Exchange-Rate Regimes and Large Exporter-Importers

Cosimo Petracchi[*]

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MOST UP-TO-DATE VERSION

Abstract

I characterize exchange-rate regime breaks for thirty countries over the 1960-2019 period, and I document how they affect the volatilities of nominal and real exchange rates without changing the volatilities of other real macro variables, even in countries that are more open than the United States to international trade. Then, I propose a general equilibrium model that does not rely on countries' openness to international trade to demonstrate a muted reaction of other real macro variables to nominal- and real-exchange rate movements across exchange-rate regime breaks. The model generates a muted reaction by considering large exporters who are simultaneously large importers, creating a natural hedging mechanism.

[*]Department of Economics, Brown University, 64 Waterman Street, Providence, RI 02906, cosimo_petracchi@brown.edu. I am grateful to Gauti B. Eggertsson, Matteo Maggiori, and Pascal Michaillat for invaluable advice. I am also indebted to Fernando Duarte, Oded Galor, Amy Handlan, Masayuki Inui, Toru Kitagawa, Yann Koby, Alessandro Lin, Abdoulaye Ndiaye, Valerio Nispi Landi, Luca Riva, and participants in the Brown University Macroeconomics Graduate-Student Seminar for helpful comments and insightful suggestions.

1 Introduction

A large literature in international macroeconomics and finance attempts to evaluate the effects of different exchange-rate regimes, but the focused natural experiment—the exogenous shock at the macro level—for most of these attempts is the monetary-policy break in the US regime when the Bretton Woods system broke down in 1973.[1] My paper goes beyond the breakdown of the Bretton Woods system and offers a more exhaustive understanding of exchange-rate regimes by presenting a novel link—between macro facts regarding exchange-rate regimes and micro evidence regarding international trade—inside a general equilibrium model.

First, I propose a new characterization of exchange-rate regimes, based on the exchange rates of thirty countries from 1957 to 2019. For all these economies, I show that structural breaks in the volatility of trade-weighted nominal exchange rates are systematically associated with structural breaks in the volatility of trade-weighted real exchange rates, which allows me to consider a larger set of exchange-rate regime breaks than the breakdown of the Bretton Woods system. Second, I show a muted reaction of real macro variables—but not the real exchange rate—to exchange-rate regime breaks. The muted reaction is present even though I consider countries that are more open to international trade than the United States.

Exchange-rate regime breaks are notoriously hard to model because they are not statistically significantly correlated with real macro variables, other than the real exchange rate, and the challenge becomes more difficult to model when a country is very open to international trade. Indeed, the muted reaction of real macro variables in the theoretical model of influential recent papers—Itskhoki and Mukhin (2021, 2022)—arises because their calibration targets the US economy, which has been one the most closed economies in the world, with an average import-to-GDP ratio of about 9% over the 1960-2019 period.[2] I show that model is not able to replicate muted effects of a exchange-rate regime break when one calibrates to a very open economy such as Belgium. Fortunately, there is a very natural way to fix the result by taking advantage of Amiti, Itskhoki, and Konings's (2014) micro evidence on large exporters that are simultaneously large importers. I am then able to model exchange-rate regime breaks for very open economies in general equilibrium, under financial-market segmentation, with deviations from the law of one price, and with large exporter-importers. That last feature is fundamental to match the observed muted reaction of real macro variables. My model is thus the missing link in the literature between the empirical macro facts on exchange-rate regimes and the micro evidence coming from international trade.

Figure 1, depicting time series for Belgium over the 1960–2019 period, motivates my analysis. Panel (a) plots the bilateral nominal exchange rate between Belgium and Germany (in magenta) and the trade-weighted nominal exchange rate between Belgium and the rest of the world (in blue). Both series are in levels, at a quarterly frequency.

[1] Examples include Friedman (1953), Mussa (1986), Baxter and Stockman (1989), Monacelli (2004), Ayres, Hevia, and Nicolini (2021), and Itskhoki and Mukhin (2022).

[2] Itskhoki and Mukhin (2021, 2022) have other examples of more open economies than the US, but they do not consider very open economies.

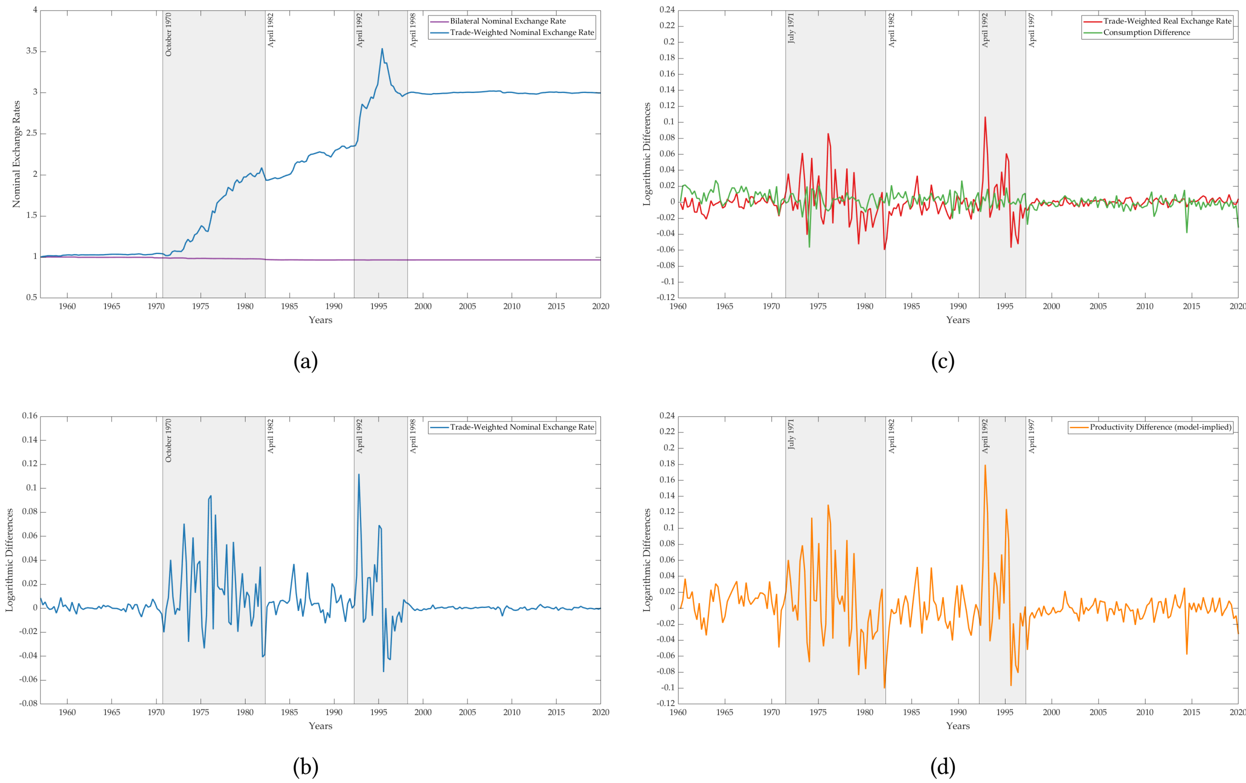


Figure 1: Belgium (1960-2019)

Notes for Panels (a) and (b): The bilateral nominal–exchange rate series between Belgium and Germany is in magenta, and the trade-weighted nominal–exchange rate series between Belgium and the rest of the world is in blue; I normalize the two series such that they are both equal to 1 in the first quarter of 1960. The vertical lines represent exchange-rate regime breaks that are identified in the trade-weighted nominal–exchange rate series in logarithmic differences. For details, see Section 2. I shade the periods with floating regimes in the trade-weighted nominal–exchange rate series.
Notes for Panels (c) and (d): The trade-weighted real–exchange rate series is in red, the real consumption-difference series is in green, and the model-implied productivity-difference series is in orange. I use Equation (23) in Itskhoki and Mukhin (2021) to construct the model-implied productivity-difference series: I set the openness-to-international-trade parameter γ equal to 0.25 to match Belgium's average imports-to-GDP ratio over the 1960–2019 period, keeping all the other model parameters unchanged. The vertical lines represent exchange-rate regime breaks that are identified in the trade-weighted real–exchange rate and model-implied productivity-difference series. For details, see Section 2. I shade the periods with floating regimes in the trade-weighted real–exchange rate series and model-implied productivity-difference series.
Sources: The Bank of Italy's Exchange Rates Portal, the International Monetary Fund's Direction of Trade Statistics and International Financial Statistics, and the Organisation for Economic Co-operation and Development's OECD.Stat. For details, see Section 2.

Panel (b) plots the trade-weighted nominal exchange rate between Belgium and the rest of the world in logarithmic difference, at a quarterly frequency. The two series suggest a novel point of view.[3]

Belgium's regime is typically considered pegged for the entire period.[4] Indeed, it was pegged if one simply considers the bilateral nominal exchange rate between Belgium and Germany, the reference country for the Belgian economy, as shown in Panel (a). But if one considers the trade-weighted nominal exchange rate between Belgium and the rest of the world, the broader picture completely changes. The trade-weighted nominal–exchange rate series presents four structural breaks in volatility that define five exchange-rate regimes: a pegged regime from

[3]See Section 2 for more details about the construction of the series and characterization of exchange-rate regimes.
[4]See Ilzetzki, Reinhart, and Rogoff (2019) and Petracchi (2022).

