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Kurzzusammenfassung

Kapitel 2:
Global Rebalancing in a Two-Country Model

Das erste Kapitel analysiert in einem einfachen theoretischen Modellrahmen die Rolle einer sektoralen Re-Allokation von handelbaren und nicht-handelbaren Gütern bei einem Abbau des amerikanischen Leistungsbilanzdefizits. Es handelt sich um ein 2-Länder-Modell, in dem die USA und der "Rest der Welt" modelliert werden. Insbesondere wird die Wirkung der Anpassung der Leistungsbilanzen auf die Änderung des realen effektiven Wechselkurses analysiert. Das Hauptergebnis ist, dass die angebotsseitige Anpassung die Anpassung auf der Nachfrageseite unterstützt, welche von Obstfeld und Rogoff (2006) betont worden war. In ihrem Modell wird von einem festen Angebot an handelbaren und nicht-handelbaren Gütern ausgegangen wodurch die gesamte Anpassung durch relative Nachfrage- und relative Preisänderungen erfolgt. Im Ergebnis berechnen sie eine starke reale Abwertung bei einem völligen Schließen der amerikanischen Leistungsbilanz. Die Modellerweiterung um eine sich endogen anpassende Angebotsseite, wie sie im zweiten Kapitel dargestellt wird, reduziert diese reale Abwertung des US-Dollars deutlich von 32% auf 24% in der Hauptspezifikation und sogar von 64% auf 32% in einer Spezifikation mit geringer nachfrageseitiger Substitutionselastizität.

Die pessimistische Sichtweise hinsichtlich der mit einer Leistungsbilanzanpassung einhergehenden Wechselkursanpassungen, welche Obstfeld und Rogoff vertreten, ist nach dieser Analyse daher übertrieben. Gleichzeitig betont sie die wichtige Rolle der Faktormärkte, welche eine bedeutende Anpassung zu bewerkstelligen haben. Diese Sichtweise wird unterstützt durch stilisierte Fakten, welche für OECD-Länder auf einen starken Zusammenhang zwischen Veränderungen des Verhältnisses von handelbarer zu nicht handelbarer Produktion auf der einen Seite und der Leistungsbilanz auf der anderen Seite hinweisen.

Der diesem Kapitel zugrundeliegende Aufsatz ist als Arbeitspapier der Europäischen Zentralbank veröffentlicht worden (Engler, P., Fidora, M. and Thimann, C., 2007. External Imbalances and the US Current Account. How Supply-Side Changes Affect an Exchange Rate Adjustment, *European Central Bank Working Paper, No. 761*) und ist zur Publikation im *Review of International Economics* angenommen worden.

Kapitel 3:
Global Rebalancing in a Three-Country Model

Das dritte Kapitel erweitert den theoretischen 2-Länder-Rahmen des zweiten Kapitels auf eine 3-Länder-Welt, in der die Anpassung der amerikanischen Leistungsbilanz analysiert wird. Dadurch können die unterschiedlichen Anpassungen unterschiedlicher Regionen im "Rest der Welt" herausgearbeitet werden. Speziell wird von einer Ländergruppe mit flexiblem Wechselkurs gegenüber dem US-Dollar ausgegangen ("Europa") und von einer zweiten, welche einen flexiblen oder einen festen Wechselkurs wählt ("Asien"). Die Ergebnisse zeigen, dass die Auswirkungen der Anpassung entscheidend von der Wechselkurspolitik Asiens abhängen. Die USA verzeichnen, wie im 2-Länder-Modell, eine deutlich Schrumpfung der relativen Größe des Sektors nicht-handelbarer Güter. In Asien erfolgt bei flexiblen Wechselkursen eine Ausweitung desselben, während sich bei einer Fixierung des bilateralen Wechselkurses gegenüber dem US-Dollar eine weitere Expansion des Sektors handelbarer Güter einstellt. Beim ersten Szenario ist die Auswirkung auf Europa (die Schrumpfung des Sektors handelbarer Güter) moderat, während im zweiten Szenario ein riesiges Leistungsbilanzdefizit Europas und eine enorme reale Aufwertung erfolgt, sich dagegen die Leistungsbilanzposition Asiens weiter verbessert. Die Verteilung der Anpassungslast ist also wesentlich bestimmt durch die Wahl des Wechselkursregimes.

Kapitel 4:
Gains from Migration in a New-Keynesian Framework

Das vierte und letzte Kapitel analysiert die Auswirkung von Migration auf die sogenannte Phillips-Kurve. Diese beschreibt den Zusammenhang von Veränderungen der Produktionslücke und der Inflation. Ein Modell einer kleinen offenen Volkswirtschaft wird so erweitert, dass in Zeiten eines konjunkturellen Aufschwungs das Angebot an Arbeitskräften durch Immigration erhöht wird. Es wird gezeigt, dass dadurch die Reaktion der Inflation auf Änderungen des Produktionslücke verringert wird, die Phillips-Kurve also flacher wird. Die Intuition für dieses Ergebnis ist wie folgt: Das zusätzliche Angebot an Arbeitskräften reduziert den Anstieg der Reallöhne im Aufschwung und damit der Grenzkosten und der Preise. Im theoretischen Modell ist eine Substitution von Arbeitsleid, welches durch Arbeit im Ausland entsteht, hin zu Arbeitsleid, welches durch Arbeit im Inland entsteht, entscheidend für das Ergebnis. Im Vergleichsmodell ohne Migration kann zusätzliche Arbeitsleistung nur durch reduzierte Freizeit entstehen, wofür eine zunehmende Kompensation in Form höherer Rellöhne erforderlich ist. Dieser Zusammenhang wird durch Migration und die beschriebene Substitution abgeschwächt.

Für das Modell wird eine soziale Wohlfahrtsfunktion aufgestellt als Approximation zweiter Ordnung der Nutzenfunktion eines repräsentativen Haushalts, der sowohl im In- als auch im Ausland seine Arbeit anbietet. Das Ergebnis zeigt, dass durch die Möglichkeit, die Arbeitszeit im In- und Ausland anzupassen, das Gewicht der Volatilität der Produktionslücke in der Wohlfahrtsfunktion sinkt während das der Inflationsvolatilität steigt. Grund hierfür ist, dass die den Nutzen senkende Volatilität des konvexen Arbeitsleids, welche mit der Volatilität der Produktionslücke verbunden ist, reduziert wird.

Chapter 1

Introduction

The world economy has become remarkably integrated in the last decades. Interdependence of national economies has gone so far that the notion of a "closed economy" or a state of autarky has become entirely obsolete.[1] Major developments in one part of the global economy are transmitted through multiple channels, both direct and indirect, to the rest of the world. Trade in industrial goods, financial institutions operating globally and people emigrating to work away from their home country are just a few of the many links between the different parts of the world economy through which transmission works. Economic activity and policies beyond domestic borders are therefore of crucial importance for domestic income generation, financing conditions and ultimately economic policies.

I mention just a few statistical facts to illustrate this general trend to a more integrated world economy. A first example is global merchandise trade that, according to the World Bank's World Development Indicators (WDI) data, constituted around 30% of world GDP in the late 1980s. This figure has doubled for low income countries (according to the World Bank's definition) and increased to almost 50% in high income countries in 2007.

A second example is annual world foreign direct investment which, although quite volatile, has increased to almost 3% of world GDP from below 1% until the late 1980s for both high middle and low income countries (ac-

[1] The probably only exception remaining today is the the People's Republic of Korea.

cording to the WDIs).

Lastly, international migration has increased as well. While in 1960 only 2.5% of the world population lived in a country in which it was not born, this figure increased to 3% in 2005 (according to data provided by the International Organization of Migration). Behind this seemingly small change, a major trend is hidden, that has been present since the 1960s but which accelerated remarkably since the late 1980s. While in the less and least developed regions[2] the fraction of the foreign born population is smaller today than it was in the 1960s, this fraction increased from 3.4% to 9.5% in more developed regions.

While for the increased trade *flows* and foreign direct investment *flows* the resulting increased interdependence between countries is obvious, the presence of a large *stock* of immigrants in rich countries on interdependence is not as clear cut. The effects of migration become more visible when looking at remittances. This income of migrant labor sent back home has increased to an average of more than 4% of low income countries in 2007. Again, this average hides a remarkable discrepancy across countries. For some countries (e.g., Tajikistan and Moldova) remittances constitute more than a third of GDP.

What are the consequences of these phenomena for domestic economies and for economic policies? In this thesis I explore two topical aspects of globally integrated economies and their implications for economic policies in three self-contained essays.

The first topic, discussed in the first and the second essay ("*Global Rebalancing in a Two-Country Model*" and "*Global Rebalancing in a Three-Country Model*" respectively) and presented in Chapters 2 and 3, relates to the relationship between trade and financial globalization. The question to which both essays attempt to provide answers, is what a correction of the international trade and financial imbalances (the "global imbalances") will imply for exchange rates. In particular, I explore the role of a re-allocation between tradable and non-tradable goods producing sectors in an unwinding of the large US current account deficit. The first essay takes a two-country

[2] See United Nations (2006) for a definition of the country groups.

perspective while the second essay takes a three-country view to that question.

The second topic, discussed in a third paper ("*Gains from Migration in a New-Keynesian Framework*") and presented in Chapter 4, is an analysis of migration in a business cycle model. The question to be answered here is what the consequences for a small open economy are when a certain fraction of the labor force not only supplies labor domestically but also in the rest of the world. I derive positive conclusions with respect to the structural implications for the small economy and normative conclusions with respect to optimal policies and welfare.

In what follows I briefly review the three essays separately.

Review of Chapter 2:

Global Rebalancing in a Two-Country Model[3]

The US current account has deteriorated remarkably since the early 1990s. In 2006 it peaked at 6% of gross domestic product but has improved slightly to 4.6% in 2008. Such large current accounts have historically tended to reverse and close at some point (see Edwards, 2004). However, never has an economy as large and as central to the world economy been in this position. Therefore, a large number of authors has addressed this issue in order to assess what the consequences of a reversal of the US deficit might be.

This paper analyzes the role of a re-allocation between tradables and non-tradables sectors in a re-balancing of the US current account deficit. In particular, its effect on the real exchange rate adjustment is analyzed in a simple theoretical framework. The main finding is that the sectoral adjustment on the supply side generally supports the adjustment on the demand side. The demand switching channel of adjustment had prominently been highlighted by Obstfeld and Rogoff (2006). In their analysis, the output of tradable and non-tradable goods is kept fixed and the entire adjustment is achieved through relative price and demand shifts. The authors come

[3] This essay is based on joint work with Michael Fidora and Christian Thimann. It is forthcoming in the *Review of International Economics*.

to the conclusion that the real effective depreciation of the dollar would be substantial. As their "preferred scenario" they calculate a real effective dollar decline of 32%, although they also emphasize the possibility of a much larger depreciation of up to 64%. We show, however, that their pessimistic view with respect to the exchange rate might be exaggerated, while stressing the importance of production factors migrating from non-tradables to tradables production.

The exact magnitude of the dampening of the exchange rate effect depends on the marginal rate of transformation determining the supply responses and, like in Obstfeld and Rogoff, upon the elasticities of substitution between foreign and domestic tradable goods, as well as domestic tradable and non-tradable goods. In what corresponds to Obstfeld and Rogoff's "preferred" scenario, we find that the effective exchange rate depreciation is reduced by a quarter to 24%, but more importantly the implied depreciation is halved in the more "alarmist" scenario from 64% to 32%. In the most benign case the implied depreciation drops from 18% to 5%.

Our extension appears to be supported by actual developments, for that we present some stylized facts, showing that the sectoral supply of tradables and non-tradables varies quite significantly with the current account. Of course, the sectoral change is likely to be stretched over time depending inter alia on the overall flexibility of the economy to adjust. However, a certain supply driven adjustment channel is likely to be present in any current account reversal.

Review of Chapter 3:

Global Rebalancing in a Three-Country Model

This paper extends the two-country perspective on the adjustment of the US current account of the last chapter to a three-country world economy. This allows an analysis of the differential impact of a reversal of the US current account on Europe and Asia. In particular, the outcomes under different exchange rate policies are analyzed. The main finding is, again, that large factor re-allocations from non-tradables to tradables will be necessary in the US. The direction of factor re-allocation in Asia, on the other hand, depends on whether the "Bretton-Woods-II" regime of unilaterally fixed or manipulated exchange rates in Asia is continued or not. If this is the case, the tradables sector and the current account surplus will continue to grow even when the US deficit closes. The flip side of this result is that Europe will face a huge real appreciation and an enormous current account deficit. With floating exchange rates worldwide, the impact on Europe will be limited while Asia's tradables sector will shrink. Policies thus matter a lot for the distribution of the burden of adjustment of the US deficit.

