_{N,t}, \tag{B.6}$$

with the measures for price dispersion $\Delta^P_{T,t} = \frac{1}{n}\int_0^n \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{\frac{-\mu}{\gamma}} dj$ and $\Delta^P_{N,t} = \frac{1}{n}\int_0^n \left(\frac{P_{N,t}(j)}{P_{N,t}}\right)^{\frac{-\mu}{\gamma}} dj$.

The goods market clearing conditions take into account tradable and non-tradable goods:

$$n\, y_{T,t}(j) = n_t\, I_{H,t}(j) + (1-n_t) I^*_{H,t}(j) \tag{B.7}$$

$$n\, y_{N,t}(j) = n_t\, c_{N,t}(j) + n_t\, V_{H,t}(j) + (1-n_t) V^*_{H,t}(j) \tag{B.8}$$

$$(1-n)\, y^*_{T,t}(j) = n_t\, I_{F,t}(j) + (1-n_t) I^*_{F,t}(j) \tag{B.9}$$

$$(1-n)\, y^*_{N,t}(j) = (1-n_t)\, c^*_{N,t}(j) + (1-n_t) V^*_{F,t}(j) + n_t\, V_{F,t}(j) \tag{B.10}$$

Finally, real output y_t is defined as the weighted average of tradable and non-tradable sector output: $y_t = \frac{P_{H,t}}{P_t} y_{T,t} + \frac{P_{N,t}}{P_t} y_{N,t}$. This average output enters the monetary policy reaction functions, as well as the money demand equations.

B.1. *Terms of trade and local prices*

Section 7.2 in the main text describes the price movements that accompanied external adjustment under the GS. The following uses the extended model to discuss the substitution effects that each of these price movements gives rise to. The terms of trade in the extended model measures the ratio of export prices to import prices at the port. The log-linearized terms of trade is

$$\widehat{ToT}_t = \hat{\tilde{P}}^{\star}_{H,t} - \hat{\tilde{P}}_{F,t}.$$

The CPI in the extended model can also be written as follows (see equation 5 in the main text):

$$\hat{P}_t = (1 - \check{\gamma})\hat{P}_{N,t} + \check{\gamma} \left[\check{\alpha} \hat{\tilde{P}}_{H,t} + (1 - \check{\alpha}) \hat{\tilde{P}}_{F,t} \right],$$

with $\check{\gamma} \equiv \tilde{\gamma} \left(\frac{P_T}{P} \right)^{1-\tilde{\lambda}}$ and $\check{\alpha} \equiv \tilde{\alpha} \left(\frac{\tilde{P}_H}{P_T} \right)^{1-\tilde{\epsilon}}$.

How do the different price components that define the terms of trade and the CPI affect real imports and real exports? From the model, we have the following demand schedules that describe how prices affect *H*-households' and *F*-households' demand for imported goods:

$$c_{F,t} = (1 - \tilde{\alpha}) \left(\frac{\tilde{P}_{F,t}}{P_{T,t}} \right)^{-\tilde{\epsilon}} c_{T,t}, \quad c^{\star}_{H,t} = (1 - \tilde{\alpha}^{\star}) \left(\frac{\tilde{P}^{\star}_{H,t}}{P^{\star}_{T,t}} \right)^{-\tilde{\epsilon}^{\star}} c^{\star}_{T,t}.$$

Using these demand schedules, we can write the log-linearized real imports to H ($IM_t = c_{F,t} n_t$) as

$$\begin{aligned} \widehat{IM}_t &= \hat{c}_{T,t} + \hat{n}_t - \tilde{\epsilon} \left(\hat{\tilde{P}}_{F,t} - \hat{P}_{T,t} \right) \\ &= \hat{c}_{T,t} + \hat{n}_t - \tilde{\epsilon} \tilde{\alpha} \left(\frac{\tilde{P}_H}{P_T} \right)^{1-\tilde{\epsilon}} \left(\hat{\tilde{P}}_{F,t} - \hat{\tilde{P}}_{H,t} \right), \end{aligned}$$