1960 to 1970, a floating regime from 1970 to 1982, a pegged regime from 1982 to 1992, a floating regime from 1992 to 1998, and a pegged regime from 1998 to 2019. Crucially, the four exchange-rate regime breaks are present not because of Belgian-German bilateral exchange-rate regime breaks but because of Belgium's trading partners, which experienced exchange-rate regime breaks in relation to Germany; as a consequence, they can be interpreted as macro-level shocks exogenous to Belgian monetary policy and its economic conditions, offering a setting to identify the effects of different exchange-rate regimes.[5]

Moreover, Belgium has been one of the most open economies in the world, with an average import-to-GDP ratio of about 51% over the 1960–2019 period, representing an ideal economy to test the absence of statistically significant correlation between real macro variables and exchange-rate regime breaks. Panel (c) in Figure 1 plots Belgium's trade-weighted real–exchange rate series and its real-consumption-difference series, at a quarterly frequency, for the 1960–2019 period. Both series are in logarithmic difference and represent Belgium versus the rest of the world. The trade-weighted real–exchange rate series presents four structural breaks in volatility, corresponding to the four exchange-rate regime breaks in the Belgian trade-weighted nominal exchange rate, whereas the real-consumption-difference series presents no structural breaks: the absence of statistically significant correlation is confirmed—even in an economy that is very open to international trade—since the macro-level shocks do not alter the volatility of the real-consumption-difference series.[6]

If one adopts the theoretical model in Itskhoki and Mukhin (2021, 2022), its prediction is implausible. Panel (d) in Figure 1 plots the model-implied productivity-difference series for the 1960–2019 period, in logarithmic difference, representing Belgium versus the rest of the world.[7] If one wants to explain the two series in Panel (c) using the model, the productivity-difference series has to change in volatility at the structural breaks of the trade-weighted real exchange rate in order to match the fact that the consumption-difference series does not jump. This unrealistic result is driven by two empirical characteristics of the Belgian data: the four exchange-rate regime breaks in its trade-weighted exchange rate series, and its very high openness to international trade.[8]

In the first part of the paper, using exchange rates covering thirty countries from 1957 to 2019, I propose a new characterization of exchange-rate regimes in open economy—understood as exchange rate regimes—that is based on a heteroskedasticity-based approach only. In standard bilateral classifications, the definition of exchange-

[5]This a much stronger identification strategy than in a standard regression-discontinuity design, where the identification does not rely on the exogeneity of the exchange-rate regime break but only requires that potential confounders evolve continuously around the exchange-rate regime breaks.

[6]Another way to interpret the upper part of Figure 2 is that complete-market models with nominal price rigidity (for example, Monacelli, 2004) are not able to match the muted reaction of the real consumption-difference series to exchange-rate regime breaks since they cannot violate the Backus and Smith (1993) condition of efficient international risk sharing.

[7]I use Equation (23) in Itskhoki and Mukhin (2021) to construct the model-implied productivity-difference series. I set the openness-to-international-trade parameter γ equal to 0.25 to match Belgium's average imports-to-GDP ratio over the 1960–2019 period, keeping all the other model parameters unchanged.

[8]Similarly to footnote 6, another way to interpret Panel (d) in Figure 1 is that imperfect-financial-market models, with or without nominal price rigidity (for example, Itskhoki and Mukhin, 2021, 2022), are not able to match the muted reaction of the real consumption-difference series to exchange-rate regime breaks since the volatility of the real exchange rate is transmitted to the rest of the economy when real factor markets clear.

rate regime for a given country relies on its central bank's decision to keep the currency pegged to a reference currency or floating. Bilateral classifications thus identify exchange-rate regime breaks—exogenous shocks at the macro level—when one of the two central banks changes its decision and induces a simultaneous volatility break in the bilateral series of the nominal and real exchange rates.[9] The building-block result of my new characterization is the identification of the structural breaks in the volatility of the trade-weighted nominal and real exchange rates by means of a structural break test only. The crucial result is that every break in the set of structural breaks in the volatility of the trade-weighted nominal exchange rate series corresponds with a structural break in the volatility of the trade-weighted real exchange rate series: this represents the first empirical contribution of the paper, the so-called Mussa puzzle for the trade-weighted exchange rates.[10]

Second, the ultimate effects of exchange-rate regime breaks can be evaluated for the thirty countries thanks to my new characterization of exchange-rate regimes. I consider other real macro-variable time series (output, consumption, investment, and net exports) to investigate what happens to real variables across exchange-rate regime breaks. It turns out that moving from pegged to floating regimes increases, in a statistically significant way, the volatility of only one real variable: the real exchange rate. Importantly, this result does not depend on countries' openness to international trade—that is, the amount of trade a country has with its trading partners—since very open economies are present in my data set. This marks the second empirical contribution of the paper: I demonstrate so-called exchange rate disconnect in economies that are more open to international trade than the United States.[11]

The challenge is to explain how, when a country moves from a pegged to a floating regime, the enormous volatility of the real exchange rate is not transmitted to other real macro variables. Can we find a set of assumptions that ensure the consistency of a theoretical model with the empirical evidence for a very open economy? The answer is yes. The three assumptions are as follows:

1. Financial markets are imperfect, following Gabaix and Maggiori (2015). In any complete-market model, the Backus and Smith (1993) condition of efficient international risk sharing holds, making the consumption difference comoves with the real exchange rate. This result is falsified empirically as Panel (c) of Figure 1 depicts. Moreover, this assumption guarantees that the financial element of the model matches a set of empirical facts, coming from the finance literature, the most relevant of which is room for deviations from uncovered interest parity (UIP).

2. There are deviations from the law of one price in the form of variable markups and local currency pricing,

[9] Traditionally, the United States has been the reference country for non-European countries, whereas Germany has been the reference country for European countries; see Ilzetzki, Reinhart, and Rogoff (2019) and Petracchi (2022).

[10] Using bilateral time series primarily on the United States and thirteen advanced countries for the period 1957–84, Mussa (1986) documents what is now referred to as "the Mussa Puzzle": the 1973 breakdown of the Bretton Woods system increased the volatility of not only the nominal US-dollar exchange rate but the real US-dollar exchange rate, which implies monetary non-neutrality.

[11] The phrase "exchange rate disconnect" generically refers to the lack of correlation between exchange rates and other macro variables; see Obstfeld and Rogoff (2000) and Itskhoki (2021).

following the empirical trade literature. For instance, Goldberg and Verboven (2001, 2005) find not only that the law of one price does not hold and that firms fix prices in the currency of the market in which they sell their products but that firms absorb the exchange rate shocks thanks to a local component in marginal costs and markup adjustment.

3. Large exporters are simultaneously large importers, following Amiti, Itskhoki, and Konings (2014), who use Belgian firm-product-level data on imports and exports for the 2000–2008 period. The introduction of this feature is the key ingredient to match observed exchange rate disconnect in a very open economy inside a general equilibrium model. It is not only theoretically appealing but empirically plausible looking at the stylized facts about the Belgian economy in Amiti, Itskhoki, and Konings (2014). First, there is evidence that 78% of exporters in Belgium also import goods and, more crucially, that (i) the exporters who intensively import goods account for 83% of all Belgian exports. Second, there is direct evidence that (ii) the ratio between imported inputs and exports is 74% for the import-intensive exporters. In other words, the import-intensive exporters account for a disproportionately large share of exports and are able to not adjust their product prices, thereby offsetting the exchange rate movements to foreign consumers by means of imported inputs in the marginal-cost channel.

Finally, using data on Belgium for the 1960–2019 period, I show that the theoretical model of Itskhoki and Mukhin (2021, 2022) is not able to match the observed exchange rate disconnect, because of the excess volatility in the real macro variables, whereas my model can reproduce the Mussa puzzle and exchange rate disconnect without compromising the fit to other business cycle moments.

Literature. My paper contributes to several strands of literature. First, the new characterization of exchange-rate regimes in the context of trade-weighted exchange rates goes beyond the monetary non-neutrality arising from bilateral exchange rates as seen in the Mussa puzzle (Mussa, 1986) and its generalization (Petracchi, 2022). Second, my analysis of real macro variables in relation to exchange-rate regime breaks connects to the literature on exchange rate disconnect, in particular Obstfeld and Rogoff (2000), and focuses on economies that are more open to international trade than the United States.[12] Finally, my theoretical model is closely related to the exchange rate portfolio-balance literature, primarily Gabaix and Maggiori (2015), and to the strand of literature that tries to evaluate the effects of different exchange-rate regimes in an open economy, in particular Itskhoki and Mukhin (2022).[13]

Outline. Section 2 establishes empirical facts on exchange-rate regimes in open economy. In Section 3, I present the general equilibrium model with exporters that directly and intensively import their intermediate inputs. Section 4 concludes. Supplementary details and proofs are relegated to the Appendix.

[12] See also Backus and Smith (1993), Chahrour et al. (2022), and Itskhoki and Mukhin (2021).

[13] For the first literature, see also Kouri (1976) and Itskhoki and Mukhin (2021); for the second one, see also Friedman (1953), Baxter and Stockman (1989), Monacelli (2004), Benigno, Benigno, and Ghironi (2007), Benigno and Benigno (2008), and Ayres, Hevia, and Nicolini (2021).

2 Empirical Facts and Exchange-Rate Regimes

In Section 2.1, I introduce a new characterization of exchange-rate regimes in open economy, based on thirty countries from 1957 to 2019, and provide novel evidence for the Mussa puzzle in the context of trade-weighted exchange rates. In Section 2.2, I consider real-macro-variable time series—output, consumption, investment, and net exports—of the thirty countries to show that exchange rate disconnect remains persistent across exchange-rate regimes.

Data. I use quarterly data covering thirty countries—twenty-four European countries and six non-European G20 countries—from 1957 to 2019:[14] twenty-one European Union member countries, Norway, Switzerland, the United Kingdom, Australia, Brazil, Canada, Japan, South Africa, and the United States.[15]

2.1 A New Characterization of Exchange-Rate Regimes

I begin by constructing trade-weighted exchange rates with a twofold purpose. First, they allow me to empirically evaluate the magnitude of exchange rate shocks, for any given country in relation to its trading partners, which have to be considered in general equilibrium models. Second, they allow me to introduce a new characterization of exchange-rate regimes in open economy, where I identify exchange-rate regime breaks through a heteroskedasticity-based approach. This new characterization forms the backbone of my critical assessment of exchange rate disconnect across exchange-rate regimes in Section 2.2.