Review of Chapter 4:

Gains from Migration in a New-Keynesian Framework

The fourth chapter discusses consequences of migration, the third aspect of international economic integration mentioned above. The chapter presents a simple New-Keynesian small open economy model that integrates migration by allowing labor to be supplied both domestically and abroad by a representative household. From this small change in the otherwise standard setup follows an important implication for the Phillips-curve: The introduction of migration reduces the sensitivity of inflation to changes in the output gap, that is, the Phillips-curve becomes flatter. The theoretic intuition is simple: When the home economy booms due to high productivity or demand, workers migrate back from abroad because real wages improve relative to those in the rest of the world. This additional labor supply at home relieves the pressure on home wages such that marginal costs, and consequently prices, increase less.

A welfare function is derived to show the welfare losses implied by a deviation from the optimal policy rule. These losses change when migration is allowed in that the weight of output gap volatility falls relative to inflation volatility. The intuition for this result derives from the risk aversion with respect to employment fluctuations. Volatility of the output gap implies volatility in domestic employment, which reduces utility. With return migration, the household is able to smooth this effect on disutility through a substitution of a job abroad for a job at home.

I show that demand shocks result in bigger output increases when migration is allowed while the effects of productivity shocks depend on the choice of parameters. The flip side of the integration of labor markets is that shocks affecting labor markets abroad have spillover effects to the domestic economy.

This chapter adds to a more general discussion on the effects of openness on micro-founded Phillips curves. Loungani et al. (2001) found that more open economies tend to have flatter Phillips curves. Razin and Yuen (2002) showed how this can be explained with respect to trade and capital market integration in a New Keynesian framework. My work thus complements this discussion by adding the third dimension of openness. My approach has recently been adopted by Binyamini and Razin (2007) in a similar framework that takes the perspective of the host country (rather than from the home country of migrants as in my model) and also find that the Phillips curve flattens.

Chapter 2

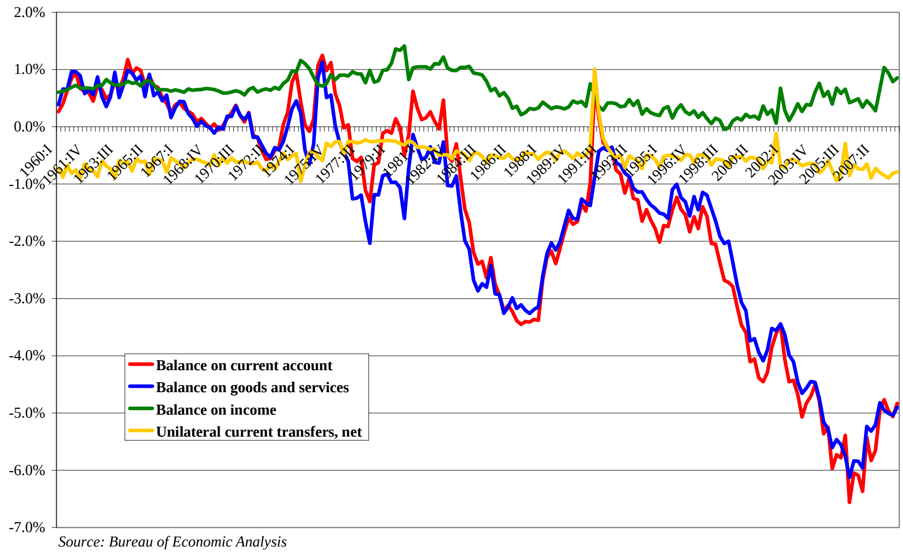
Global Rebalancing in a Two-Country Model

2.1 Introduction

The US current account deficit has been at the center of an intensive debate for at least a decade. The increasing trade deficits (see Figure 2.1) and an ever deteriorating net asset position have put into question the sustainability of the current trajectory, not least since the financial market turmoil starting in August 2007. Over the short and medium-term, however, many economists consider the US current account deficit to be sustainable. Reserve accumulation by the emerging Asian economies, whose currencies closely follow the dollar, and the elevated oil price, which has transferred wealth to a few oil exporting countries with often still underdeveloped financial systems, leads to a steady flow of purchases of US dollar denominated financial assets. This system of stabilized exchange rates has been named a Bretton-Woods-II system by some authors (e.g., Dooley et al., 2003, 2004a-c, 2005a-b).[1] Other authors point at investors' belief in the relative strength of the US economy justifying an ever bigger share of US assets in global portfolios and therefore

[1]See also McKinnon (2006) who labels the system the "East Asian dollar standard". The name "Bretton-Woods-II" should be taken with care, however, since the original Bretton-Woods was a multilateral system rather than a unilateral peg as today's system.

Figure 2.1: US current account (Q1 1960-Q3 2008; in % of GDP)



capital inflows (Engel and Rogers, 2006).[2] Economists do vary in their assessment of this situation, ranging from "temporarily stable disequilibrium" to "an equilibrium of global imbalances and low interest rates" (Caballero, Farhi and Gourinchas, 2006 and 2008), but all concur that short-run sustainability is not an issue. Indeed, even since the beginning of the financial turmoil in August 2007 investors continued to finance the somewhat smaller but still huge deficit.

Over the longer term things will change, however, since stocks, rather than flows of gross assets move into the forefront. An ever increasing imbalance between gross assets and gross liabilities will deteriorate the income balance and thereby the current account balance. Furthermore, investors' changing risk perception will certainly reduce the willingness to hold an ever increasing claim on the US economy. Hence, the past and current trajectory will in all likelihood reverse at some point. The main question then is how the external imbalance of the United States is likely to adjust.

[2]Cooper (2005) stresses that even in the long run the deficit is sustainable due to the high investment in education and R&D activities in the United States implying high returns to these investments in the future.

This paper contributes to the discussion on how the reversal will work itself out. In particular, we stress the importance of a supply side adjustment along the often stated re-balancing on the demand side and its implications for the US real exchange rate. We find that a devastating scenario with respect to the US dollar is much less likely than what the pessimists' view suggest.

Several papers have looked into the adjustment from a demand side angle, considering that it would primarily be global demand that would shift away from foreign tradable goods to US tradable goods and US demand shifting from (imported or domestically produced) traded goods to (domestically produced) non-traded goods. These studies have also provided conclusions on the exchange rate change entailed in this process. Among the best known contributions to this literature are those by Obstfeld and Rogoff (2001, 2005, 2006), who examine various constellations of the demand shift and quantify the exchange rate implication.[3]

For instance, Obstfeld and Rogoff (2005 and 2006) develop a stylized general equilibrium framework in order to illustrate the "mechanics" of a current account rebalancing based on changes in the relative prices between traded and non-traded goods and eventually the terms of trade and the real exchange rate. They use this model to examine the implications of a closing of the US current account deficit. In their analysis, the output of tradable and non-tradable goods is kept fixed and the entire adjustment is achieved through relative price and demand shifts. The key policy question in this analysis is the following: What rate of depreciation of the US dollar would accompany such a scenario? In Obstfeld and Rogoff (2006) – which is used as the main reference point for our paper – the authors come to the conclusion that the real effective depreciation of the dollar would be substantial and comparable to the post 1985 decline of the dollar – 30% in real effective terms between March 1985 and April 1988 – that was enrobed in one of the largest efforts of international monetary cooperation centred on the Plaza-

[3] Other authors pointing to the exchange rate implication of an adjustment in the US current account are Feldstein (2006), Blanchard, Giavazzi and Sa (2005), Freund and Warnock (2006) or Roubini and Setser (2004).

Louvre accords. The authors give as their "preferred" scenario a real effective dollar decline of 32%, although they also emphasize the possibility of a much larger depreciation of up to 64%.

We believe that this scenario analysis misses an important point: The relative price changes accompanying the adjustment are unlikely to go unnoticed by US firms, unless for a very rapid closing of the deficit, there will be adjustments on the supply side in response to the changing relative prices. This, as we will show, mutes the exchange rate response during the adjustment.

The model presented here is a modified version of the model in Obstfeld and Rogoff (2006). We are particularly interested in whether, and to what extent, the exclusive focus on a price adjustment biases the findings of Obstfeld and Rogoff towards a higher depreciation than when allowing for endogenous production. We therefore drop the assumption of an endowment economy and the entire adjustment being driven by changes of demand, and we extend their model to include endogenous supply-side changes. Such an extension appears to be supported by actual developments. For that we will present some stylized facts, showing that the sectoral supply of tradables and non-tradables varies quite significantly with the current account. Of course, the sectoral change is likely to be stretched over time depending inter alia on the overall flexibility of the economy to adjust. However, a certain supply driven adjustment channel is likely to be present in any current account reversal.

The supply-shift is introduced by transformation curves between tradable and non-tradable goods produced in the United States and the rest of the world respectively. Hence, any change in the relative price of non-tradables relative to domestically produced tradables will incur a shift in production from one sector to the other. A fall in this price will then not only imply a shift in demand from tradables to non-tradables, it will, in addition, increase the relative supply of tradable output. Accordingly, these two effects will help improve the trade balance, defined as output of tradable goods net of consumption of tradable goods. Because both effects work in the same direction, the necessary depreciation implied by a reduction of the current account deficit is smaller than in the case in which the entire adjustment rests solely on demand adjustments.

The exact magnitude of the dampening of the exchange rate effect depends on the marginal rate of transformation determining the supply responses and, like in Obstfeld and Rogoff, upon the elasticities of substitution between foreign and domestic tradable goods, as well as domestic tradable and non-tradable goods. In what corresponds to their "preferred" scenario, we find that the effective exchange rate depreciation is reduced by a quarter to 24%, but more importantly the implied depreciation is halved in the more “alarmist” scenario from 64% to 32%. In the most benign case the implied depreciation drops from 18% to 5%.

The exchange rate dimension of the re-balancing is important for several reasons. First, worldwide trade flows will be re-directed. Second, a large dollar devaluation has an impact on the distribution of wealth across the globe due to valuation effects. There is strong evidence that a dollar decline would favour the United States, given that its debt is denominated almost exclusively in US dollars, while its assets are to a significant degree denominated in foreign currency (Tille, 2002; Lane and Milesi-Ferretti, 2005, 2006; Gourinchas and Rey, 2006). Estimates suggest that a 10% decline in the dollar would imply a wealth transfer of close to $700 billion from the rest of the world to the United States. Furthermore, Cavallo and Tille (2006) have shown that valuation gains also help to make the adjustment more smoothly over time.

Third, it would also imply potentially large changes for domestic prices in the economies concerned, even though recent evidence points to a decline in pass-through (Campa and Goldberg, 2005; Marazzi et al., 2005; Gust and Sheets, 2006; Goldberg and Tille, 2006). And finally, large exchange rate changes could significantly impact bond yields, which could be another element impacting adversely the global economic environment (Mehl and Capiello, 2007). Hence, the size of exchange rate movements in an adjustment scenario may matter greatly for its economic consequences.

The flip side of our analysis, and therefore of our policy implications, is that the adjustment will rely less on exchange rate movements but more on supply side changes: the US current account deficit is unlikely to close up without a substantial change in its own and its trading partners' industrial structure. The degree of flexibility in factor markets will determine whether this adjustment will be smooth or abrupt and accompanied by large unemployment. Therefore, measures that help smooth the adjustment, in particular facilitating an orderly switching of jobs, would facilitate an orderly adjustment of the US current account deficit and hence of global imbalances.

Given our analysis below, this last point relates more to the United States than the rest of the world because the required sectoral re-allocations are limited in the rest of the world. However, in a related paper (Engler, 2009) which constitutes the next chapter of this thesis, the impact in a three-country framework is analyzed. The differential exposures to the United States and differential exchange rate policies in Europe and Asia result in differential consequences for the two regions. Hence, the need for flexible factor markets may matter for the rest of the world too.

The next section provides a brief overview of the literature on global imbalances. We then shed some light on the empirical relationship between current account developments and sectoral shifts between tradable and non-tradable goods sectors. This is supposed to motivate our approach. Then, we introduce the theoretical model and analyze adjustment scenarios in this framework, and finally conclude.

2.2 Literature Review

A number of definitions and explanations have been offered to describe and explain the occurrence of global imbalances. We start the overview of this literature with a definition of "global imbalances" and then present the various approaches summarized in three broad groups: The Bretton-Woods-II approach, the optimists' approach and the alarmists' approach.

In the discussion below we understand global imbalances as[4]

unsustainable external positions of systemically important economies

[4] See European Central Bank (2008) for a similar definition.

that reflect distortions or entail risks for the global economy.

Hence, the term relates to external positions (both current account and financial positions) of systemically important economies, that is, only economically large ones with strong influences on other economies. Obviously, the United States, Europe and Asia as a group could easily be subsumed under this definition.