where the second line makes use of the relation $\hat{P}_{T,t} = \tilde{\alpha} \left(\frac{\tilde{P}_H}{P_T} \right)^{1-\tilde{\epsilon}} \hat{\tilde{P}}_{H,t} + (1 - \tilde{\alpha}) \left(\frac{\tilde{P}_F}{P_T} \right)^{1-\tilde{\epsilon}} \hat{\tilde{P}}_{F,t}$, as well as the steady state definition of P_T. The equation demonstrates that a unit drop in the import price ($\hat{\tilde{P}}_{F,t}$) is associated with an increase in imports of $\tilde{\epsilon}\tilde{\alpha}\left(\frac{\tilde{P}_H}{P_T}\right)^{1-\tilde{\epsilon}}$. Furthermore, a unit increase in the local price of tradable goods ($\hat{\tilde{P}}_{H,t}$) would have exactly the opposite effect on imports. As discussed in section 7.2, during major external adjustments, the local price of tradable goods falls by more than the import price. This implies a net reduction in H-imports.

Real H-exports ($EX_t = c^{\star}_{H,t} n^{\star}_t$) in log-linearized form can be written as

$$\begin{aligned}\widehat{EX}_t &= \hat{c}^{\star}_{T,t} + \hat{n}^{\star}_t - \tilde{\epsilon}^{\star}\left(\hat{\tilde{P}}^{\star}_{H,t} - \hat{P}^{\star}_{T,t}\right) \\ &= \hat{c}^{\star}_{T,t} + \hat{n}^{\star}_t - \tilde{\epsilon}^{\star}\tilde{\alpha}^{\star}\left(\frac{\tilde{P}^{\star}_F}{P^{\star}_T}\right)^{1-\tilde{\epsilon}^{\star}}\left(\hat{\tilde{P}}^{\star}_{H,t} - \hat{\tilde{P}}^{\star}_{F,t}\right),\end{aligned}$$

where the second line makes use of the relation $\hat{P}^{\star}_{T,t} = \tilde{\alpha}^{\star}\left(\frac{\tilde{P}^{\star}_F}{P^{\star}_T}\right)^{1-\tilde{\epsilon}^{\star}}\hat{\tilde{P}}^{\star}_{F,t} + (1-\tilde{\alpha}^{\star})\left(\frac{\tilde{P}^{\star}_H}{P^{\star}_T}\right)^{1-\tilde{\epsilon}^{\star}}\hat{\tilde{P}}^{\star}_{H,t}$, as well as the steady state definition of $P^{\star}_T$. A one unit decrease in the H-export price ($\hat{\tilde{P}}^{\star}_{H,t}$) leads to an increase in the foreign demand for H-produced tradable goods of $\tilde{\epsilon}^{\star}\tilde{\alpha}^{\star}\left(\frac{\tilde{P}^{\star}_F}{P^{\star}_T}\right)^{1-\tilde{\epsilon}^{\star}}$.

For an equal fall in H-import prices ($\hat{\tilde{P}}_{F,t}$) and H-export prices ($\hat{\tilde{P}}^{\star}_{H,t}$), the increase in exports will exceed the increase in imports. The reason for this is that the H-region is smaller than the F-region ($n < 1 - n \equiv n^{\star}$). Absent home bias (i.e. $n = \tilde{\alpha}$ and $n^{\star} = \tilde{\alpha}^{\star}$), this implies that a fall in export prices increases exports by more than an equivalent fall in import prices increases imports. This remains the case for all realistic degrees of home bias.[67]

B.2. *Sectoral structure and external adjustment: model vs. data*

Here, in order to show that the extended model naturally accommodates features of external adjustment under the GS, we compare simulated moments to the data. For the most part, the extended model is calibrated according to the baseline model estimation for the U.K. (see Table 1, Table 3 and Table 4).

The extended model's additional parameters are calibrated as follows: The shares of tradable goods in final consumption ($\tilde{\gamma}, \tilde{\gamma}^{\star}$) are calibrated to target the U.K.'s share of tradable value

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[67] Only extreme degrees of home bias in the H region, and an extreme preference of the F region for H goods can overturn this.