Monthly time-series data on bilateral nominal exchange rates come from the Exchange Rates Portal of the Bank of Italy; I use the Deutsche Mark as the reference currency for the studied European countries and the US dollar for the non-European G20 countries. I obtain the bilateral nominal–exchange rate time series for each European country by combining the dollar/Deutsche Mark time series and the dollar/euro time series after December 2001, at which time 1 euro was worth 1.95583 Deutsche Marks, with the various other dollar/foreign-currency time series.[16] I then convert monthly nominal exchange rates to quarterly ones and combine them, using the trade weights from the International Monetary Fund's Direction of Trade Statistics, to obtain trade-weighted nominal exchange rates.[17] Finally, I combine the latter rates with quarterly CPIs from the International Monetary Fund's International Financial Statistics, using the same weights as above, to obtain CPI-based trade-weighted real exchange rates.[18]

[14]Complete data for all the considered countries are not available. A list of time periods for each country's variable can be found in Table 6 in Appendix A.2.

[15]The twenty-four studied member countries of the European Union are Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany (West Germany before October 1990), Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, the Slovak Republic, Slovenia, Spain, and Sweden.

[16]If a currency was renominated—for example, the French franc in January 1960—I normalized the series in order to remove the ensuing jump.

[17]For any given country, I use as weights the mean values of its exports and imports, averaged over the 1957-2019 period, to and from Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

[18]For brevity, from here on, I use the phrase "the rest of the world" (home country) to indicate Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States; the term "nominal exchange rate" to refer to the trade-weighted nominal exchange rate; and the term "real

Next, I identify the exchange-rate regime breaks by applying the heteroskedasticity-break test, developed by Lavielle (1999) and Lavielle and Moulines (2000), to the first difference of the natural logarithm of the nominal exchange rate, Δe_t, and the first difference of the natural logarithm of the real exchange rate, Δq_t, which are formally defined as follows:

$$\Delta q_t = \Delta e_t + \pi_t^* - \pi_t.$$

Here, $q_t = ln(\mathcal{Q}_t)$, $e_t = ln(\mathcal{E}_t)$, and $\pi_t^* - \pi_t$ is the difference between the inflation rate in the foreign country, $\pi_t^* = ln(P_t^*) - ln(P_{t-1}^*)$, and the inflation rate in the rest of the world (home country), $\pi_t = ln(P_t) - ln(P_{t-1})$.[19]

The test yields the results for Belgium that are reported in the third column of Table 1. Table 1, together with Table 7, which reports the results for all the other studied countries, represents the first main empirical result of this paper. The heteroskedasticity-break test identifies structural breaks in the exchange rate series that characterize two types of exchange-rate regime: periods of low exchange rate volatility (pegged regimes) and periods of high exchange rate volatility (floating regimes).[20]

This new characterization of exchange-rate regimes in open economy confirms the Mussa puzzle for the reference-currency countries (Germany and the United States) and countries that formally switched their exchange-rate regime from pegged to floating or vice versa (for example, Brazil and the Czech Republic). It also shows the puzzle for economies that never formally switched in the studied period—for example, Austria and Belgium. For two reasons, this turns out to be crucial for understanding how exchange-rate regimes affect the real economy. First, in the economies that did not switch, the exchange-rate regime breaks are exogenous to their monetary-policy decisions and domestic economic conditions, offering a novel setting to identify the effects of different exchange-rate regimes.[21] Second, Tables 1 and 6 identify exchange-rate regime breaks, and hence changes from periods of low volatility of the exchange rate series to periods of high volatility (and vice versa), for countries that are very open to international trade, offering an ideal setting to test exchange rate disconnect. In other words, does real macro variables' volatility vary across exchange-rate regimes?

2.2 Exchange Rate Disconnect across Exchange-Rate Regimes

Quarterly time-series data on real macro variables—output, consumption, investment, exports, and imports—come from the Organisation for Economic Co-operation and Development's OECD.Stat and allow me to evaluate the effect of different exchange-rate regimes. A strand of literature, dating back to Friedman (1953), evaluates the

exchange rate" to refer to the CPI-based trade-weighted real exchange rate.

[19]A complete description of the Lavielle (1999) and Lavielle and Moulines (2000) test can be found in Appendix A.2.1.

[20]The figures for the Δe_t andΔq_t series with the identified regimes, for all the considered countries, are in Appendix A.2.1. The heteroskedasticity-break test does not always identify the structural breaks in the volatility of the nominal– and real–exchange rate series in the same quarters since it is very sensitive to observations that significantly depart from the rest.

[21]See footnote 5.

Table 1: Belgium's Exchange-Rate Regimes

Nominal Exchange Rate	Real Exchange Rate	Exchange-Rate Regime
January 1957 - September 1970	January 1957 - June 1971	Pegged Regime
October 1970 - March 1982	July 1971 - March 1982	Floating Regime
April 1982 - March 1992	April 1982 - March 1992	Pegged Regime
April 1992 - March 1998	April 1992 - March 1997	Floating Regime
April 1998 - December 2019	April 1997 - December 2019	Pegged Regime

effects of different exchange-rate regimes in an open economy and asks one of the fundamental questions in international macroeconomics and finance: what are the effects of different exchange-rate regimes? Surprisingly, though, it examines principally the breakdown of the Bretton Woods system in 1973 and neglects other, similar natural experiments. This neglect has induced researchers to focus on the United States since the breakdown of the Bretton Woods system represented a break in the US exchange-rate regime. Thus, most answers rely on an exogenous shock that happened almost fifty years ago and, more importantly, hit a country that is relatively closed to international trade.[22] This section offers a more comprehensive answer by considering thirty countries over the 1960–2019 period and including several exchange-rate regime breaks (in addition to the breakdown of the Bretton Woods system), as presented in Tables 1 and 8.

The upper part of Figure 2 plots annualized standard deviations of real exchange rates in logarithmic difference and percentage points ($\sigma(\Delta y_t)$) against annualized standard deviations of real output in logarithmic difference and percentage points ($\sigma(\Delta q_t)$). These annualized standard deviations are computed across the exchange-rate regimes presented in Tables 1 and 8; the standard deviations are in red for the pegged regimes and in blue for the floating regimes. It is easy to see that when moving from pegged to floating regimes, the volatility of real exchange rates systematically increases for all the studied countries. But it is not obvious what happens to output volatility when moving from pegged to floating regimes: for some countries, output volatility increases (for instance, Greece [GRD]); for others, it decreases (for instance, Brazil [BRL]). To offer a more systematic answer to what happens to output volatility, the lower part of Figure 3 reports, country by country, the differences in $\sigma(\Delta y_t)$ across exchange-rate regimes ($\Delta\left[\sigma(\Delta y_t)\right]$) against the differences in $\sigma(\Delta q_t)$ across exchange-rate regimes ($\Delta\left[\sigma(\Delta q_t)\right]$). Overall, Figure

[22]The imports-over-GDP ratio of the United States, averaged over the period 1960-2019, is about 8.8%. See Figure 3 for evidence on other countries.

3 shows a negative correlation that is not statistically significant.[23]

Figure 3 expands on this result by plotting $\sigma(\Delta q_t)$ and $\sigma(\Delta y_t)$ against countries' openness to international trade across exchange-rate regimes.[24] Under the pegged regimes, the standard deviations of Δq_t and Δy_t are in red; under the floating regimes, in blue. The figure documents that when one orders the countries by openness to international trade, moving from a pegged to a floating regime increases mean real–exchange rate volatility (upper part) without changing mean output volatility (lower part). The new characterization of exchange-rate regimes in open economy proves that exchange-rate regime breaks are associated with large changes in the volatility of trade-weighted real exchange rates. This result can also be seen in the upper part of Figure 3, where we see that moving from pegged to floating regimes increases the mean standard deviation of the real exchange rate by about 350%, from 2.389 to 8.351. However, this result makes the results of the lower part of the figure much more puzzling in respect to the Mussa puzzle and the US economy, which is represented by the left-most two points: not only does moving from pegged to floating not change the mean standard deviation of real output across regimes, but it does not systematically increase output volatility in economies that are very open to international trade (those in the center and left). Moreover, Table 2 reports the OLS coefficients of the regression of $\sigma(\Delta q_t)$ on openness to international trade and the regression of $\sigma(\Delta y_t)$ on openness to international trade across exchange-rate regimes. It formally shows that there is no statistically significant correlation between the volatilities of real exchange rates (nor real output) and countries' openness to international trade across exchange-rate regimes.

Countries experience exchange-rate regime breaks, increasing the volatility of their real exchange rates (upper part of Figure 3) and hence real shocks to their economies, but do not display systematically increased volatility in their real output (lower part); additionally, I find no statistically significant correlation between the volatilities of real exchange rates (nor output) and countries' amount of trade with the rest of the world in either regime (Table 2).

Finally, Table 3 provides some additional details by including other real macro variables: consumption (Δc_t), investment (Δz_t), and net exports (Δnx_t). Under the pegged regimes, the mean volatility of the real exchange rate is low and at the same order of magnitude as real output's mean volatility, but there is a disconnect under the floating regimes: the floating-pegged ratio for the real exchange rate is about 3.5, but the ratio is around 1 for all the other real variables. Thus, the second main empirical result of the paper is that exchange rate disconnect remains persistent across exchange-rate regimes, even when countries more open to international trade than the United States are studied. The above patterns of change in the volatility of the real exchange rate and other macro variables motivate my theoretical analysis in the next section, which aims to resolve exchange rate disconnect without relying on a country's openness to international trade.

[23]The coefficient of the OLS regression of $\Delta\left[\sigma(\Delta y_t)\right]$ on $\Delta\left[\sigma(\Delta q_t)\right]$ is -0.062 and the relative 95% confidence interval [-0.311, 0.188], using heteroskedasticity-robust standard errors, indeed includes the zero (the p-value of the test, under the null hypothesis of an OLS coefficient equal to zero, is 0.616).

[24]For each country, I use as a proxy for openness to international trade its mean imports-to-GDP ratio for the corresponding time period in Table 6 in Appendix A.2.