It reflects distortions that may be due to political interference (e.g., exchange rate policies) or structural inflexibilities implying deviations from equilibria that would be observed in a frictionless world. And it relates to resulting risks for the global economy. These risks in turn might be the result of other distortions or inadequate adjustment mechanisms that are not themselves responsible for external deficits or surpluses. For example, the euro area as a whole has only a slightly unbalanced current account position. In an adjustment scenario in which the US deficit closes, however, low flexibility of goods and factor markets might well lead to negative implications for the European economy, which in turn might have implications for the world economy as a whole.

Lastly, the external positions need to be unsustainable, which implies that there are conceivable distortions and potential risks that might not materialize over a relevant horizon. This later point relates in particular to policy interventions that allow deviations from frictionless world equilibria for a long time.[5]

2.2.1 The Bretton-Woods-II Approach

The Bretton-Woods-II approach has been put forward in a series of papers by Dooley et al. (2003, 2004a, 2004b, 2004c, 2005a, 2005b). According to this approach the US current account deficit is the outcome of a deliberate

[5] Of course, measuring sustainability is "notoriously difficult" and "largely judgemental" (ECB, 2008, p.13). Hence, from a policy viewpoint the notion of sustainability is of little help and it was therefore not included in the definition in that publication. However, judgements about the underlying dynamics that caused the current external positions and about possible future paths of those are necessary in detecting potentially negative reversals. And these depend critically on the sustainability of the current configuration.

policy followed by several Asian governments. This policy is an export-led growth strategy with the United States as the preferred destination for these exports. To that end, exchange rates are fixed or stabilized vis-à-vis the US dollar while they float jointly with the dollar relative to other major currencies, such as the euro. The authors have mainly China in mind, but they also point to a broader group of countries where exchange rates are manipulated, including Japan trying to export itself out of an era of slow growth.[6]

There are two important questions that need to be answered if this framework is supposed to be a realistic description of reality. First, why is the United States and not other industrialized economies central in this strategy. Europe might just as well have served as a market for growing exports. Second, why have the Asian governments been willing to accumulate the enormous amount of foreign reserves, in particular low yield treasury bonds. From an investment perspective other allocations for national wealth appear more profitable.

The answer that Dooley et al. give addresses both questions. They argue that what is lacking for a sustainable export-led growth strategy that assures ongoing integration of the hundreds of millions of under-employed rural poor are sophisticated domestic financial markets. Without these markets savings cannot be transformed into high quality financial assets and thereby efficient investment products. Therefore, savings are exported to the potentially most sophisticated financial center of the world economy, the United States.[7] In return, this financial center exports its financial services in the form of foreign direct investment. These investments assure that the capital stock is improved to world class status, helping to increase productivity and reduce poverty. In accordance with this view, Gourinchas and Rey (2006) named the United States the "venture capitalist of the world economy". So the stock of dollar reserves is the flip-side of the stock of foreign direct investment in

[6]The name Bretton-Woods might be regarded as misleading. The post war Bretton-Woods system was, of course, a global and coordinated system, while today's "Bretton-Woods system" consist of a few countries unilaterally manipulating their exchange rates. Therefore, we use the name for convenience rather than historical similarity.

[7]See Krishnamurthi and Vissing-Jorgensen (2007) for evidence on this.

Asian economies.[8]

The accumulated reserves serve as collateral in the relationship between exporters and the financial center. Investors face particular risks when investing in emerging markets. Those range from political uncertainties to risks of severe financial crises. Hence, provision of collateral is a useful means to keep investors on board. This collateral is provided by the stock of official reserves, invested in the financial center economy. As a consequence, the value of these reserves goes beyond the interest earned on them. Furthermore, the exports generated by these investments serve as another form of collateral and its value can be increased by keeping the currencies competitive.

As long as this strategy is and can be followed by Asian governments, there is no reason to believe that the current account surpluses are not sustainable. It cannot last forever, however, since at some point every economy will see its resources exhausted and inflation picking up. This makes the control of real exchange rates increasingly difficult. Furthermore, sterilization of capital inflows is bound to loose its effectiveness in an ever more integrated financial economy. But, as Dooley et al. argue, many economies before the Asian ones have been able to follow similar strategies for extended periods, which implies that sustainability might not be an issue for the time being.

An important weakness of the Bretton-Woods-II approach is the idea that foreign direct investment plays an overwhelming role in Asian government's growth strategy. Recent research highlighted that foreign direct investment plays only a minor role in the most successful emerging market economies, while own financing through retained profits is a much more important source to finance investment projects (Aizenman et al., 2007, Gourinchas and Jeanne, 2007). Thus, the interpretation of the United States as a venture capitalist exaggerates the role of US financial institutions. This is reinforced by the recent finding by Curcuru et al. (2007 and 2008) who find no positive returns differential in favor of the United States (i.e., US

[8] That it is mainly governments and not the private sector that invest in the United States is, according to that view, a result of the underdeveloped financial markets in which central banks absorb private savings from domestic banks and export them. Furthermore, capital controls allow central banks to keep real exchange rates undervalued in order to keep exports growing.

foreign gross debt yielding a lower return than US gross foreign assets), the central building block of the interpretation of the United States as a venture capitalist and the so-called "exorbitant privilege".[9]

As a consequence, the United States may be less important as a financial center than suggested by Dooley et al. and the sustainability of the current configuration of current accounts would rest on less solid foundations. In other words, the observed imbalances may not be stable.

Another problem with the Bretton-Woods-II approach is that in many Asian emerging economies (an exception being China), the large current account surpluses started in the aftermath of the Asian financial crisis of the 1990s and were initiated by a significant fall in investment rates (Chinn and Ito, 2007), which are hard to reconcile with government policies fostering export led growth. Furthermore, the interpretation of a development strategy and the lack of an adequate financial system as the source of global imbalances makes it mostly a China story. This is not very convincing because a much larger part of global surpluses originates in the financially developed countries of Germany and Japan.

However, what is quite plausible about the Bretton-Woods-II approach, at least with respect to China, is the undervaluation strategy that has already proved successful as a means to foster export-led growth for several other economies in the past (among them Germany and Japan). But the extent of the accumulation of reserves may be interpreted more as a nasty and increasingly embarrassing side effect than part of a deliberate strategy to build up collateral. A more rapid real appreciation might at some point be the first best strategy, in particular once the benign inflationary environment ends. Then, the current account surplus might not be as persistent as Dooley et al. believe. For the time being, however, Chinese authorities' strong interest in stable exchange rates will persist, given the still large number of rural poor and the state of the Chinese financial system that might not be capable of managing a more open capital account. Thus, from this part of

[9] This novel finding is in stark contrast to many results and assumptions of other authors. In most analyses of global imbalances, the "exorbitant privilege" is assumed or found.

the global economy, no quick adjustment should be expected.

Caballero et al. (2006, 2008) set up a model that is similar in part to the approach by Dooley et al.. Their starting point is the observation of three stylized facts that they believe any reasonable model needs to be able to explain jointly: The large and (by the time the papers were written) increasing US current account deficit, the decrease in global real interest rates over the last decade and the increasing share of US assets in global portfolios.

Their explanation lies in the integration of Asian economies into the world economy explaining the trade surpluses of these countries, while their exports of savings is due to a strong demand for high quality assets that cannot be supplied by their own financial markets. Only developed nations have the sophisticated financial markets able to produce such high quality financial assets. Asian investors are thus willing to finance a large current account deficit with the size determined by their savings in excess of investments. The flip side of this is low interest rates in the United States inducing an increase of domestic absorption and thereby generating the counterpart to the capital inflows, that is, the current account deficit. Hence, the three stylized facts (the US current account deficit, low interest rates and an increasing share of US assets in global portfolios) are jointly explained.

According to this view, the configuration of current accounts in recent years has been an equilibrium phenomenon. With strong demand for US assets from abroad and fast growing economies in Asia, the world was not "unbalanced". But the most recent trends cast doubt on whether this perception prevails and the question of sustainability has increased in importance. Thus, the market-based variant of the Bretton-Woods-II view of Caballero et al. (2006, 2008) has lost appeal, while, as already mentioned, the Chinese government's undervaluation strategy has not.

For the analysis below of a closing of the US current account deficit, this means that, at least to some extent, an assumption of a Bretton-Woods-II scenario is indeed reasonable.

2.2.2 The Optimists' Approach

The second approach relates the observed configuration of current account positions to the integration of international financial markets and to the superiority of the US real and financial economy, highlighting the role of the private sector rather than deliberate government policies, as in the former approach.

Among the various papers that can be summarized under this approach, Hausmann and Sturzenegger (2006) take the most radical position by denying that the United States is a net debtor country and that there have been current account deficits of the size reported by official statistics. They argue that those statistics do not provide an adequate picture of international financial positions and that "dark matter" that is not taken into account, plays a stabilizing role. More precisely, the stock of US net foreign assets is supposedly much larger than usually claimed, in particular, so they argue, the stock of foreign direct investment is underestimated. If net foreign assets are larger than assumed, past current account deficits must have been much smaller than reported. With much smaller deficits a disorderly and severe adjustment appears much less likely.

However, as pointed out by Buiter (2006), the *mistrust* in trade data and *trust* in net foreign investment income data Hausmann's and Sturzenegger's analysis is based on, is rather arbitrary and the services exports (liquidity, insurance and knowledge services) that they refer to and that supposedly are not captured by official statistics, are hugely exaggerated or non-existent. Furthermore, rather than assuming reliable income flows data, Gros (2006a-b) reckons that those reported flows are systematically biased because of fiscal and regulatory considerations. US firms supposedly report their true reinvested earnings, while foreigners under-report their reinvested earnings in the United States to avoid taxation. Thus, according to Gros (2006a-b), the true net international investment position and the current account of the United States may be even worse than commonly assumed, rather than better, as reckoned by Hausmann and Sturzenegger. So "dark matter" might even flow in the opposite direction.

In the calibration below, however, we only rely on official current account data and do not use any estimates of dark matter. This is, as the discussion on that matter indicates, of unknown magnitude.

Engel and Rogers (2006) interpret the huge capital inflows to the United States financing the current account deficit as a deliberate, forward looking investment strategy by international investors. This strategy, according to this view, is based on the extrapolation of the last decades' increasing United States output share among the group of industrialized economies. Under this assumption, it is the expected increasing strength and size of the US economy relative to other economies that justifies an increasing share of US assets in a global portfolio. It follows from this "shares model", that the US deficit is sustainable, as long as markets perceive the United States a better investment opportunity than the rest of the world. Market sentiment, rather than government policies, determine the sustainability of the US current account deficit and whether the world economy is in balance or not, according to this view.

The very recent developments in world financial markets demonstrate the limits of the approach by Engel and Rogers (2006). Market sentiment has changed, global imbalances have increased in importance for financial markets' perceptions and the appeal of the US economy has decreased significantly. Therefore, the alarmists' approach, which is now outlined, has certainly gained appeal.

2.2.3 The Alarmists' Approach

Blanchard et al. (2005) come to the most adverse conclusion with respect to the exchange rate implications of a global rebalancing scenario. They set up a portfolio balance model with imperfect substitutability between domestic and foreign assets to jointly explain exchange rates and the current account. They interpret the revaluation of the dollar in the second half of the 1990s and the following depreciation as a consequence of two underlying developments. First, a shift in preferences towards US assets induces the dollar to appreciate originally and depreciate thereafter, reflecting the need for an improved trade balance to service the higher US foreign debt. Second, a shift in preferences towards goods produced in Asia and away from United States produced goods induced a deterioration of the current account and an ongoing depreciation of the dollar, again due to the increased interest payments on the accumulated foreign debt. The first effect dominated the second initially while both effects worked in the same direction afterwards, depreciating the dollar. According to their calculations, the dollar would still have to depreciate considerably.

An interesting result of the model in Blanchard et al. (2005) is the effect of an end of the dollar peg by Asian central banks. In a portfolio balance model, this would imply that an investor with a strong preference for dollar assets leaves the market, hence, reducing relative demand for US assets and increasing relative demand for other currencies like the euro. Thus, and in contrast to the result of Obstfeld and Rogoff (2005), an end of the dollar peg would increase the appreciation of the euro vis-à-vis the dollar rather than reduce it in a rebalancing scenario.

However, an end of the dollar peg and an end of Chinese capital controls will be accompanied by a new actor in the financial world, the private Chinese sector, and imply a new destination for asset allocation for foreigners, the Chinese market. How these two effects will alter the relative demand for various currencies, and thereby the future path of exchange rates, is unclear. Hence, the interpretation of Blanchard et al. (2005) needs to be taken with care.

In light of this interpretation, the world economy has been in an unbalanced position because of a distortion in the form of a certainly unsustainable relative demand for US assets due to government intervention. Sustainability hinges crucially on the willingness of Asian central banks to continue to accumulate ever more US assets. The risks implied by a reduction of the distortion are related to their potentially adverse effects on economic growth in Europe. An end of the dollar peg might easily lead to another distortion because a politically unbearable appreciation of the euro might in turn result in an intervention by the European Central Bank.