added relative to total value added (47%), and the sample average of tradable value added relative to total value added (40%). For this we rely on the sectoral share data provided by Buera and Kaboski (2012), defining services as non-tradable and all other sectors as tradable. The weights of domestically produced goods in tradable goods ($\tilde{\alpha}, \tilde{\alpha}^{\star}$) are calibrated to target the U.K. import-to-GDP and export-to-GDP ratios, as in the baseline model calibration. According to input-output tables the share of non-tradable inputs in tradable goods ($1 - \tilde{\phi}$) was around 10% during the GS era. More specifically, based on the Swedish input-output table for 1913 (Bohlin, 2007), non-tradable inputs to the tradable sector amounted to 5.4% of the total tradable sector's output. The corresponding number for the U.K., as calculated from the British input-output table for 1907 (Meyer, 1955), is higher, at 11.3%.[68] Thus, a value of 10% for $1 - \tilde{\phi}$ is of the right order of magnitude. For export goods, $\check{\phi}$ is chosen to reflect a 40% transportation cost, which implies that the export good consists of 60% tradable wholesale goods.[69]

Concerning the intra-temporal elasticity, we follow Berka, Devereux and Engel (forthcoming) in assuming an elasticity of substitution between tradable goods and non-tradable goods of 0.7 ($\tilde{\lambda} = \tilde{\lambda}^{\star} = 0.7$), an elasticity of substitution between tradable goods and services of 0.25 ($\tilde{\psi} = \tilde{\psi}^{\star} = 0.25$), and a trade elasticity of 8 ($\tilde{\epsilon} = \tilde{\epsilon}^{\star} = 8$).[70]

The introduction of a sectoral structure also results in four Phillips curves, that determine the price

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[68] As $\tilde{\phi}$ reflects the non-tradable input in a wholesale product, we would ideally distinguish retail distribution services from other non-tradable inputs. However, the historical input-output tables for Sweden and the U.K. do not provide this degree of granularity.

[69] This is in line with origin-destination spreads for agricultural produce (Wilson and Dahl, 2011). For example, the price spread between corn prices in Minneapolis (the origin region) and corn prices in Georgia or the Pacific North West (ports for export) lies in the 12 to 25% range (Yu et al., 2006). On top of this, international overseas transport under the GS drove another 10 to 20% wedge between origin and destination port prices (see Persson, 2004).

[70] The higher elasticity estimates obtained from industry- and product-level data are more relevant for the two-sector model, whereas the lower trade elasticity estimates obtained from aggregate trade data are more in line with the single good baseline model (see Bas, Mayer and Thoenig, 2017).

evolution of $P_{H,t}$, $P_{N,t}$, $P^{\star}_{H,t}$, and $P^{\star}_{N,t}$. To reflect the price rigidity in the non-tradable sector, we set the Phillips curve slopes for the non-tradable goods $\widetilde{\kappa}_N$, and $\widetilde{\kappa}^*_N$ to 0.05. This value corresponds to an average price duration of around 4.5 quarters, which is within the range of price rigidity estimates for advanced economies today. The Phillips curve slopes for the tradable goods are set to target a weighted average Phillip curve slope (weighted according to value-added sector shares), which equals the aggregate Phillips curve slope of 0.35 in the baseline estimation. This results in $\widetilde{\kappa}_T = \widetilde{\kappa}^*_T = 0.65$.

The simulation results are presented in Table B.1. As in the data, increases in the CA/GDP ratio in the model are associated with an increase in tradable sector size and a decrease in non-tradable sector size (Table B.1 panel A). The sectoral prices in the model also behave similarly to the data: the tradable prices drop during external adjustments while non-tradable prices stay more stable (panel B). The model is able to generate a relatively stable terms of trade and a larger fall in the CPI when the CA/GDP ratio increases (panel C). Finally, the model matches the observed correlation between export and import prices (panel D).

Table B.1: *Correlation between external adjustments, sectoral size and prices*

	Δ CA / GDP	
	Model	Data
Panel A: Sectoral sizes		
ΔTradable sector share	0.49	0.11
Δ Non-tradable sector share	-0.49	-0.08
Panel B: Sectoral prices		
Δ Tradable prices	-0.36	-0.22
Δ Non-tradable prices	0.16	-0.05
Panel C: ToT and CPI		
Δ Terms of trade	-0.11	0.07
Δ CPI	-0.21	-0.15
Panel D: Export and import prices		
	Δ Export prices	
Δ Import prices	0.52	0.59

Notes: The model moments are calculated on the basis of 2000 34-year simulations of the extended model. For more details on the stochastic simulation, see Section 6. Non-tradable sector share was approximated by tertiary sector share. Tradable sector share was approximated by primary sector share. Tradable prices were approximated by agricultural and raw material prices. Non-tradable prices were approximated by service sector prices.