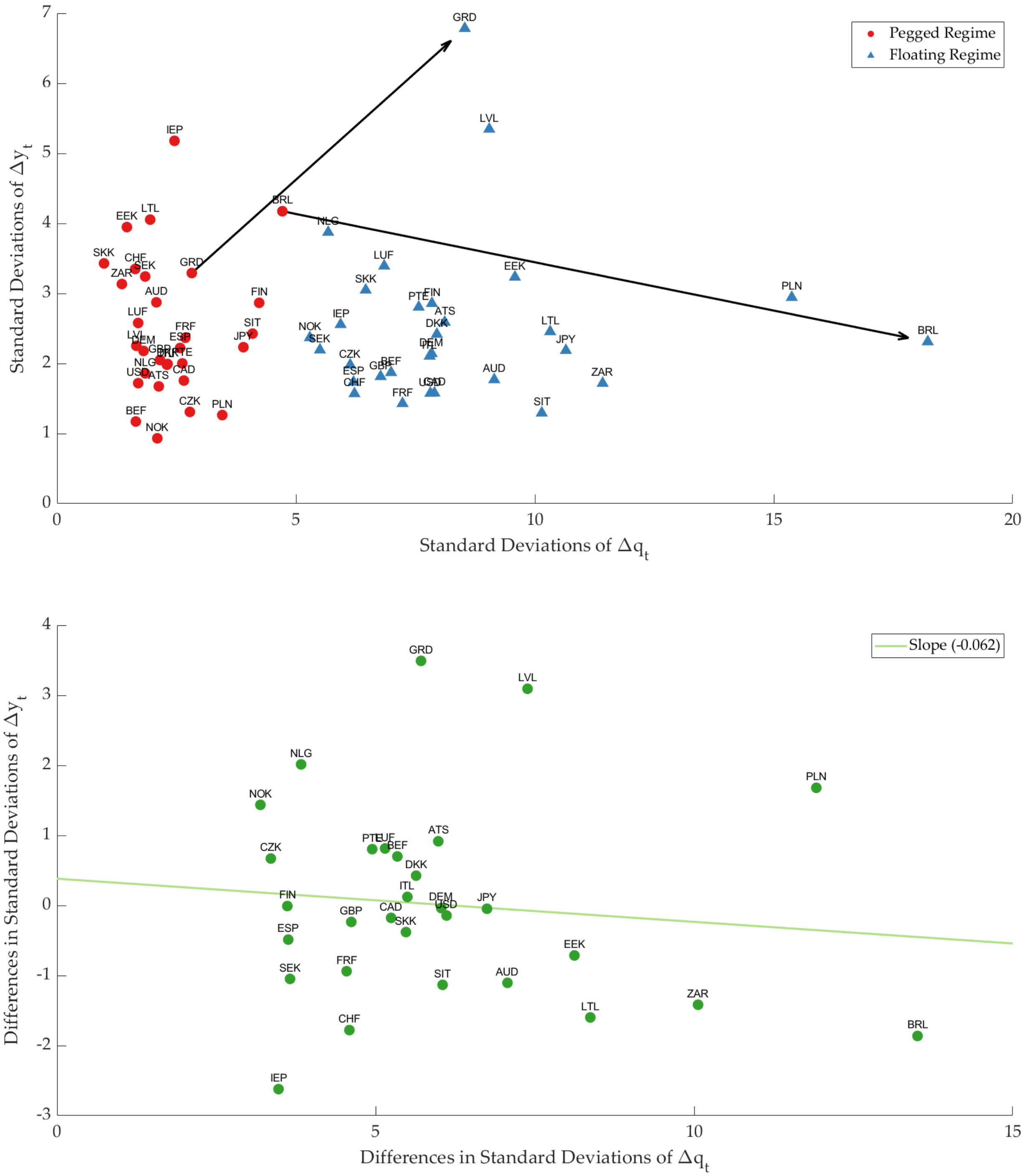
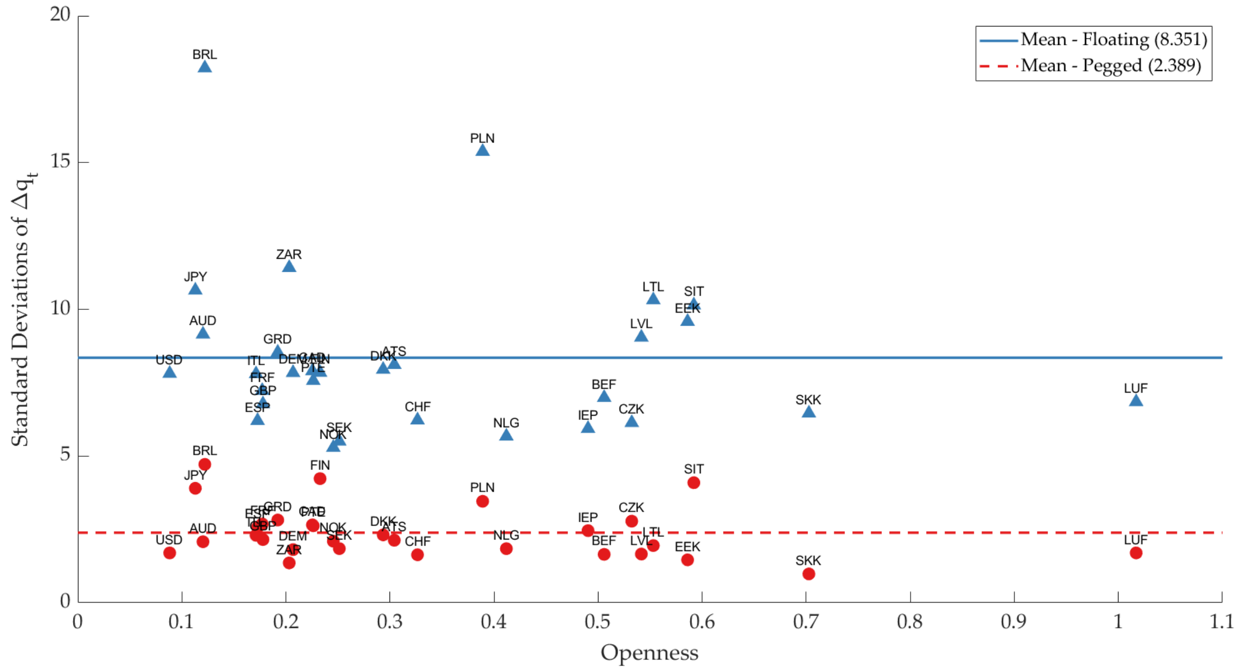


Figure 2: Volatility of Real Exchange Rates against Volatility of Outputs across Exchange-Rate Regimes

Notes: The annualized standard deviations are in red under the pegged regimes and in blue under the floating regimes; the differences in the annualized standard deviations across regimes are in green.
Sources: The Bank of Italy's Exchange Rates Portal, the International Monetary Fund's Direction of Trade Statistics and International Financial Statistics, and the Organisation for Economic Co-operation and Development's OECD.Stat.



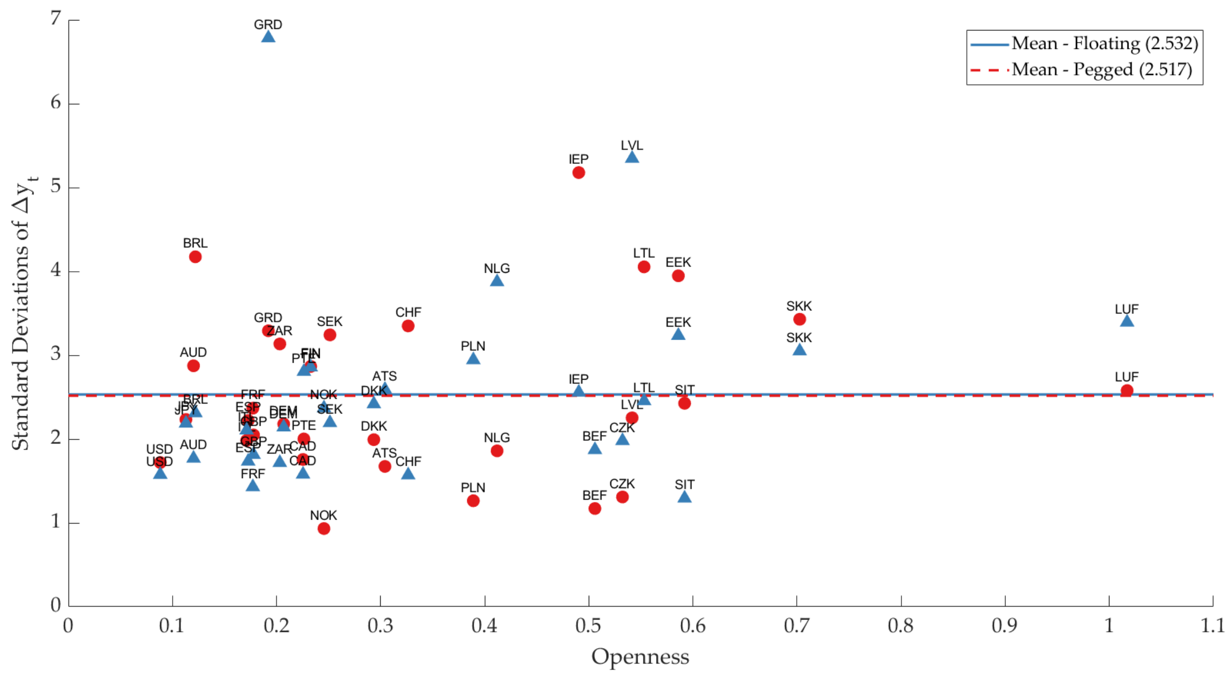


Figure 3: Volatility of Real Exchange Rates (above) and Volatility of Outputs (below) against Countries' Openness across Exchange-Rate Regimes

Notes: The annualized standard deviations are in red under the pegged regimes and in blue under the floating regimes.
Sources: The Bank of Italy's Exchange Rates Portal, the International Monetary Fund's Direction of Trade Statistics and International Financial Statistics, and the Organisation for Economic Co-operation and Development's OECD.Stat.