A similarly pessimistic view is taken by Obstfeld and Rogoff (2001, 2005, 2006). They take the unsustainable domestic and external positions of the United States as given. Unsustainably low personal savings rates, combined with a housing bubble, a fiscal deficit in recent years and the strong reliance on Asian central banks and oil exporters in financing the huge current account deficit hinted at vulnerabilities[10] at the time of writing their papers, which in the meantime partly seem to have materialized. Hence, they believed a correction was inevitable. The remaining question then was, "When, how fast and through which channels would the adjustment occur?". They hint at the strong association between the current account and the trade balance (see Figure 2.1) and that consequently any adjustment would imply an adjustment of trade flows.

This adjustment in trade flows would imply a consumption switching from rest of the world tradables towards US tradables globally, from tradables towards non-tradables in the United States and vice versa in the rest of the world. But because goods markets are not very integrated, that is, substitution elasticities being low, the relative price changes needed to bring about a given reduction in the US trade deficit would have to be large. The relative prices of non-tradables and the terms of trade would move strongly and thereby the real exchange rate and, with inflation kept under control by central banks, nominal exchange rates.

In a static two-country model (Obstfeld and Rogoff, 2006) the US real exchange rate has to depreciate by up to 64% in the most drastic parameterization of a low degree of substitutability between goods. Increasing the assumed degree of substitutability, of course, reduces the required exchange rate movements. Obstfeld and Rogoff interpret the lower degrees of substitutability as short-term responses while higher elasticities could be regarded as longer-term responses. Hence, a crash scenario, which the authors regarded as quite likely, in which markets might no longer be willing to finance the deficit would be associated with large exchange rate adjustments while a longer term rebalancing would be associated with more benign exchange rate implications.

In an extension to a three-country setting (Obstfeld and Rogoff, 2005)

[10] Roubini and Setser (2004) argue similarly.

consisting of Asia, Europe and the United States, the distribution of the adjustment across different regions can be assessed, in particular under different policies pursued by Asian governments. Under a Bretton-Woods-II scenario, as proposed by Dooley et al., the dollar rate of Asian currencies is kept constant. In this case the Asian current account surplus would even increase, implying that Europe would have to absorb the entire deficit from the United States as assumed in the analysis and the additional surplus of Asia. The bilateral US-euro real exchange rate would have to appreciate spectacularly and certainly to a degree that would be unbearable politically.

In a "muted Bretton-Woods-II" scenario Asian governments keep the current account surplus constant while letting their currencies adjust. When the US deficit is closed, the Asian currencies depreciate slightly in effective terms while the euro appreciates much less than in the Bretton-Woods-II scenario. The authors interpret this as proving that Asian economies can let their currencies float while continuing to absorb their surplus labor according to their development strategy.

This approach is a valuable contribution because it highlights the crucial role of trade adjustment in rebalancing global imbalances. Figure 2.1 reveals that the current account position of the United States remains largely a trade phenomenon. Several authors point to the increasing importance of valuation effects mitigating the required adjustment in trade flows and exchange rates. Behind this argument is that the US income balance would improve after a depreciation due to its mainly US dollar denominated external liabilities and mainly foreign currency denominated assets. However, other effects on the income balance, such as increasing US interest rates, are likely to at least partially offset the gains due to valuation effects. Hence, trade adjustment will in any case play a prominent role in any adjustment scenario.

However, the sole reliance of the trade adjustment on demand switching while real output of tradables and non-tradables is assumed to be constant misses an important channel of adjustment. Not surprisingly, the entire adjustment occurs through price changes, which in turn need to be large. What is very likely to happen in addition, however, is a production switching from US non-tradables towards tradables and vice versa in the rest of the world.

As shown below in a model that nests the two-country framework of Obstfeld and Rogoff (2006) as the limiting case of no production switching, a re-allocation of production factors supports the adjustment. Thereby, the exchange rate response is mitigated, in case of the very low degrees of substitution from 64% to about 33%, a reduction of about 50%.

Engler (2009), which is included as the next chapter below, analyzes the three country perspective and the implications of a rebalancing scenario for Europe and Asia under differential exchange rate regimes. It turns out that Asia is able to shift a large share of the burden of adjustment of the US deficit towards Europe with potentially devastating effects for the European tradables sector.

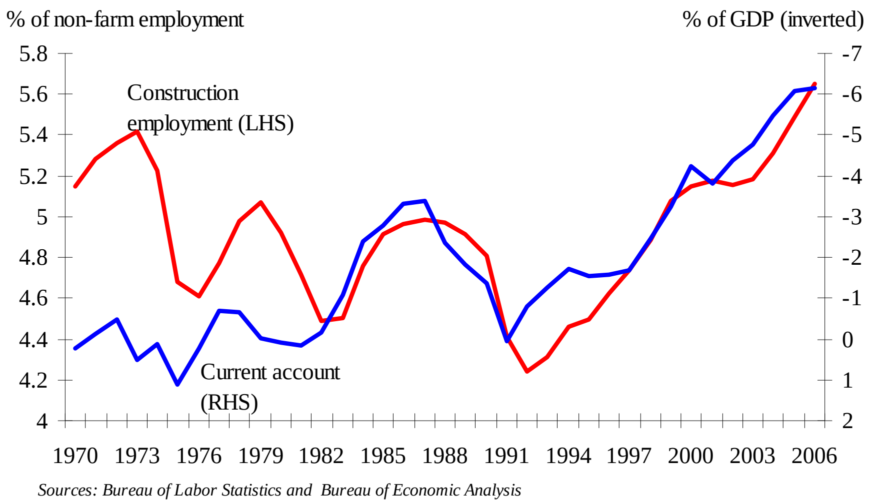
We also present evidence for relative price changes AND production switching between sectors associated with current account movements in an empirical analysis using data of 28 OECD economies including the United States. We find that the relative volume of tradable production co-moves (positively) with the relative price and both significantly (and positively) correlate with the current account balance. A 10% depreciation is on average accompanied by an increase in the volume of tradable goods relative to non-tradable goods of $5\frac{1}{2}\%$ to 7%. A 10% increase of relative tradable output comes with an improvement of the current account by around 2 to 3 percentage points.

2.3 The Current Account and the Supply Side

In this section, we first have a look at co-movements of two US time series, the current account and employment in the construction sector. Then, we examine co-movements between the current account and the relative volume and relative price of tradables as well as the real exchange rate more formally for a sample of OECD countries. These analyses, we believe, support our supply-side view to the re-balancing of the US current account.

There is a remarkable relationship between employment in the US non-tradables sector and the current account deficit. Figure 2.2 presents the co-movements between the current account to GDP ratio and the share of construction employment in total non-farm employment. Construction is a non-tradable activity and its employment share a good indicator of relative sectoral developments. Both time series have been co-moving since the early 1970s and particularly tightly during the last twenty years. Figure 2.3

Figure 2.2: US construction employment and current account

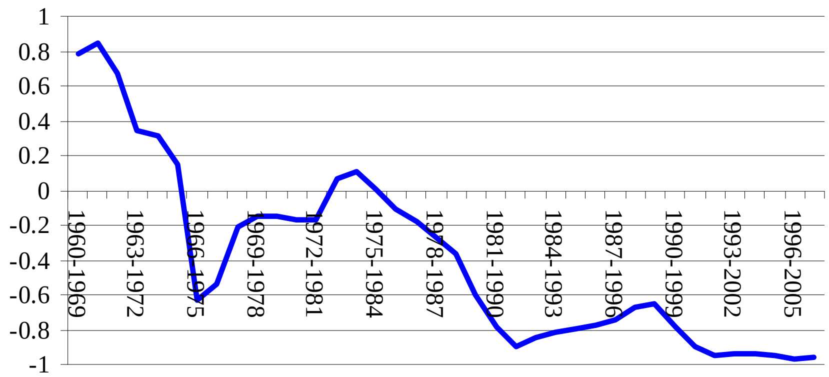


presents the ten-year, time-varying correlation coefficients between the two series in Figure 2.2. This correlation has gone from positive (i.e., increasing current account surpluses occurring in times of increasing construction employment), but unstable[11], in the 1960s to quite persistent values of almost minus one (i.e., increasing current account deficits occurring in times of increasing construction employment). Hence, the global financial integration since the end of the Bretton-Woods system seems to have played an important role for structural shifts in the US economy. The construction boom in recent years was not only financed by foreign investors and thereby related to the current account, it was also associated with a shift of production factors away from tradables sectors to non-tradables activity such as housing. Consequently, a reversal of the current account is likely to be accompanied

[11] The large swings in the correlations until the early 1970s suggest that there has been no clear link between the current account and construction employment.

by a sectoral re-allocation away from non-tradables and towards tradables if this correlation is caused by a structural relationship. Such a structural relationship is what we assume in our theoretical model presented below.

Figure 2.3: Correlation between US current account and construction employment



Note: Ten-year correlation coefficients between current account to GDP ratio and share of construction in total nonfarm employment.
Source: Bureau of Labor Statistics, own calculations

Next, we briefly examine co-movements between the current account and the relative volume and relative price of tradables as well as the real exchange rate. We therefore construct value-weighted volume indices for both tradable and non-tradable goods from disaggregated data[12] taken from the OECD Structural Analysis Statistics, which provide information on value added in constant and current prices in 57 sectors of 20 OECD countries.[13] Price indices are constructed as deflators of value added in both sectors. Finally, relative volume and price indices are calculated.

In practice, the distinction between tradable and non-tradable goods is less clear-cut than in theory. We therefore construct two different sets of sectoral data. The first is a traditional one where tradables comprise (i) agriculture, hunting, forestry and fishing, (ii) mining and quarrying, and (iii)

[12] See also Goldstein and Officer (1979) for this approach.
[13] The OECD Structural Analysis Statistics are based on the United Nations' International Standard Industrial Classification of all Economic Activities, Revision 3 (ISIC Rev. 3).

total manufacturing.[14] A second, broader definition, adds finance, insurance, real estate and business services taking account of the trend to an increasing share of tradable services.[15]

We focus on two questions. First, we want to assess whether changes in the relative price of tradables have an impact on the (relative) supply of tradables. In particular, we want to explore whether an increase in the relative price of tradables can trigger a reallocation of production factors to the tradable goods sector and eventually result in an increase in the relative supply of tradables. Second, we want to assess if there is a link between the production of tradable goods and the current account, whether an increase in the relative quantity of tradable goods produced results in an improvement of the current account.[16]

In order to capture the long run dimension of the relation between the real exchange rate and the relative volume of tradable goods in total production, we run an error correction type regression that tests for a long run relation between the real exchange rate and the relative volume of tradable goods and short run adjustments of the volume of tradables to deviation from the long run equilibrium. As error-correction implies cointegration between the two variables, we test for a unit-root in the levels of the real exchange rate and the relative volume of tradable output. Since we fail to reject the hypothesis of a unit-root in the level, while we can reject the hypothesis of a unit-root in the first difference, we proceed under the assumption of first order integration. The error-correction equation takes the following form:

[14] This distinction is the same as in Goldstein and Officer (1979), Goldstein Khan and Officer (1980) and de Gregorio, Giovanni and Wolf (1994). See also Kravis and Lipsey (1988).

[15] Mann (2003, 2004) and Jensen and Kletzer (2005) highlight the increasing "tradedness" of some services. However, since for most services there is no trade data, we can use this broad definition only as a rough guess of actual "tradedness".

[16] Concerning the first hypothesis, our analysis is subject to two caveats. First, the analysis suffers from an identification problem. While (supply side) shocks to productivity imply a negative correlation between the price and the volume of tradable goods, demand shocks would tend to yield a positive correlation between the price and the volume of tradables. Second, our hypotheses focus on long-term developments which are extremely difficult to isolate from other factors that impact the volume and price of tradable goods production and the current account.

$$\Delta\left(\frac{Y^N}{Y^H}\right)_{i,t} = \alpha_i + \beta\left(\left(\frac{Y^N}{Y^H}\right)_{i,t-1} - \gamma REER_{i,t-1}\right)$$

The fraction Y^N/Y^H is the natural logarithm of the relative volume of non-tradable and tradable output, $\Delta(Y^N/Y^H)$ denotes the percent change in the relative volume, and $REER$ is the natural logarithm of the real exchange rate (where an increase represents an appreciation). A positive value for γ indicates a positive long-run relationship between the relative volume of non-tradables and the real exchange rate. Temporary deviations from this long-run equilibrium are adjusted each period by a fraction β of the disequilibrium.

Table 2.1: Error correction model of real exchange rate and tradable output

Tradable aggregate	**Adjustment coefficient**	**Long run coefficient**	**R^2**	**Number of obs.**
Narrow definition				
full sample	-0.12	0.71	0.16	515
	(-5.62)	(3.52)		
excluding EMEs	-0.11	0.70	0.15	448
	(-5.18)	(3.01)		
Broad definition				
full sample	-0.11	0.54	0.17	515
	(-6.40)	(2.57)		
excluding EMEs	-0.11	0.55	0.17	448
	(-5.87)	(2.09)		

Table 2.1 summarizes results for the full sample and for a sample excluding emerging market economies (EMEs), and for the narrow and the broad definition of the tradable aggregate. First, we find that the long run coefficient γ is statistically significant both when using the narrow and – although to a lesser extent – when using the broad definition of tradable goods. Sec-

ond, the coefficient is also economically significant, as it implies that a 10% depreciation on average results in a long run increase of the relative volume of tradable to non-tradable output by around 7% when using the narrow measure or around 5.5% when using the broad measure. This estimated long run coefficient is in fact consistent with the elasticities as implied by the model simulation presented below. The adjustment coefficient β is significant and has the expected sign, indicating that the share of tradables in output indeed adjusts to the long-run equilibrium. Finally, the residuals from the error correction regression are well behaved and serially uncorrelated. Unit-root tests on the residuals fail to reject the hypothesis of a unit-root in the residuals thus lending support to our hypothesis of cointegration between the real exchange rate and the relative volume of tradable output.

A final note refers to the relation between the volume and price of tradables and the nominal current account. Since we are interested in the long-run correlation of the production of non-tradable goods (and their relative price) and the current account, we divide our sample into four five-year windows and regress five-year changes in the current account (CA/GDP) on five-year percentage changes in the relative volume (Y^N/Y^H) and price (P^N/P^H) of non-tradable goods over the same period:

$$\Delta\left(\frac{CA}{GDP}\right)_{i,t} = \alpha + \beta\left(\frac{Y^N}{Y^H}\right)_{i,t} + \gamma\left(\frac{P^N}{P^H}\right)_{i,t}$$

Results are summarized in Table 2.2. Although our aim is not to postulate a causal relationship, our results clearly show that indeed there is significant co-movement between the current account and both the quantities and prices of tradable production. In all specifications, the coefficients on both the percentage change of the relative volume of non-tradable goods and the percentage change of the relative price of non-tradable goods are highly significant and have the expected sign. The point estimates for the relationship between the relative volume and the current account suggests that a 10% decrease in the relative volume of non-tradable goods is on average accompanied by an improvement in the current account between 1.8 and 2.7 percentage points. Furthermore, a 10% decrease in the relative price of

Table 2.2: Regression of current account on relative volume and price

Tradable aggregate	**Change in rel. volume**	**Change in rel. price**	**R^2**	**Number of obs.**
Narrow definition				
full sample	-0.18	-0.11	0.14	87
	(3.62)	(2.72)		
excluding EMEs	-0.21	-0.11	0.16	77
	(3.73)	(2.36)		
Broad definition				
full sample	-0.26	-0.20	0.23	87
	(4.96)	(3.73)		
excluding EMEs	-0.27	-0.20	0.23	77
	(4.68)	(3.49)		

non-tradables comes with an improvement of the current account by between 1 and 2 percentage points. Hence, the quantity adjustments appear to be quantitatively more important than the price adjustment.

In summary, we found evidence that the supply of tradable goods tends to adjust to price changes. For a sample of up to 28 OECD countries including the United States, we find that a depreciation of the currency by 10% on average increases the volume of tradable goods relative to non-tradable goods by between 5% and 7.5%, and that a 10% increase of relative tradable output comes on average with an improvement of the current account by around 2 percentage points.

These are the stylized facts. In the next section, we present a theoretical model that can explain them and it turns out that these stylized facts are quantitatively broadly in line with our simulation results.

2.4 The Model

The model we employ is a variant of the set-up used by Obstfeld and Rogoff (2006). There, two large countries, the United States and the rest of the world, are connected through trade and holdings of foreign assets. Both the United States and the rest of the world produce a tradable and a non-tradable good. Domestic and foreign demand for non-tradable and domestic and foreign tradable goods is a function of relative prices in the four different sectors. The main innovation in the model presented here, is that – in contrast to Obstfeld and Rogoff (2006) – supply in all sectors is not fixed but – like demand – a function of relative prices in the four different sectors. This is implemented by introducing Cobb-Douglas type production functions with labor as the only input in each sector and profit maximizing firms that allocate labor among the different sectors.

Thus, for any given level of the current account balance, relative prices between the different goods, relative quantities in production and consumption in each of the two countries, the terms of trade, and the real exchange rate are simultaneously determined. We can then simulate changes in these variables that are consistent with changes – or a closing up – of the current account balance.

2.4.1 The Demand Side

We introduce the demand side through relative demand functions for tradable and non-tradable goods in the United States and the rest of the world. These are derived from CES-aggregators of consumption goods, with asterisks denoting rest of the world variables:

$$C = \left[\gamma^{\frac{1}{\theta}} C_T^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{2.1}$$

$$C^* = \left[\gamma^{\frac{1}{\theta}} C_T^{*\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_N^{*\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}} \tag{2.2}$$

The term C_N represents consumption of non-tradable goods produced in the respective country, and γ is a weight parameter of tradable goods, while C_T represents aggregate consumption of tradable goods, consisting of goods produced in the United States ("at home") and abroad, denoted C_H and C_F respectively:

$$C_T = \left[\alpha^{\frac{1}{\eta}} C_H^{\frac{\eta-1}{\eta}} + (1-\alpha)^{\frac{1}{\eta}} C_F^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{2.3}$$

$$C_T^* = \left[\alpha^{*\frac{1}{\eta}} C_F^{*\frac{\eta-1}{\eta}} + (1-\alpha^*)^{\frac{1}{\eta}} C_H^{*\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{2.4}$$

The shares α and α^* are assumed to be greater than 0.5, implying a home bias in tradable goods consumption. Crucial parameters in the analysis are the elasticities of substitution between non-tradables and tradables, θ, and between home and foreign tradables, η, for simplicity assumed to be equal in the United States and the rest of the world.

For these consumption indices the standard price indices can be derived by optimizing the consumption index subject to some expenditure constraint:

$$P = \left[\gamma P_T^{1-\theta} + (1-\gamma) P_N^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{2.5}$$

$$P^* = \left[\gamma P_T^{*1-\theta} + (1-\gamma) P_N^{*1-\theta}\right]^{\frac{1}{1-\theta}} \tag{2.6}$$

$$P_T = \left[\alpha P_H^{1-\eta} + (1-\alpha) P_F^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{2.7}$$

$$P_T^* = \left[\alpha^* P_F^{*1-\eta} + (1-\alpha^*) P_H^{*1-\eta}\right]^{\frac{1}{1-\eta}} \tag{2.8}$$

The term P denotes the consumer price index and is defined as the minimum price for the purchase of a unit of the consumption bundle C. Accordingly, P_T is a price index for tradable goods consumption in the United States. By assumption, the law of one price holds for tradables, (i.e., $P_F = \varepsilon P_F^*$ and $P_H = \varepsilon P_H^*$ where ε is the nominal exchange rate expressed in US dollars per foreign currency unit). However, because of the home bias in tradable consumption, the consumption indices and respective price indices in the United States and rest of the world differ and purchasing power parity does not hold (i.e., generally $P \neq \varepsilon P^*$).

The terms of trade τ are defined as the relative price of rest of the world and US tradable goods, and the real exchange rate q is given by the relative aggregate price levels, expressed in a common currency:

$$\tau = \frac{P_F}{P_H} = \frac{P_F^*}{P_H^*} \tag{2.9}$$

$$q = \frac{\varepsilon P^*}{P} \tag{2.10}$$

We denote the relative prices of the domestic and foreign non-tradable goods as ι and ι^*:

$$\iota = \frac{P_N}{P_H} \text{ and } \iota^* = \frac{P_N^*}{P_F^*} \tag{2.11}$$

From these definitions the precise relationship between the real exchange rate q and the three relative prices can be derived:

$$q = \left(\frac{\alpha^*\tau^{1-\eta} + (1-\alpha^*)}{\alpha + (1-\alpha)\tau^{1-\eta}}\right)^{\frac{1}{1-\eta}} * \left(\frac{\gamma + (1-\gamma)\left(\alpha^* + (1-\alpha^*)\tau^{\eta-1}\right)^{\frac{\theta-1}{1-\eta}}\iota^{*1-\theta}}{\gamma + (1-\gamma)\left(\alpha + (1-\alpha)\tau^{1-\eta}\right)^{\frac{\theta-1}{1-\eta}}\iota^{1-\theta}}\right)^{\frac{1}{1-\theta}} \tag{2.12}$$

where q, τ and ι^* are positively related, while q and ι move in opposite directions:

$$\frac{dq}{d\tau}, \frac{dq}{d\iota^*} > 0 \quad \text{and} \quad \frac{dq}{d\iota} < 0 \tag{2.13}$$

Through maximization of C subject to an expenditure constraint, one obtains the demand functions for domestic non-tradable and tradable goods, Y_N^D and Y_H^D :

$$Y_N^D = C_N = (1-\gamma)\left(\frac{P_N}{P}\right)^{-\theta} C \tag{2.14}$$

$$\begin{aligned} Y_H^D &= C_H + C_H^* \\ &= \alpha\gamma\left(\frac{P_H}{P_T}\right)^{-\eta}\left(\frac{P_T}{P}\right)^{-\theta} C + (1-\alpha^*)\gamma\left(\frac{P_H/\varepsilon}{P_T^*}\right)^{-\eta}\left(\frac{P_T^*}{P^*}\right)^{-\theta} C^* \end{aligned} \tag{2.15}$$

The above equations show that the demand for domestic non-tradables, as well as the demand for domestic tradables, decrease in their respective relative price. For the rest of the world, corresponding equations apply. As we are not concerned with the determination of total period consumption and savings, which are usually determined in an intertemporal setting, but with relative demand for tradable and non-tradable goods, we write the demand for US tradables and non-tradables as a function of the tradables consumption index:

$$Y_H^D = \alpha \left(\frac{P_H}{P_T}\right)^{-\eta} C_T + (1-\alpha^*) \left(\frac{P_H/\varepsilon}{P_T^*}\right)^{-\eta} C_T^* \tag{2.16}$$

$$Y_N^D = \frac{1-\gamma}{\gamma} \left(\frac{P_N}{P_T}\right)^{-\theta} C_T \tag{2.17}$$

Expressing this in nominal terms and normalizing by domestic tradables output yields:

$$1 = \alpha \left(\frac{P_H}{P_T}\right)^{1-\eta} \frac{P_T C_T}{P_H Y_H^D} + (1-\alpha^*) \left(\frac{P_H/\varepsilon}{P_T^*}\right)^{1-\eta} \frac{\varepsilon P_T^* C_T^*}{P_H Y_H^D} \tag{2.18}$$

$$\frac{P_N Y_N^D}{P_H Y_H^D} = \frac{1-\gamma}{\gamma} \left(\frac{P_N}{P_T}\right)^{1-\theta} \frac{P_T C_T}{P_H Y_H^D} \tag{2.19}$$

For the rest of the world, these equations read as follows:

$$\frac{P_F Y_F^D}{P_H Y_H^D} = (1-\alpha) \left(\frac{P_F}{P_T}\right)^{1-\eta} \frac{P_T C_T}{P_H Y_H^D} + \alpha^* \left(\frac{P_F}{\varepsilon P_T^*}\right)^{1-\eta} \frac{\varepsilon P_T^* C_T^*}{P_H Y_H^D} \tag{2.20}$$

$$\frac{\varepsilon P_N^* Y_N^{*D}}{P_H Y_H^D} = \frac{1-\gamma}{\gamma} \left(\frac{P_N^*}{P_T^*}\right)^{1-\theta} \frac{\varepsilon P_T^* C_T^*}{P_H Y_H^D} \tag{2.21}$$

Hence, relative demand is described by equations (2.18) to (2.21).