Table 2: Relationship between Openness and Volatilities across Exchange-Rate Regimes

Exchange-Rate Regime	$\sigma(\Delta q_t)$	$\sigma(\Delta y_t)$
Pegged Regime	-1.260 [-2.767, 0.246]	0.721 [-0.776, 2.219]
Floating Regime	-2.000 [-6.082, 2.083]	1.324 [-0.282, 2.930]

Notes: The second column reports the OLS coefficients of the regression of annualized standard deviations of Δq_t on openness to international trade across exchange-rate regimes; the third column reports the OLS coefficients of the regression of annualized standard deviations of Δy_t on openness to international trade across exchange-rate regimes; 95% confidence intervals, using heteroskedasticity-robust standard errors, are in square brackets, and the p-values of the test, under the null hypothesis of an OLS coefficient equal to zero, are 0.098 [pegged regime / $\sigma(\Delta q_t)$], 0.332 [pegged regime / $\sigma(\Delta y_t)$], 0.324 [floating regime / $\sigma(\Delta q_t)$], 0.102 [floating regime / $\sigma(\Delta y_t)$].

Table 3: Volatilities across Exchange-Rate Regimes

Exchange-Rate Regime	$\sigma(\Delta q_t)$	$\sigma(\Delta y_t)$	$\sigma(\Delta c_t)$	$\sigma(\Delta z_t)$	$\sigma(\Delta nx_t)$
Pegged Regime	2.389 [2.051, 2.726]	2.517 [2.146, 2.889]	2.320 [1.8745, 2.766]	8.904 [5.308, 12.500]	3.844 [2.975, 4.713]
Floating Regime	8.351 [7.301, 9.401]	2.532 [2.099, 2.965]	2.806 [2.257, 3.356]	7.996 [6.533, 9.458]	4.231 [3.592, 4.872]
Floating-Pegged Ratio	3.5	1.0	1.2	0.9	1.1

Notes: The table reports the mean annualized standard deviations of real macro variables across exchange-rate regimes; 95% confidence intervals, using heteroskedasticity-robust standard errors, are in square brackets, and the p-values of the test, under the null hypothesis of equal means across exchange-rate regimes, are respectively 0.000, 0.958, 0.165, 0.635, and 0.466.

3 Theoretical Framework

My model builds on an international real business cycle model with productivity and financial shocks, and it includes three crucial features: imperfect financial markets, deviations (in the form of variable markups and local currency pricing) from the law of one price, and large exporter-importers. Section 3.1 explains the model. Sections

3.2 explains how resolving exchange rate disconnect requires that exporters simultaneously be intensive importers. In Section 3.3, I complement the model-based analysis with the quantitative results from the calibration, which uses data on Belgium for the 1960–2019 period. I show that the theoretical model of Itskhoki and Mukhin (2021, 2022) cannot match the observed exchange rate disconnect and that my model can reproduce the Mussa puzzle and exchange rate disconnect without compromising its ability to the fit of other business cycle moments.

3.1 Model

Time is discrete and runs forever: $t = 0, 1, 2, ...$. There are two countries—home (France) and foreign (Belgium, denoted with an asterisk)—each with its own nominal unit of account in which local prices are quoted. The nominal exchange rate $\mathcal{E}_t$ is the price of Belgian francs in French francs: an increase in $\mathcal{E}_t$ corresponds to a nominal devaluation of the home currency (the French franc). The real exchange rate, $\mathcal{Q}_t \equiv (P_t^* \mathcal{E}_t)/P_t$, is the relative consumer price level in the two countries, with P_t^* being the CPI in the foreign country and P_t being the CPI in the home country. An increase in $\mathcal{Q}_t$ corresponds to a real depreciation of the home currency—that is, a decrease in the relative price of the home consumption basket. Each country's economy is populated by households, two type of firms (domestic firms and exporters), and a government.

The countries are symmetric with the exception of their exchange-rate regime: the foreign country always conducts its monetary policy according to a Taylor rule by targeting inflation (a floating regime), while the home country conducts its monetary policy according to a Taylor rule that switches from targeting the nominal exchange rate (a pegged regime) to targeting inflation (a floating regime). In the following description, I focus on the home country.

3.1.1 The Home Country

Households. The representative household solves the following consumption-savings problem, maximizing its discounted expected utility over final consumption C_t and labor L_t:

$$\max_{\{C_t, L_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{1}{1+\varphi} L_t^{1+\varphi} \right).$$

Here, β is the household discount factor, σ is the relative risk aversion parameter, and φ is the inverse Frisch elasticity of labor supply, subject to the following budget constraint:

$$P_t C_t + P_t Z_t + \frac{B_{t+1}}{R_t} \leq W_t L_t + R_t^k K_t + B_t + \Pi_t + \Pi_t^e.$$

Here, P_t is the CPI, B_t is a quantity of the home-currency risk-free bond paying out one unit of the home currency next period, R_t is the gross nominal interest rate, W_t is the nominal wage rate, R_t^k is the nominal rental rate of capital, K_t is the capital stock, Π_t are the dividends from the domestic firms, and Π_t^e are the dividends from the exporters.

The representative household allocates its within-period consumption expenditure $P_t C_t$, between the home good C_{Ht} and the foreign good C_{Ft}, to minimize expenditure on final consumption C_t:

$$P_t C_t = \int_0^1 \left[P_{Ht}(i) C_{Ht}(i) + P_{Ft}(i) C_{Ft}(i) \right] \mathrm{d}i.$$

Here, P_{Ht} and P_{Ft} are the home-currency prices of the home and foreign goods. Final consumption C_t is implicitly defined by Kimball (1995) aggregator as follows:

$$\int_0^1 \left[(1-\gamma) g \left(\frac{C_{Ht}(i)}{(1-\gamma) C_t} \right) + \gamma g \left(\frac{C_{Ft}(i)}{\gamma C_t} \right) \right] \mathrm{d}i = 1.$$

Here, γ is the openness-to-international-trade parameter and the function $g(\cdot)$ is increasing and concave with $-g''(1) \in (0,1)$ and $g(1) = g'(1) = 1$. This minimization results in the following demand schedules:

$$C_{Ht}(i) = (1-\gamma) h \left(\frac{P_{Ht}(i)}{\mathcal{P}_t} \right) C_t \qquad \text{and} \qquad C_{Ft}(j) = (1-\gamma) h \left(\frac{P_{Ft}(j)}{\mathcal{P}_t} \right) C_t.$$

Here, the function $h(\cdot) = g'^{-1}(\cdot)$ and controls the curvatures of the demand schedules.[25]

Z_t, gross investment in the capital stock K_t, accumulates according to the following rule—quadratic capital adjustment costs—with depreciation δ and capital adjustment cost κ:

$$K_{t+1} = (1-\delta) K_t + \left[Z_t - \frac{\kappa}{2} \frac{(\Delta K_{t+1})^2}{K_t} \right].$$

Gross investment Z_t is a bundle of domestic and foreign varieties, as the final consumption C_t, aggregated according to an analogous Kimball (1995) aggregator and demanded according to analogous demand schedules.

Finally, I assume that the representative household in the home country trades only home-currency bonds and owns only home domestic firms and exporters.

Domestic Firms. The representative domestic firm i produces using a Cobb-Douglas technology with labor L_t, capital K_t, and intermediate inputs X_t:

$$Y_{Ht} = \left(e^{a_t} K_t^{\vartheta} L_t^{1-\vartheta} \right)^{1-\phi} X_t^{\phi}.$$

[25] In this setting, the point elasticity $\theta = -h'(1)$, whereas the CPI P_t and the auxiliary variable $\mathcal{P}_t$ are implicitly defined by the consumption-expenditure equation and by the Kimball (1995) aggregator, after substituting the home demand schedules. The constant-elasticity-of-substitution aggregator, with elasticity of substitution θ, is a special case of the Kimball (1995) aggregator when $g(x) = 1 + \frac{\theta}{\theta-1} \left(x^{1-\frac{1}{\theta}} - 1 \right)$.

Here, a_t is the natural logarithm of the total factor productivity, which follows an AR(1) process:

$$a_t = \rho_a a_{t-1} + \sigma_a \epsilon_t^a, \qquad \epsilon_t^a \sim \mathcal{N}(0,1).$$

Here, the persistent parameter $\rho_a \in [0,1]$ and the volatility of the innovation $\sigma_a \geq 0$. The intermediate input X_t is a bundle of domestic and foreign varieties, as the final consumption C_t and the gross investment Z_t, aggregated according to an analogous Kimball (1995) aggregator and demanded according to analogous demand schedules.

Given the nominal rental rate of capital R_t^k, the nominal wage rate W_t, and the CPI P_t, the associated marginal cost of production for the domestic firm is

$$MC_t = \frac{1}{\varpi}\left[e^{-a_t} {R_t^k}^{\vartheta} W_t^{1-\vartheta}\right]^{1-\phi} P_t^{\phi}, \qquad \text{where} \qquad \varpi \equiv \phi^{\phi}\left[(1-\phi)\vartheta^{\vartheta}(1-\vartheta)^{1-\vartheta}\right]^{1-\phi}.$$

In serving the home market, the domestic firm maximizes profits,

$$\Pi_t(i) = \left(P_{Ht}(i) - MC_t\right) Y_{Ht}(i),$$

by optimally setting $P_{Ht}(i)$. Thanks to the Kimball (1995) aggregator, such profit maximization results in variable-markup pricing with a common price across all domestic firms i:

$$P_{Ht}(i) = P_{Ht} = \mu\left(\frac{P_{Ht}}{\mathcal{P}_t}\right) MC_t.$$

Here, the markup function $\mu(x) = \frac{-\frac{\partial \ln h(x)}{\ln x}}{-\frac{\partial \ln h(x)}{\ln x} - 1}$ is derived from the demand schedules of C_t, K_t, and X_t in the home country. The aggregate profits of the domestic firms, $\Pi_t = \int_0^1 \Pi_t(i)\mathrm{d}i$, are distributed to the households.