2.4.2 The Supply Side

Production of the four goods is described by Cobb-Douglas functions with labor as the only input:

$$Y_i^S = A_i L_i^{\beta} \text{ for } i = N,\ H,\ N^*,\ F \tag{2.22}$$

The term L_i is labor input in sector i, β is the coefficient for the labor share in total output, assumed to be equal across sectors and countries, and A_i is the total factor productivity in sector i. Assuming perfect integration of domestic sectoral labor markets and no international migration, there will be a single nominal wage rate ω in the United States and a single wage rate ω^* in the rest of the world. Hence, profit maximization requires equalization of marginal value products to the same nominal wage in both sectors in the same country:

$$\beta P_N A_N L_N^{\beta-1} = \varpi = \beta P_H A_H L_H^{\beta-1} \tag{2.23}$$

Solving the production function for the relative quantities of non-tradable and tradable goods and the wage equation shown above for the relative labor input in the two sectors and substituting for labor yields the relative supply function:

$$\frac{Y_N^S}{Y_H^S} = \left(\frac{A_N}{A_H}\right)^{\frac{1}{1-\beta}} \left(\frac{P_N}{P_H}\right)^{\frac{\beta}{1-\beta}} \tag{2.24}$$

From this equation, one can see that for plausible $\beta < 1$ the relative supply of non-tradable goods increases in their relative price. Furthermore, rearranging the equation shows that the share in output also increases in the relative price, ι:

$$\frac{P_N Y_N^S}{P_H Y_H^S} = \left(\frac{A_N}{A_H}\iota\right)^{\frac{1}{1-\beta}} \tag{2.25}$$

This equation describes a simple production possibility frontier. For the rest of the world, this relationship is:

$$\frac{P_N^* Y_N^{*S}}{P_F^* Y_F^S} = \left(\frac{A_N^*}{A_F}\iota^*\right)^{\frac{1}{1-\beta}} \tag{2.26}$$

A similar equation for relative supply of US and rest of the world tradable output is a function of the terms of trade, the relative nominal wage and relative total factor productivities, where the production of domestic tradable relative to foreign tradable goods increases in the productivity differential and the terms of trade and decreases in the wage differential:

$$\frac{Y_F^S}{Y_H^S} = \left(\left(\frac{\varepsilon\varpi^*}{\varpi}\right)^{-\beta}\tau^\beta\frac{A_F}{A_H}\right)^{\frac{1}{1-\beta}} \tag{2.27}$$

From the three preceding equations relating to the production frontier, one can see that the Obstfeld and Rogoff model is a special case of the one proposed here, with β set to zero and relative quantities therefore only determined by – exogenous – total factor productivities.

Relative wages in turn are determined through the firms' first order conditions, which can be re-written as:

$$L_H = \left(\frac{\varpi}{\beta P_H A_H}\right)^{\frac{1}{\beta-1}} \tag{2.28}$$

$$L_N = \left(\frac{\varpi}{\beta P_N A_N}\right)^{\frac{1}{\beta-1}} \tag{2.29}$$

Using the definition for economy-wide labor input $L = L^H + L^N$ yields:

$$\frac{\varpi}{P_H A_H} = \beta \left[\frac{1 + \left(\iota \frac{A_N}{A_H}\right)^{\frac{1}{1-\beta}}}{L}\right]^{1-\beta} \tag{2.30}$$

For the rest of the world, with $L^* = L_{N^*} + L_F$, an equivalent equation applies:

$$\frac{\varepsilon\varpi^*}{P_F A_F} = \beta \left[\frac{1 + \left(\iota^* \frac{A_N^*}{A_F}\right)^{\frac{1}{1-\beta}}}{L^*}\right]^{1-\beta} \tag{2.31}$$

Combining these two equations and re-arranging them yields an expression in terms of relative prices and total factor productivities that completes the supply side of the economy:

$$\frac{\varepsilon\varpi^*}{\varpi} = \left(\frac{L}{L^*}\right)^{1-\beta} \left[\frac{1 + \left(\iota^* \frac{A_N^*}{A_F}\right)^{\frac{1}{1-\beta}}}{1 + \left(\iota \frac{A_N}{A_H}\right)^{\frac{1}{1-\beta}}}\right]^{1-\beta} \frac{A_F}{A_H}\tau \tag{2.32}$$

2.4.3 General Equilibrium

A general equilibrium is defined as a vector of relative prices (τ, ι, ι^*, ω^*/ω, q) for which

(a) goods markets clear:

$$Y_i^D = Y_i^S \quad \text{for } i = N,\ H \quad \text{and} \quad Y_i^{*D} = Y_i^{*S} \qquad \text{for } i = N^*,\ F \tag{2.33}$$

and (b) the current account identity, which is the sum of net absorption of tradables and the income balance, holds:

$$CA = P_H Y_H + iF - P_T C_T \tag{2.34}$$

$$\varepsilon CA^* = \varepsilon P_F^* Y_F - iF - \varepsilon P_T^* C_T^* = -CA \tag{2.35}$$

Here, F is the stock of net foreign assets and i the interest rate. Combining the above results yields a system of five simultaneous equations in the five endogenous variables τ, ι, ι^*, ω^*/ω and q. They are shown in Appendix A.

2.5 Rebalancing of the US Current Account

In the following section, we compute two sets of relative equilibrium prices, one with the US current account being in a deficit range broadly corresponding to the level observed in recent years and another set of relative prices with the current account being balanced. These two sets of equilibrium prices allow us to compute the real depreciation implied by the closing of the current account deficit as the logarithmic difference of the real exchange rate. Furthermore, the movements in the terms of trade, the relative prices of non-tradable goods and the relative outputs can be derived. Hence, we can differentiate between the contribution of quantities and prices to the hypothetical rebalancing of the US current account. In order to allow for a direct comparison, we choose the same parameters and initial relative quantities as Obstfeld and Rogoff (2006).

2.5.1 Calibration

The baseline parameter choice follows Obstfeld and Rogoff (2006) with $\alpha = 0.7$, $\alpha^* = 0.925$, and $\gamma = 0.25$. Hence, we assume a home bias in tradables consumption ($\alpha > 0.5$) and set non-tradable output to three times tradable output, a figure roughly consistent with US data. Furthermore, we report results for different combinations of θ and η, the elasticities of substitution between tradable and non-tradable goods, as well as between domestic and foreign produced tradables. The literature has found relatively low values for θ, between 0.5 and 1 (see Mendoza, 1991, and Stockman and Tesar, 1995). These will be used as the main reference point here, but larger elasticities are also presented in order to shed light on longer adjustment horizons. The labor share β is set to 0.7 in our benchmark parameterization.[17] Extensions to the baseline calibration are presented for differing values of α, β, θ and η.

We make the same assumption as Obstfeld and Rogoff (2006) with respect to the original relative quantities in order to allow comparisons to be as transparent as possible:

$$\frac{Y_N}{Y_H} = \frac{Y_N^*}{Y_F} = 1 \tag{2.36}$$

and

[17] Data on labor compensation taken from the Industry Growth Accounting Database of the Groningen Growth and Development Centre indicate a labor share of between 0.70 and 0.74 between 1980 and 2001.

$$\frac{Y_F}{Y_H} = 4.55 \tag{2.37}$$

In principle it would be desirable if relative prices multiplied with relative quantities resulted in observable relative sector sizes. However, results do not change significantly when choosing initial quantities such that this feature is fulfilled.

The assumptions on (initial) relative quantities imply values for relative total factor productivities, assumed to be constant, once relative prices and relative nominal wages are determined. We calculate them by solving the relative output relations for the relative total factor productivities:

$$\frac{A_N}{A_H} = \left(\frac{Y_N}{Y_H}\right)^{1-\beta} \iota^{-\beta} \tag{2.38}$$

$$\frac{A_N^*}{A_F} = \left(\frac{Y_N^*}{Y_F}\right)^{1-\beta} \iota^{*-\beta} \tag{2.39}$$

$$\frac{A_F}{A_H} = \left(\frac{Y_F}{Y_H}\right)^{1-\beta} \left(\frac{\varpi^*}{\varpi}\right)^{\beta} \tau^{-\beta} \tag{2.40}$$

For the initial current account, expressed as a share of the value of domestic tradable production, we follow Obstfeld and Rogoff (2006) and assume a value of -0.2. Obstfeld and Rogoff take this value as consistent with a current account deficit of 5% of GDP and the assumption of around a quarter of total output being tradable. f, the net foreign asset position expressed as a fraction of tradables output, and i are set to -0.8 and 0.05 respectively and assumed to be constant, that is, the net foreign asset position and the income balance are kept at around -20% and -1% of GDP.

As a last assumption, we need to assign a value to $(L/L^*)^{1-\beta}$. On first glance, it is hard to see why one should not treat this term as an endogenous expression since changes in hours are likely to occur in an adjustment process. However, two reasons speak in favor of treating this as a constant. First, since we abstract from consumers' and workers' intertemporal optimization decisions, we assume a constant consumption index C, which in more elaborate frameworks is determined by respective Euler equations. If the determination of C is assumed as exogenous, the same should apply for the total labor supply L. Second, according to data from the Groningen Growth and Development Center, $(L/L^*)^{1-\beta}$ fluctuated almost not at all for the available time series between 1980 and 2002 and all changes over the last twenty years are reflected in lower digit variations. For $\beta = 0.7$, it is 0.8.

2.5.2 Benchmark Simulation Results

In the following section, we present the benchmark specification in which the current account deficit is closed completely, that is, set to zero. For this benchmark, results for six different parameter combinations of the elasticities of substitution between tradables and non-tradables and between US and rest of the world tradables are shown. Then, a number of different specifications are presented in order to check the sensitivity of the result with respect to the size of the required adjustment; the assumption with respect to productivity changes; the assumption of a home bias in consumption; the labor share and finally a number of other values of the elasticities of substitution.

The results of the benchmark simulation exercise are presented in Tables 2.3 and 2.4, jointly with the benchmark results of Obstfeld and Rogoff, denoted "w/o supp.". Four main results and three remarks are noteworthy.

First, the most striking feature is the reduced real depreciation in all specifications with the greatest reductions occurring at low elasticities of substitution between tradable and non-tradable goods. For Obstfeld and Rogoff's most "alarmist" scenario, the implied depreciation is halved, from 64% to 33%, and in their baseline case the depreciation is reduced by a quarter, from 32% to 24%. The adjustment is now partly borne by a quantity adjustment reducing the foreign tradables output relative to US tradables output by 22% and 13% respectively.

Second, the exchange rate hardly moves as long as foreign and domestic

Table 2.3: Deficit closed: Changes of real exchange rate and terms of trade

		Real depreciation		**TOT depreciation**		**ROW/US quantity**
θ	η	**w/o supp.**	**supp.**	**w/o supp.**	**supp.**	**supp.**
0.5	2	64	33	16	24	-22
1	2	32	24	16	21	-13
1	3	26	17	9	13	-13
2	2	19	18	16	18	-6
2	3	14	12	9	11	-7
1	1000	18	5	0	0	-66

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

tradable goods are close substitutes, as illustrated by a very high elasticity of substitution between foreign and domestic tradable goods of $\eta = 1000$, and $\theta = 1$. In fact, the exchange rate depreciation already falls below 10% when using an elasticity of substitution between foreign and domestic tradables of $\eta = 6$, while in the same parameterization it would still be as high as 21% when not allowing for an endogenous supply side change (not reported in Table 2.3). In the parameterization presented here, the implied quantity adjustment is huge, reducing the foreign relative tradables output by 66%.

A third result refers to the terms of trade. On first glance, possibly surprisingly, these move more in the case of endogenous production. This is explained by the fact that the relative output of foreign to domestic tradables, for which the terms of trade are the relative price, falls due to the domestic tradables output expansion. In order for the bigger domestic quantity to be absorbed by the market, its relative price has to fall by more relative to its foreign (imperfect) substitute. Hence, the depreciation of the terms of trade is larger than in the Obstfeld and Rogoff setup.

Fourth, the relative price of domestic tradable and domestic non-tradable goods, as well as the relative price of foreign tradable and foreign non-tradable goods, move less for all specifications, contributing to the reduction of the depreciation of the real exchange rate (Table 2.4). In the case of a very low demand elasticity, the fall in the relative price of domestic non-tradables and domestic tradables is huge, from 43% to 8%. Hence, the main impact of the introduction of the supply changes is on the relative price of non-tradables when demand is relatively inelastic. The "bottleneck" of a sluggish demand response, which is responsible for the big price adjustment, is thus circumvented by the supply response. The impact is much lower for higher demand elasticities. Furthermore, the impact within the rest of the world is negligible in this set-up, the relative price of non-tradables moves by no more than 2% while relative non-tradables output increases only between 2% and 5%.

Table 2.4: Deficit closed: Changes in US and ROW price and quantity of non-tradables relative to tradables

		US			**ROW**		
		Price		**Quantity**	**Price**		**Quantity**
θ	η	**w/o s.**	**supp.**	**supp.**	**w/o s.**	**supp.**	**supp.**
0.5	2	-43	-8	-19	11	2	5
1	2	-19	-6	-13	5	2	4
1	3	-19	-6	-13	5	1	3
2	2	-7	-3	-7	2	1	2
2	3	-8	-4	-8	2	1	2
1	1000	-19	-6	-13	4	2	4

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

Three last remarks with respect to the benchmark specification refer to the magnitude of the quantity adjustment. On first glance, the implied increase in the relative volume of tradable production in the United States of between 7% and 19% might seem rather big. However, the overall effect on the share of tradable output in total GDP is comparable and even somewhat smaller than implied by the original Obstfeld and Rogoff framework. Assuming an initial share of tradable output of around 25% of nominal GDP (which is implicitly underlying the parameterization of both the original Obstfeld and Rogoff model and the extension proposed in this paper) the share of tradable output increases by less than five percentage points of GDP in nearly all specifications. Only in the case of $\theta = 0.5$ does the share of tradable output in nominal GDP increase to slightly above 30%. In the original Obstfeld and Rogoff framework, however, the increase is much bigger and the share of tradable output approaches 40% of GDP.