Exporter-Importers. The main innovation of my theoretical model is the representative exporter-importer j, which still produces using a Cobb-Douglas technology with labor L_t, capital K_t, and intermediate inputs X_t but also directly imports intermediate inputs E_{Ft}^* from the foreign country. That technology is the following:

$$Y_{Ht}^* = \left[\left(e^{a_t} K_t^{\vartheta} L_t^{(1-\vartheta_t)}\right)^{1-\phi} X_t^{\phi}\right]^{1-\phi^e} \left(E_{Ft}^*\right)^{\phi^e}. \tag{1}$$

Here, E_{Ft}^* is foreign good priced in the foreign currency.

Given the foreign-currency price of the foreign good P_{Ft}^*, the associated marginal cost of production for the exporter-importer is

$$MC_t^e = \frac{1}{\varpi^e}\left\{\left[e^{-a_t} {R_t^k}^{\vartheta} W_t^{1-\vartheta}\right]^{1-\phi} P_t^{\phi}\right\}^{1-\phi^e} \left(\mathcal{E}_t P_{Ft}^*\right)^{\phi^e}, \quad \text{where}$$

$$\varpi^e \equiv \phi^{e\phi^e} \left\{ (1-\phi^e)\phi^\phi \left[(1-\phi)\vartheta^\vartheta (1-\vartheta)^{1-\vartheta} \right]^{1-\phi} \right\}^{1-\phi^e}.$$

In serving the foreign market, the exporter-importer maximizes profits

$$\Pi_t^e(j) = \left(P_{Ht}^*(j)\mathcal{E}_t - MC_t^e \right) Y_{Ht}^*(j),$$

by optimally setting $P_{Ht}^*(j)$. Thanks to the Kimball (1995) aggregator, such profit maximization results in variable-markup pricing with a common price across all exporter-importers j:

$$P_{Ht}^*(j) = P_{Ht}^* = \mu \left(\frac{P_{Ht}^*}{\mathcal{P}_t^*} \right) \frac{MC_t^e}{\mathcal{E}_t},$$

Here, the markup function $\mu(x) = \frac{-\frac{\partial \ln h(x)}{\ln x}}{-\frac{\partial \ln h(x)}{\ln x} - 1}$ is derived from the demand schedules of C_t^*, K_t^*, and X_t^* in the foreign country. The aggregate profits of the exporter-importers, $\Pi_t^e = \int_0^1 \Pi_t^e(j)\mathrm{d}j$, are distributed to the households.

Government in the Home Country. The fiscal authority is fully passive in the sense that I abstract from government spending and taxation, whereas the monetary authority conducts monetary policy according to the following Taylor rule:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)[\omega_\pi \pi_t + \omega_e(e_t - \bar{e})].$$

Here, $i_t = ln(R_t)$, $\bar{e}$ is the natural logarithm of the targeted nominal exchange rate, $0 \geq \rho_i \leq 1$, $\omega_\pi > 1$, and $\omega_e \geq 0$. The parameter ρ_i represents interest rate smoothing in the monetary-policy rule, whereas the parameters ω_π and ω_e respectively represent the weights of the two monetary-policy objectives, inflation targeting and nominal exchange rate targeting. When $\omega_e = 0$, the monetary authority implements a floating regime; when $\omega_e > 0$, a pegged regime.

3.1.2 The Foreign Country

The foreign country is fully symmetric to the home country except that the monetary authority conducts monetary policy according to the following Taylor rule:

$$i_t^* = \rho_{i^*} i_{t-1}^* + (1-\rho_{i^*})\omega_{\pi^*}\pi_t^*,$$

Here, $0 \geq \rho_{i^*} \leq 1$ and $\omega_{\pi^*} > 1$. The parameter ρ_{i^*} represents interest rate smoothing in the monetary-policy rule. Unlike in the home country, the monetary authority always implements a floating regime.

3.1.3 International Financial Market

The international financial market is segmented as in Gabaix and Maggiori (2015) since the home and foreign households cannot directly trade any bonds with each other. Their international financial positions, which are intermediated by a unit mass of global financial firms, each managed by a financier. The representative financier solves the following constrained problem:

$$\max_{Q_t} V_t = \mathbb{E}_t \left[\beta (R_t - R_t^* \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}) \right] Q_t, \quad \text{subject to} \qquad V_t \geq \Gamma_t \frac{Q_t^2}{\mathcal{E}_t}.$$

Here, Q_t is balance-sheet position of the financier, in French francs, and $\Gamma_t = \xi \left[var_t(\mathcal{E}_{t+1}) \right]^{\alpha}$, with $\xi \geq 0$ and $\alpha \geq 0$. Γ_t represents the financiers' risk-bearing capacity.[26]

3.1.4 Market Clearing

Labor and Capital Markets. In the home and foreign countries, nominal wage rates W_t and W_t^* adjust to clear the home and foreign labor markets, respectively, and nominal rental rates of capital K_t and K_t^* adjust to respectively clear the home and foreign capital markets, respectively.

Goods Market. In the home country, clearing the goods market requires that total production by the home domestic firms and exporters is split between supply to the home and foreign markets respectively and satisfies the demand in each market:

$$Y_t = Y_{Ht} + Y_{Ht}^*,$$

$$Y_{Ht} = C_{Ht} + X_{Ht} + Z_{Ht} + E_{Ht} = (1-\gamma) h \left(\frac{P_{Ht}}{\mathcal{P}_t} \right) [C_t + X_t + Z_t] + E_{Ht}, \text{ and}$$

$$Y_{Ht}^* = C_{Ht}^* + X_{Ht}^* + Z_{Ht}^* = \gamma h \left(\frac{P_{Ht}^*}{\mathcal{P}_t^*} \right) [C_t^* + X_t^* + Z_t^*].$$

Finally, I derive the home country's budget constraint:

$$\frac{B_{t+1}}{R_t} - B_t = NX_t \qquad \text{with} \qquad NX_t = (\mathcal{E}_t P_{Ht}^* Y_{Ht}^* + P_{Ht} E_{Ht}) - (P_{Ft} Y_{Ft} + \mathcal{E}_t P_{Ft}^* E_{Ft}^*).$$

Here, NX_t are net exports in units of the home currency.

Net exports contain two extra terms, relative to a model without large exporter-importers: the directly imported inputs of the foreign exporter-importers (E_{Ht}) and the directly imported inputs of the home exporter-importers (E_{Ft}^*) which are priced in home and foreign currencies, respectively.

[26] I introduce exogenous financial shocks to the international financial market only in the linearized version of the model, without taking a stance on their microfoundation, as they can be equally generated in the nonlinear model from exogenous portfolio flows of the households, as in Gabaix and Maggiori (2015); from noise traders, as in Itskhoki and Mukhin (2021, 2022); or from biased exchange rate expectations, as in Jeanne and Rose (2002).

International Financial Market. Clearing the international financial market requires that the balance sheet position of the financiers in French francs Q_t equals B_t and the balance sheet position of the financiers in Belgian francs Q_t^* equals B_t^*.

3.1.5 Equilibrium Definition and Model Solution

In the Appendix, I define an equilibrium in the nonlinear model. I then solve the model by logarithmic linearization around a symmetric steady state and define an equilibrium in the linearized model. From now on, I denote all the expressions in terms of deviations from the symmetric steady-state equilibrium; for example, $y_t \equiv \ln(Y_t) - \ln(\bar{Y})$, using small letters for natural logarithms.[27]

3.2 Large Exporter-Importers Resolving Exchange Rate Disconnect

Two equations characterize the linearized model around a symmetric steady state: the modified UIP condition in the international financial market, and the home flow budget constraint.[28]

Equilibrium in the international financial market results in the following modified UIP condition, which is subject to exogenous financial shocks:

$$i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1} = \chi_1 \psi_t - \chi_2 b_{t+1}. \tag{2}$$

Here, $b_{t+1} = B_{t+1}/\bar{Y}$, $\chi_1 = \frac{\Gamma}{\beta}$, and $\chi_2 = \bar{Y}\Gamma$.[29] The financial shocks ψ_t follow an AR(1) process:

$$\psi_t = \rho_\psi \psi_{t-1} + \sigma_\psi \epsilon_t^\psi, \qquad \epsilon_t^\psi \sim \mathcal{N}(0,1).$$

The persistent parameter $\rho_\psi \in [0,1]$, and the volatility of the innovation $\sigma_\psi \geq 0$.

When the financiers' risk-bearing capacity $\Gamma = 0$, they can absorb any imbalances, which results in no deviation from the UIP condition; $i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1} = 0$. The higher the Γ—that is, the lower the financiers' risk-bearing capacity—the more segmented the international financial market. For $0 < \Gamma < \infty$, the model endogenously generates UIP deviations.[30]

The home country's flow budget constraint results in the following equation:

$$nx_t = (1-\phi^e)\tilde{\gamma} e_t + \tilde{\gamma}(y_{Ht}^* - y_{Ft} + p_{Ht}^* - p_{Ft}) + \phi^e \tilde{\gamma}(e_{Ht} - e_{Ft}^* + p_{Ht} - p_{Ft}^*). \tag{3}$$

Here, $nx_t = \frac{NX_t}{\bar{Y}}$ and $\tilde{\gamma} \equiv \frac{\gamma}{1+\phi^e \gamma}$.

[27] The complete derivation of the model solution, together with the approximated equilibrium definition in the linear model, is in the Appendix.
[28] Given the symmetry in the model, the foreign country's flow budget constraint is analogous.
[29] See footnote 25.
[30] If $\Gamma \uparrow \infty$, the financiers are unwilling to absorb any imbalances; that is, they do not take any positions in international financial markets.

Thanks to the inclusion of large exporter-importers, I can state the following proposition on how to resolve exchange rate disconnect under the floating regime.[31] I relegate the quantitative analysis to Section 3.3.

PROPOSITION.

Assume that $\Gamma > 0$ and $\omega_e = 0$. For any value of γ, $c_t - c_t^*$ $(y_t - y_t^*)$ is independent of q_t if $\phi^e \to 1$.

Proof. See Appendix.

Discussion. Here, I show how my model's novel feature contribute to the literature with the aid of three crucial parameters: Γ, the financiers' risk-bearing capacity; γ, the openness-to-international-trade parameter; and ϕ^e, the import intensity of the exporters.

Monacelli (2004). If the financiers' risk-bearing capacity $\Gamma = 0$, the financiers are able to absorb any imbalances, resulting in no deviation from the UIP condition. The model collapses to a complete-market model, similar to Monacelli's (2004) model, in which the Backus and Smith (1993) condition of efficient international risk sharing holds and the consumption difference across countries comoves with the real exchange rate. This model outcome is empirically implausible under the floating regimes, as shown in Figure 1 for Belgium, because of the absence of simultaneous structural breaks in the consumption-difference volatility.[32]

Itskhoki and Mukhin (2021, 2022). $\Gamma > 0$ with $\gamma \to 0$ is the solution adopted by Itskhoki and Mukhin (2021, 2022), which works well for the US economy (which lies at the far left in Figure 3). In this world, $\phi^e = 0$, the exporters are not intensive importers, and their production technology is identical to domestic firms'.[33] Equation (3) becomes equal to the following:

$$nx_t = \gamma(e_t + y_{Ht}^* - y_{Ft} + p_{Ht}^* - p_{Ft}). \tag{4}$$

Equation (4) illustrates how the openness-to-international-trade parameter plays a crucial role in isolating the exchange rate volatility in the home economy under the floating regimes. This is because if $\gamma \to 0$, as is true for the US economy, real variables do not react ($\gamma = 0$ represents complete autarky). However, as we will see in Section 3.3, this resolution does not work for Belgium under the floating regimes since real variables strongly react when the openness-to-international-trade parameter $\gamma > 0$.

Large exporter-importers. Incorporating large exporter-importers is my main theoretical contribution, as it allows me to extend the work of Itskhoki and Mukhin (2021, 2022) by accounting for very open economies with large exporter-importers à la Amiti, Itskhoki, and Konings (2014): $\Gamma > 0$, $\gamma > 0$, and $\phi^e > 0$.

Under the pegged regimes, the resolution of exchange rate disconnect is straightforward and does not rely on

[31] I state the proposition for the home country; a symmetric one applies for the foreign country.

[32] However, if one introduces price stickiness à la Calvo (1983), the model is able to match the fact that nominal and real exchange rates comove across exchange-rate regime breaks.

[33] Indeed, when $\phi^e = 0$, my production side collapses to that in Itskhoki and Mukhin (2021, 2022).

the exporter-importer model feature. Suppose that the home country's monetary authority implements a perfect currency board, implying that $e_t = \bar{e}$ for any t. Then the financiers' risk-bearing capacity $\Gamma = 0$ and there are no deviations from the UIP condition, so $i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1} = i_t - i_t^* - \bar{e} + \bar{e} = 0$. Consequently, real variables are not affected by exchange rate volatility, which is absent because $e_t = \bar{e}$ for any t, but only by productivity shocks.[34]

Under the floating regimes, the resolution of exchange rate disconnect is more complex and crucially relies on large exporter-importers. Suppose that the home country's monetary authority implements a fully floating regime such that $\omega_e = 0$. Then the financiers' risk-bearing capacity $\Gamma > 0$, implying endogenous UIP deviations and a decreasing capacity to bear the risk of an increasing volatility of e_t because $\Gamma = \xi \left[var_t(\mathcal{E}_{t+1})\right]^{\alpha}$. Now, suppose that $\phi^e > 0$the exporters are intensive importers, and their production technology is very different from domestic firms', as they largely take advantage of imported inputs. The exporter-importers then are playing an active role in isolating the exchange rate volatility in the home economy, *independently* of the openness-to-international-trade parameter γ. This can be seen in Equation (3), in which real variables are increasingly muted to the volatility of e_t for $\phi^e > 0$ and become completely isolated in the limit as $\phi^e \to 1$.[35]

If output is produced by a unique firm that sells in the domestic and foreign markets, as in Itskhoki and Mukhin (2021, 2022), the firm has no incentive to specialize its production to serve one of the two markets, in particular the foreign one. So the firm cannot hedge an eventual exchange rate shock: either it is transmitted to the final consumer through a different price, or it is absorbed through the firm's markup. However, if output is produced by two types of firms, one selling in the domestic market and the other selling in the foreign market, the latter firm—the exporter—has an incentive to specialize its production to serve the foreign market and import a large part of its inputs from the foreign country. This results in an exporter-importer that can hedge the eventual exchange rate shock, independently of its magnitude, without transmitting it to the rest of the economy.

3.3 Calibration

I adopt Itskhoki and Mukhin (2021) model parameters, as summarized in Table 8 in Appendix A.3, with three exceptions: first, I change the openness-to-international-trade parameter γ from 0.07 (the US calibration in Itskhoki and Mukhin, 2021) to 0.25 to be consistent with the average imports-to-GDP ratio of Belgium over the 1960–2019 period; second, I modify the capital-adjustment-cost parameter κ to match a relative volatility of investment and output—$std(\Delta z_t)/std(\Delta y_t)$, whose value is 2.5 as in Itskhoki and Mukhin (2021); third, I choose 0.23 as the value of ω_e, the weight of nominal–exchange rate targeting (in the pegged regime) in the Taylor rule of the home country, following Itskhoki and Mukhin (2022), as Itskhoki and Mukhin (2021) do not analyze the pegged regimes. Finally, I set $\phi^e = 0.74$ following the empirical finding in Amiti, Itskhoki, and Konings (2014) that 74% is the ratio between

[34] Indeed, the first term on the right-hand side of the home country's flow budget constraint, Equation (3), is a constant.

[35] Indeed, the exporter-importers use no local inputs if $\phi^e = 1$.

imported inputs and exports for import-intensive exporters.[36]

My model, like the multi-shock version of Itskhoki and Mukhin's (2021) model, features three exogenous shocks for which I need to calibrate the covariance matrix: two country-specific productivity shocks (a_t, a_t^*) and a financial shock (ψ_t). I assume that ψ_t is orthogonal to (a_t, a_t^*), whereas a_t and a_t^* have the same variance (that is, $\sigma_a = \sigma_{a^*}$), and a nonzero correlation (ρ_{a,a^*}). In Itskhoki and Mukhin (2021), the relative volatility of the shocks, σ_a/σ_ψ, is always chosen to match the Backus-Smith correlation between the US and the rest of the world, $corr(\Delta q_t, \Delta c_t - \Delta c_t^*) = -0.4$, while the cross-country correlation of productivity shocks, ρ_{a,a^*}, is always set so $corr(\Delta y_t, \Delta y_t^*) = 0.35$ to match the correlation of the US with the rest of the world. For a transparent comparison between my model with large exporter-importers and the model in Itskhoki and Mukhin (2021), I follow the same approach.

3.3.1 Calibration Results

Floating regime. I find three main results. First, the real exchange rate is strongly correlated with the nominal exchange rate in both models. Second, for values of $\gamma \geq 0.25$, the theoretical model of Itskhoki and Mukhin (2021) loses its ability to not transmit the volatility of exchange rates to the other real macro variables, whereas my model maintains that ability thanks to the large exporter-importers that actively hedge the exchange rate shocks. Finally, price and wage stickiness à la Calvo (1983) does not increase the quantitative fit of my model.

Tables 5 reports the simulation results, for 10,000 simulations of 120 quarters, and compares the quantitative results of my model under the floating regimes (that is $\omega_e = 0$) with the quantitative results of the "preferred" version of the Itskhoki and Mukhin (2021) model, the one with price and wage stickiness à la Calvo (1983). In doing so, I choose different values for κ, σ_a, and ρ_{a,a^*} to match $std(\Delta z_t)/std(\Delta y_t) = 2.5$, $corr(\Delta q_t, \Delta c_t - \Delta c_t^*) = -0.4$, and $corr(\Delta y_t, \Delta y_t^*) = 0.35$, respectively. In the first part of Table 4, I set the three values to target the moments in the Itskhoki and Mukhin (2021) model with $\gamma = 0.07$; in the second part, I set the values to target the moments in that model with $\gamma = 0.25$; in the third part, I set them to target the moments in my model (with large exporter-importers), which does not feature price and wage stickiness, with $\gamma = 0.25$. Additionally, I propose a version of my model—in the fifth column of Table 4—that features price and wage stickiness à la Calvo (1983) with the same stickiness parameters of the model in Itskhoki and Mukhin (2021). I do this to make the two models more comparable and to emphasize the pivotal role of large exporter-importers.