Second, comparing the magnitude of the quantity adjustment in the United States and the rest of the world, we see that the impact in terms of the non-tradables to tradables ratios is three to four times larger in the United States than in the rest of the world. Furthermore, the impact in the rest of the world is rather modest. Hence, from the perspective of this model, the supply side effects of the adjustment will be borne mainly by the United States rather than the rest of the world. This result, however, is not robust once a third country is introduced, as in Engler (2009). There, the different "countries" Europe and Asia are differentially affected, and this impact depends in particular on the exchange rate policies conducted in the three regions. For Europe, under some plausible scenarios, the adjustment might easily put factor markets to a severe stress test.

Third, the results from Tables 2.3 and 2.4 are roughly consistent with the empirical predictions with respect to the relationship between the real depreciation and the change of the non-tradables to tradables ratio in Tables 2.1 and 2.2. The depreciation of about 30% in the first line of Table 2.3 corresponds with a reduction of the non-tradables to tradables ratio of around 20%. Furthermore, they are also consistent with the result that the quantity adjustment is quantitatively more important for an adjustment of the current account than the price change. The first is at least twice as large as the second.

2.5.3 Extensions

Having established the benchmark results for a complete closing of the US current account deficit, we now shed light on a number of extensions. First, we analyze the relationship between the size of the required deficit reduction and the implied size of the exchange rate and sectoral re-allocation, then we turn to the role of productivity changes during the adjustment. Next, we shed light on the sensitivity of our results to the assumed home-bias in tradables consumption and the labor share, and finally we analyze different values of the demand elasticities.

Size of the Deficit Reduction We now turn to the relationship between the size of the reduction of the deficit and the magnitude of the implied price and quantity adjustments. Table 2.5 presents results for an adjustment

Table 2.5: Deficit reduced by half: Changes of real exchange rate and terms of trade

		Real depreciation		TOT depreciation		ROW/US quantity
θ	η	w/o supply	supply	w/o supply	supply	supply
0.5	2	32	16	8	12	-11
1	2	16	12	8	10	-6
1	3	13	8	5	6	-6
2	2	10	9	8	9	-3
2	3	6	7	5	5	-3

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

under the assumption that the US current account deficit is only reduced to half of its starting value, to 10% of tradable output. The results show that adjustments of prices and quantities are all reduced by about one half. Hence, the adjustment is roughly proportional to the change in the current account.[18]

Productivity Changes Next, we want to relate our analysis to two contributions to the literature incorporating adjustments on the supply side. The first one is Obstfeld and Rogoff (2006), who analyze an alternative scenario where the adjustment is accompanied by a change in relative output driven by a boost to productivity in the tradable goods sector. However, the authors claim that an increase of 20% of tradables output underlying this exercise is unrealistic and hence, this analysis is supposedly of little use. In our analysis, the relative output change is between 7% and 13% (in the cases which Obstfeld and Rogoff present for this exercise) while the real depreciation is comparable to that reported by Obstfeld and Rogoff. Hence, the relative output change required is significantly less than what Obstfeld and Rogoff had in mind and it does not need to rely on assumptions for productivity changes.

The second contribution is Engel and Rogers (2006) who explicitly allow the share of tradable output to vary over time in response to changes in relative productivity between the domestic and foreign tradables and non-tradables sector and do find a significant effect of relative productivity and hence, supply changes in the tradable sector on the real exchange rate. However, in their approach, it is the change in relative productivity that is exogenous. Therefore, our benchmark analysis is not comparable to the exercises undertaken by Obstfeld and Rogoff and Engel and Rogers, as we stress the endogenous nature of both demand and supply and the structural change that is inevitably involved in the closing of the US current account. Furthermore, we highlight the role for sectoral adjustments in the current account reversal, which is of particular interest for economic policy, which may have to support the sectoral migration pattern in order to prevent widespread unemployment.

However, a boost to US tradables productivity relative to non-tradables productivity due to increased price competitiveness of the former is not un-

[18] Results for relative non-tradables price and quantity changes are not shown but are also reduced to half the benchmark results.

Table 2.6: US tradables productivity increases by 20 percent: Changes of real exchange rate and terms of trade

		Real depreciation		**TOT depreciation**		**ROW/US quantity**	
θ	η	**w/o supp.**	**supp.**	**w/o supp.**	**supp.**	**w/o s.**	**supp.**
0.5	2	41	19	23	30	-18	-37
1	2	25	20	23	31	-18	-40
1	3	17	9	14	19	-18	-40
2	2	19	21	23	32	-18	-43
2	3	12	11	14	20	-18	-44

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

likely to occur. The underlying reason might be an improved capacity utilization to meet increased demand. Therefore, we present a scenario in which the US tradables productivity increases by 20% during the adjustment in Tables 2.6 and 2.7. Hence, the assumptions of an exogenous increase in productivity and an endogenous quantity adjustment are combined. Not surprisingly, the required real depreciation is muted, while the terms of trade move more. The flip side of this result is much larger movements in the relative quantities[19], the relative output of rest of the world tradables now falls by around 40% in all parameterizations. However, the main result from the benchmark specification of a muted real exchange rate response due to endogenous supply responses survives. The only exception is the case for which $\theta = \eta = 2$. Here, the difference between the terms of trade deteriorations is particularly large (23% and 32% respectively), supporting a larger real exchange rate response, while the difference in the change of the relative price of non-tradables is relatively small between the two specifications (3% and 12%) thus reducing

[19]In the scenario with $\beta = 0$, the increase in US tradable output equals the change in productivity as can be seen in equations (2.24) and (2.27). This corresponds to the 18% changes in Tables 2.6 and 2.7.

the offsetting effect in support of a muted real exchange rate response.

Table 2.7: US tradables productivity increases by 20 percent: Changes in US and ROW price and quantity of non-tradables relative to tradables

		US				**ROW**		
		Price		**Quantity**		**Price**		**Quantity**
θ	η	**w/o s.**	**with s.**	**w/o s.**	**with s.**	**w/o s.**	**with s.**	**with s.**
0.5	2	-9	13	-18	-30	12	2	5
1	2	-1	13	-18	-31	5	2	4
1	3	-1	13	-18	-31	5	2	4
2	2	3	12	-18	-33	2	1	2
2	3	2	11	-18	-35	2	1	2

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

US relative non-tradables prices now no longer fall but increase, between 11% and 13% (Table 2.7) while relative nontradables output falls significantly by around 30%. At the same time the adjustment within the rest of the world is hardly affected by the productivity change in the United States, the effects remain small.

Home Bias Next, we want to exclude that the assumption of some home bias in consumption ($\alpha = 0.7$) alone is driving the results. With a lower degree of home bias, a reduction in domestic demand has a relatively smaller impact on the relative demand for domestic tradables, and hence results in a smaller depreciation of the terms of trade. In this case, relative price changes may not be large enough to induce significant factor reallocations. However, as shown in Table A.1 in Appendix A.2, even assuming no home bias ($\alpha = 0.5$) does not qualitatively affect the results.

Labor Share The next extension shows that results are robust to the parameterization of the labor share in output. As the Obstfeld and Rogoff framework is equivalent to assuming $\beta = 0$ or fixed sectoral supply in the very short run, the case of $\beta = 1$ can be interpreted as the opposite extreme or very long run scenario. In the later case, as can be seen in Tables A.2 and A.3, the entire adjustment within the United States and within the rest of the world (i.e., the adjustment of domestic variables) occurs through quantity adjustments while the relative non-tradables prices do not move at all. This further reduces the required real depreciation. Furthermore, small variations of β around our benchmark of 0.7 do not change results much, confirming the robustness of the above results.

Different Demand Elasticities Finally, we try different parameterizations of the demand elasticities. In particular, we want to assess whether low enough elasticities of substitution between domestic and foreign tradables can in the extended model actually result in a higher depreciation than in the original framework without supply. In fact this depends crucially on the difference in the magnitude of η and θ. The results in Table A.4 indicate that this is the case only for a very restricted parameter space, when the elasticity of substitution between domestic and foreign tradables η is very small and the elasticity of substitution between nontradables and tradables θ is not larger than η. For equal values, the model with endogenous supply yields similar results as the original framework abstracting from supply side effects. However, these parameter choices do not seem to be very realistic, as one would typically expect a higher degree of substitutability between domestic and foreign tradables, than between tradable and non-tradable goods. Furthermore, the required depreciation is implausibly high both in the extended model but also when neglecting the supply side.

2.6 Conclusion

This paper contributes to the literature on the adjustment of global imbalances in several ways. First, it adds to the recent policy-oriented literature that provides a number of extensions of the Obstfeld and Rogoff model, which emphasizes the considerable sensitivity of stylized models of the current account not only to calibration but also to assumptions on the structure of the economy.

Second, the paper shows how changes in the industrial structure of an economy are linked to the current account and hence – within the Obstfeld and Rogoff (2006) framework – to the exchange rate. In particular, allowing for an endogenous supply – or some flexibility in the industrial structure of the economy responding to price signals – significantly attenuates the exchange rate change implied in the Obstfeld and Rogoff framework. Moreover, supply side changes will almost “mechanically” share part of the burden in a current account adjustment.

In Obstfeld and Rogoff (2006), the supply side was modelled by a fixed endowment of tradable and non-tradable goods. Therefore, any change in the trade balance can only be achieved through a re-balancing on the demand side in that model. This assumption resulted in a huge real depreciation of the US dollar in a simulation of the closing of the US current account deficit. The extension introduced here allows adjustments also on the supply side.

The core result is that the depreciation of the dollar results in an increased production of US tradable goods. Thereby the trade balance and the current account improve, in addition to the improvement through the adjustment on the demand side. There is thus a second channel of adjustment towards a better current account position. This reduces the implied real depreciation for any given improvement of the current account position. However, the flip side of this result is that a large factor re-allocation from non-tradable to tradable goods production is required. The analysis therefore shifts the focus from the exchange rate dimension of the adjustment to the potentially difficult adjustment on factor and goods markets.

The simulation results reveal a crucial influence of several key parameters and assumptions. Most notably, demand elasticities matter. The smaller the elasticities of substitution between goods are, the greater the implications for exchange rates and factor re-allocation. Since typical estimates for these elasticities are small, the risks implied by the closing of the US current account are indeed significant.

Chapter 3

Global Rebalancing in a Three-Country Model

3.1 Introduction

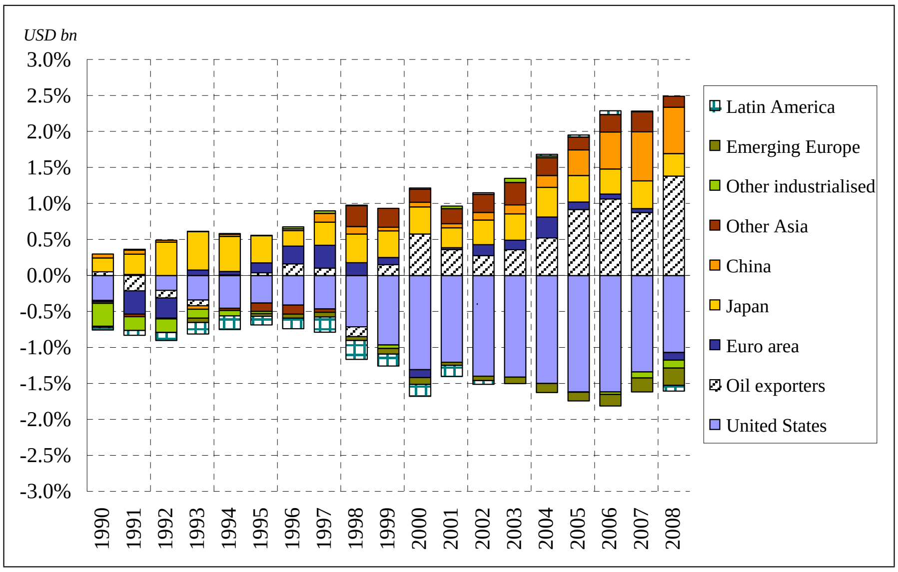
Global current account positions have become remarkable in their size and configuration in recent years. Looking at the size, the sum of deficits has grown to almost 2% of world GDP in 2006 (Figure 3.1)[1], a figure unmatched in the history of international economic integration. Hence, globalization is clearly at work. The deficits have started to decline since 2006, but aggregate surpluses have not. The question that ultimately comes to commentators' minds is whether, and under which conditions, this development will last or reverse and what the consequences of the possible scenarios might be. These topics have been hotly debated in recent years.