The first result in Table 4 is that both models match the real exchange rate's strong correlation with the nominal exchange rates in all three calibrations. However, while for $\gamma = 0.07$ the Itskhoki and Mukhin (2021) theoretical model can capture the disconnect between the volatility of exchange rates and the other real macro variables, it loses

[36] Remarkably, this represents, at most, a conservative value of ϕ_e, as Amiti, Itskhoki, and Konings (2014) use Belgian firm-product-level data on exports and imports for the 2000–2008 period, during which Belgium features a pegged regime under my new characterization of exchange-rate regimes. Indeed, if one excludes from the calculation exports and imports to and from the euro area, the ratio between imported inputs and exports for the import-intensive exporters becomes 1.44. However, I set $\phi^e = 0.74$ in my calibration, as Belgium was still pegged to some countries (for example, Germany, Austria, the Netherlands) under the floating regimes.

this capability when γ is greater than or equal to 0.25. For any of the three calibrations, my model performs better than the other in insulating the real macro variables from exchange rate volatility. This is because of the role of the large exporter-importers, which actively hedge the exchange rate shocks, independently of the shocks' magnitude, thanks to their large amount of directly imported inputs. When moments are targeted under $\gamma = 0.25$, my model requires a much lower value for σ_a (namely, $\sigma_a = 2.9$; see lower part of Table 4) than the Itskhoki and Mukhin (2021) model (namely, $\sigma_a = 5$; see middle part of Table 4). This confirms the above finding in Panel (d) of Figure 1: the Itskhoki and Mukhin (2021) model, with no large exporter-importers, can match a $corr(\Delta q_t, \Delta c_t - \Delta c_t^*)$ of -0.4 only by means of high volatility in productivity shocks. However, the fifth and sixth columns of Table 4 show that my model performs better without price and wage stickiness à la Calvo (1983), which represents another key difference from the Itskhoki and Mukhin (2021) model, the "preferred" version of which assumes price and wage stickiness à la Calvo (1983). This is not surprising given that price stability in my model endogenously arises as a result of the capacity of large exporter-importers to be shock absorbers, thanks to their direct importation and local-currency pricing.[37]

Overall, there are two key takeaways from these calibration results under the floating regime: (i) the Itskhoki and Mukhin (2021) model cannot replicate exchange rate disconnect for a value of the openness-to-international trade parameter $\gamma \geq 0.25$; (ii) the same model can be easily rectified by introducing the key feature of large exporter-importers.

Pegged regime. Table 5 shows that my model can also accommodate a pegged regime for a value of $\omega_e = 0.23$, without recalibrating the covariance matrix of exogenous shocks. This results in decreased output and consumption volatilities relative to the exchange rate volatility, but the correlation between the nominal and the real exchange rate is still strong, confirming my model's ability to replicate the Mussa puzzle.

However, it looks like the model quantitative under-performs, in the pegged regime, in replicating the same moments as before.[38] This is because the real macro variables' volatility is too low, which can be easily understood in light of my discussion in Section 3.2. Under pegged regimes, countries feature only two exogenous shocks—the country-specific productivity shocks (a_t, a_t^*)—as the financial shock, ψ_t, is completely absorbed by the financiers, which have full risk-bearing capacity (that is, $\Gamma = 0$) under the pegged regimes. I can easily improve on this by adding a third type of shock—a preference shock—to the model, as in Itskhoki and Mukhin (2022), and recalibrating the covariance matrix of exogenous shocks under the floating regime. Nevertheless, as my goal is to explain exchange rate disconnect and the Mussa puzzle, with large exporter-importers playing a key role in preventing transmission

[37] My conjecture is that this latter result would drastically change in the presence of additional exogenous shocks. Indeed, a standard result in the literature on dynamic stochastic general equilibrium is that price and wage stickiness can improve the quantitative fit when preference or monetary shocks are also incorporated in models. Finally, for a complete comparison between the two models, I also allow the two countries to be asymmetric in the same fashion as Itskhoki and Mukhin (2021, 2022). The main results do not change, and Table 9 summarizes them in the Appendix.

[38] This can be seen by looking at $\sigma(\Delta nx_t)/\sigma(\Delta q_t)$.

of exchange rate volatility to the rest of the economy under the floating regime, I do not include preference shocks, as it keeps my model as simple as possible and fully comparable with Itskhoki and Mukhin's (2021) model.

Table 4: Itskhoki and Mukhin (2021) versus Large Exporters-Importers

Floating Regime ($\omega_e = 0$)		Itskhoki and Mukhin (2021)		This Paper		
	US Moments	United States	Belgium	Belgium		Belgian Moments
		$\gamma = 0.07$	$\gamma = 0.25$	$\gamma = 0.25$ and $\phi^e = 0.74$		
$corr(\Delta e_t, \Delta q_t)$	0.99	1.00	0.99	1.00	1.00	0.95
$\sigma(\Delta e_t)/\sigma(\Delta y_t)$	5.2	3.38	1.74	2.40	2.99	3.74
$\sigma(\Delta e_t)/\sigma(\Delta c_t)$	6.3	5.77	4.24	5.06	5.14	4.79
$\sigma(\Delta nx_t)/\sigma(\Delta q_t)$	0.10	0.17	0.59	0.29	0.28	0.17
$corr(\Delta e_t, \Delta q_t)$	0.99	1	0.99	1.00	1.00	0.95
$\sigma(\Delta e_t)/\sigma(\Delta y_t)$	5.2	1.63	1.08	1.31	1.55	3.74
$\sigma(\Delta e_t)/\sigma(\Delta c_t)$	6.3	3.01	2.26	2.57	2.78	4.79
$\sigma(\Delta nx_t)/\sigma(\Delta q_t)$	0.10	0.16	0.59	0.30	0.28	0.17
$corr(\Delta e_t, \Delta q_t)$	0.99	1.00	0.99	1.00	0.98	0.95
$\sigma(\Delta e_t)/\sigma(\Delta y_t)$	5.2	3.18	1.70	2.30	2.32	3.74
$\sigma(\Delta e_t)/\sigma(\Delta c_t)$	6.3	5.06	3.76	4.42	4.85	4.79
$\sigma(\Delta nx_t)/\sigma(\Delta q_t)$	0.10	0.17	0.60	0.30	0.28	0.17
Price and Wage Stickiness	–	YES	YES	YES	NO	–

Notes: Each cell in the third and fourth columns of the table is the median value of moments across 10,000 simulations of 120 quarters; I choose κ, σ_a, and ρ_{a,a^*} to respectively match the targeted moments $std(\Delta z_t)/std(\Delta y_t) = 2.5$, $corr(\Delta q_t, \Delta c_t - \Delta c_t^*) = -0.4$, and $corr(\Delta y_t, \Delta y_t^*) = 0.35$. In the calibration in the upper part of the table, I set $\kappa = 6.8$, $\sigma_a = 2.5$, and $\rho_{a,a^*} = 0.37$ to match the targeted moments in the model of Itskhoki and Mukhin (2021) with $\gamma = 0.07$. In the calibration in the middle part, I set $\kappa = 5$, $\sigma_a = 5$, and $\rho_{a,a^*} = 0.45$ to match the targeted moments in the model of Itskhoki and Mukhin (2021) with $\gamma = 0.25$. In the calibration in the lower part, I set $\kappa = 9$, $\sigma_a = 2.9$, and $\rho_{a,a^*} = 0.45$ to match the targeted moments in my model with large exporter-importers with $\gamma = 0.25$ and no price and wage stickiness; the last of row of the table indicates whether the model is calibrated when taking price and wage stickiness à la Calvo (1983) into account.

Table 5: Quantitative Results for Belgium across Exchange-Rate Regimes

Pegged Regime	$\omega_e = 0.23$	Belgian Moments
$corr(\Delta e_t, \Delta q_t)$	0.99	0.61
$\sigma(\Delta e_t)/\sigma(\Delta y_t)$	1.73	1.10
$\sigma(\Delta e_t)/\sigma(\Delta c_t)$	2.96	1.39
$\sigma(\Delta nx_t)/\sigma(\Delta q_t)$	0.28	0.88

Floating Regime	$\omega_e = 0$	Belgian Moments
$corr(\Delta e_t, \Delta q_t)$	0.98	0.95
$\sigma(\Delta e_t)/\sigma(\Delta y_t)$	2.32	3.74
$\sigma(\Delta e_t)/\sigma(\Delta c_t)$	4.85	4.79
$\sigma(\Delta nx_t)/\sigma(\Delta q_t)$	0.28	0.17

Notes: Each cell in the second column is the median value of moments across 10,000 simulations of 120 quarters; I choose $\kappa = 9$, $\sigma_a = 2.9$, and $\rho_{a,a^*} = 0.45$ to respectively match the targeted moments $std(\Delta z_t)/std(\Delta y_t) = 2.5$, $corr(\Delta q_t, \Delta c_t - \Delta c_t^*) = -0.4$, and $corr(\Delta y_t, \Delta y_t^*) = 0.35$ under the floating regime; I set $\omega_e = 0.23$, as in Itskhoki and Mukhin (2022), under the pegged regime.

4 Conclusion

How should researchers think about exchange-rate regimes in an open economy? In this paper, consistently with the previous literature on the Mussa puzzle and exchange rate disconnect, I showed that such regimes affect the volatilities of nominal and real exchange rates but not the volatilites of other real macro variables, even for economies that are more open to international trade than the US. I also provide a minimal set of assumptions under which modeling this muted reaction is possible for very open economies, and I show how this result crucially relies on exporters also being large importers. In the future, I plan to investigate three further questions.

First, using the results from a simple generalized autoregressive conditional heteroskedasticity model on the trade-weighted nominal– and real–exchange rate series, we can empirically observe that during episodes of very high inflation and hyperinflation, the real exchange rate comoves less and less with the nominal exchange rate, resulting in a weakening of the Mussa puzzle. In such cases, exchange-rate regimes interact with inflationary regimes, an empirical result that is at odds with the price stability that ultimately generates the Mussa puzzle. However, this can be rationalized in light of menu-cost pricing à la Mankiw (1985): if exogenous shocks affect nominal exchange rates when firms are already changing their prices because of the inflationary regime, such shocks can be incorporated in the new prices at no additional cost.

Second, is the import intensity of the large exporters a structural parameter of the economy—as I assume in my model—or is it endogenous to the exchange-rate regime? In other words, does ϕ^e adjust at the time of a exchange-rate regime break that modifies the volatility of the nominal exchange rate? The question has to be systematically investigated at the micro level by asking: how do firms adjust their production function immediately before and after a exchange-rate regime break that changes the volatility of the nominal exchange rate? The model developed here could be easily extended to account for this additional feature of firm optimization.

Third, I emphasize that the exogenous shock in the exchange-rate regime appears in the theoretical model, and its calibration, as a different value of parameter ω_e. This is not necessarily true in the case of a regime break that endogenously arises in response to conditions that are exogenous to the two economies.

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