Looking at the configuration, the single country contributing most (and almost entirely from a global perspective when the euro-area is taken as an entity) to the "global deficit" is the United States while the creditor side is taken mainly by the oil exporters and Asian economies. The US deficit reached a peak of 1.6% of world GDP in both 2005 and 2006 but is expected to have shrunk by around one third to 1.1% in 2008. This points to the critical

[1] Actual numbers would be even higher if individual countries were displayed rather than groups of countries, as in Figure 3.1. However, this categorization helps to focus on broader patterns of the current configuration.

dependence of the world economy on developments in a single country. Not surprisingly, in recent analyses of current imbalances and its unwinding that has now begun, the US economy and its role in the world economy took center stage.

Figure 3.1: Global current account configuration (% of world GDP; Source: ECB)



This paper takes a three-*country* view of imbalances in which the United States, Asia and Europe add up to a hypothetical world economy. Therein, different rebalancing scenarios are analyzed. In a related paper, Engler et al. (2007) extended the analysis by Obstfeld and Rogoff (2006) taking account of supply side changes, rather than purely demand-switching in an endowment economy, through which the exchange rate implications of a closing of the US current account are moderated. In particular, a re-allocation of factors from non-tradable towards tradable goods sectors in the United States and vice versa in the rest of the world is induced by the adjustment. With regard to the United States, this would stop the last decade's trend towards an ever increasing share of non-tradables in total output. This quantity adjustment severely reduced the implied adjustment of real exchange rates in a two-country framework (the United States and the rest of the world).

What this two-country-approach cannot capture is the differential impact on different regions in the hypothetical rest of the world, in particular under differential exchange rate policies in a rebalancing scenario. Many Asian central banks intervene heavily in foreign exchange markets or fix their currencies in order to keep their currencies undervalued relative to the US dollar, while the US dollar floats vis-à-vis other industrialized countries' currencies. Hence, the relative exchange rate and quantity adjustments in different parts of the world are likely to be affected by such differential policies.

The core result of this paper is that the effect of continuing interventions on the side of Asian central banks severely shifts the burden of adjustment of a closing of the US current account deficit to Europe. In particular, the fixed exchange rates, or in other words, the joint depreciation of Asian currencies with the dollar vis-à-vis the euro, result in a complete reversal of the sectoral adjustment in Asia in a rebalancing scenario compared to a flexible exchange rate scenario. Rather than reducing the relative size of the tradables sector as in the case of flexible exchange rates, it further increases it, even more than in the case of an endowment economy. The flip side of this result is that the European non-tradables sector needs to increase much more relative to the tradables sector implying a large factor reallocation. This change in relative size of sectors is much larger than in the case of fixed supplies. Hence, European economies will be tested severely in a rebalancing in which Asia keeps its peg vis-à-vis the US dollar. For instance, countries with inflexible labor markets might see an increase in unemployment. And, both by implication and by assumption, Asia will build up a massive current account surplus vis-à-vis Europe of up to 11% of US GDP.

The most recent developments in the world financial system point to an unwinding solution that is somewhere between the pure Bretton-Woods scenario and a scenario under flexible exchange rates. China has not abandoned its peg, while the Japanese yen has appreciated significantly. Although it is too early for an overall assessment, a severe risk to the world economy consists in insufficient flexibility in goods and factor markets, in particular in many European countries. This might potentially lead to large increases in unemployment and exert, in addition to the purely economic stress, increased political pressure on the current world trade and financial system.

The paper is structured as follows: Section 3.2 lays out the theoretical framework used for the analysis. Section 3.3 presents and discusses the results for different adjustment scenarios, and Section 3.4 concludes.

3.2 The Model

This paper extends the model in Engler et al. (2007) in a crucial dimension. Not only does it introduce a supply side channel mitigating the exchange rate implications of an unwinding of global imbalances, which is an extension to the Obstfeld and Rogoff (2006) model. It also differentiates between regions in the "rest of the world". The heterogeneity of the rest of the world is made explicit in a three-country setting as in Obstfeld and Rogoff (2005), incorporating a "European" and an "Asian" economy as well as the United States (denoted by E, A and U respectively). Thus, the effects of a rebalancing on goods and factor markets can be assessed from the perspective of countries/regions and which may follow different exchange rate policies.[1]

The experiment is to analyze the effects of a closing of the US current account deficit. What is implicitly assumed is that there are either policy-induced or financial market-induced changes relative to the current situation. It could be that Asian central banks or financial markets are no longer willing to finance the US deficit. Hence, this analysis does not rest on any particular explanation for the current situation, it rather assumes that the stabilizing forces for the US deficit no longer prevail.

The main contribution from this approach is that European goods and factor markets will be severely tested if Asian central banks continue to fix their US dollar exchange rates under a rebalancing scenario, while European currencies continue to float vis-à-vis the US dollar. Real effective exchange rates continue to be less affected because of the supply response, but the

[1] These terms should not be taken too literally since in the calibration "Europe" is rather a group of countries with flexible exchange rates, which also contains a few non-European countries (Canada, Australia and New Zealand). But since the European Union plus other European non-EU countries form by far the most important block, the term "Europe" serves as a good proxy for the countries in this group.

terms of trade change a lot more. The direction and extent of the implied change in trade flows crucially depends on exchange rate regimes. A lack of willingness in Asia to share the burden of the necessary trade adjustment shifts this burden entirely to the European economies, thereby shrinking the European tradables sector remarkably.

The model is built around standard supply and demand sides. Each region produces a non-tradable and a tradable good with Cobb-Douglas production functions with labor as the only input. Labor markets are assumed to be perfectly integrated within countries (but not between countries), hence labor flows freely between the tradables and the non-tradables sectors and a single wage rate prevails within each country. Demand functions are derived from CES consumption indexes and depend on the current account balances of the respective country. Hence the current accounts, defined as the difference between tradables production and tradables consumption plus the income balance, can be interpreted as budget constraints.

Equilibrium prices and quantities for given current account balances are computed by equating supply and demand of each good. When two sets of equilibrium prices and quantities are determined, each for a certain configuration of current accounts, these sets of equilibrium prices and quantities can be compared and price and quantity changes be calculated for the assumed change of current accounts. In particular, I determine the changes of real exchange rates, the terms of trade, the relative price of non-tradables, relative non-tradables quantities and the relative tradables quantities across countries.

Regarding relative supplies, I assume the same relative quantities as Obstfeld and Rogoff (2005) in the original allocation (i.e., with the US current account deficit), but let them adjust together with relative prices in the simulations of changes in current accounts. Using the same original allocation allows a direct comparison of results and the impact of supply responses in a rebalancing scenario.

Because I assume a frictionless factor re-allocation between sectors, my results can be regarded as a limiting case, just as the endowment economy assumed by Obstfeld and Rogoff (2005) is a limiting case for complete inflexibility on the supply side. Any real world adjustment is likely to be somewhere between these two extremes, and the closeness of actual results to the two extremes will be determined by a number of factors that cannot be made explicit in the present framework. One important factor will be time, that is, whether a financial market crash makes a quick closing of the US current account necessary leaving little time for factor and goods markets to adjust or whether the adjustment occurs over a longer time span. Closely related is the degree of factor market rigidities that will determine to what extent the re-allocation is possible in a given time.

The demand side and the supply side are introduced below, then a general equilibrium is defined and determined.

3.2.1 The Demand Side

Each country's preferences for tradable and non-tradable goods are described by constant elasticity of substitution (CES) consumption indexes,

$$C^i = \left[\gamma^{\frac{1}{\theta}} \left(C_T^i\right)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} \left(C_N^i\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \qquad i = U, E, A$$

where C_T^i and C_N^i are consumption of tradables and non-tradables in region i respectively, γ is a weighting factor and θ the elasticity of substitution between tradables and non-tradables. Below, the focus will be on the special case of $\theta = 1$, for which this index simplifies to

$$C^i = \frac{\left(C_T^i\right)^{\gamma} \left(C_N^i\right)^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}}, \qquad i = U, E, A.$$

The C_T^i in turn are indexes of the three tradable goods produced in the three regions,

$$C_T^U = \left[\alpha^{\frac{1}{\eta}}\left(C_U^U\right)^{\frac{\eta-1}{\eta}} + (\beta-\alpha)^{\frac{1}{\eta}}\left(C_E^U\right)^{\frac{\eta-1}{\eta}} + (1-\beta)^{\frac{1}{\eta}}\left(C_A^U\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

$$C_T^E = \left[\alpha^{\frac{1}{\eta}}\left(C_E^E\right)^{\frac{\eta-1}{\eta}} + (\beta-\alpha)^{\frac{1}{\eta}}\left(C_U^E\right)^{\frac{\eta-1}{\eta}} + (1-\beta)^{\frac{1}{\eta}}\left(C_A^E\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

and

$$C_T^A = \left[\delta^{\frac{1}{\eta}}\left(C_A^A\right)^{\frac{\eta-1}{\eta}} + \left(\frac{1-\delta}{2}\right)^{\frac{1}{\eta}}\left(C_E^A\right)^{\frac{\eta-1}{\eta}} + \left(\frac{1-\delta}{2}\right)^{\frac{1}{\eta}}\left(C_U^A\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

with α determining the degree of home-bias in tradables consumption in the United States and Europe and δ in Asia. The term $1-\beta$ is a preference parameter for consumption of Asia's tradable good in the United States and Europe and η is the elasticity of substitution between the different goods in the indexes. This parameterization indicates that the United States and Europe have identical preferences for Asia's tradable good, while Asia gives equal weight to both the United States' and Europe's goods.

From these consumption indexes, standard price indexes can be derived. For overall consumption in the three regions, these are the broad consumer price indexes (CPIs)

$$P_C^i = \left[\gamma\left(P_T^i\right)^{1-\theta} + (1-\gamma)\left(P_N^i\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}, \qquad i = U, E, A$$

which for $\theta = 1$ simplify to

$$P_C^i = \left(P_T^i\right)^{\gamma}\left(P_N^i\right)^{1-\gamma}, \qquad i = U, E, A$$

and where

$$P_T^U = \left[\alpha P_U^{1-\eta} + (\beta-\alpha)P_E^{1-\eta} + (1-\beta)P_A^{1-\eta}\right]^{\frac{1}{1-\eta}},$$

$$P_T^E = \left[\alpha P_E^{1-\eta} + (\beta - \alpha) P_U^{1-\eta} + (1-\beta) P_A^{1-\eta}\right]^{\frac{1}{1-\eta}},$$

and

$$P_T^A = \left[\delta P_A^{1-\eta} + \left(\frac{1-\delta}{2}\right) P_U^{1-\eta} + \left(\frac{1-\delta}{2}\right) P_E^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

with P_T^i and P_N^i denoting the price indexes of tradable goods and the price of the non-tradable good in country i while the P_i's are the prices of the tradable goods produced in region i. All prices are in terms of US dollars and the law of one price holds, that is, each tradable good has the same price in all regions when expressed in the same currency. However, purchasing power parity in terms of aggregate prices does not hold because CPIs differ across regions.

Relative Prices Below, we need the terms of trade, the relative prices of non-tradables and the real exchange rates. The bilateral terms of trade are defined as the relative price of the respective tradable goods,

$$\tau_{U,E} = \frac{P_E}{P_U}, \quad \tau_{U,A} = \frac{P_A}{P_U} \text{ and } \tau_{E,A} = \frac{P_A}{P_E} = \frac{\tau_{U,A}}{\tau_{U,E}}$$

while the relative prices of non-tradables ("internal terms of trade") are

$$\iota_U = \frac{P_N^U}{P_U}, \quad \iota_E = \frac{P_N^E}{P_E} \text{ and } \iota_A = \frac{P_N^A}{P_A}.$$

Bilateral real exchange rates are defined as the ratios of respective CPIs,

$$q_{U,E} \;=\; \frac{P_C^E}{P_C^U},\;\; q_{U,A} = \frac{P_C^A}{P_C^U} \text{ and } \; q_{E,A} = \frac{P_C^A}{P_C^E} = \frac{q_{U,A}}{q_{U,E}}$$

where $q_{i,j}$ is the relative price of region j's consumption in terms of region i's consumption.

Bilateral real exchange rates can be shown to be functions of the terms of trade and the relative prices of non-tradables. For the special case of $\theta = 1$[2], these simplify to

$$q_{U,E} \;=\; \left[\frac{\alpha\tau_{U,E}^{1-\eta} + (\beta-\alpha) + (1-\beta)\tau_{U,A}^{1-\eta}}{\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}}\right]^{\frac{\gamma}{1-\eta}} \left(\frac{\iota_E}{\iota_U}\tau_{U,E}\right)^{1-\gamma}$$

and

$$q_{U,A} \;=\; \left[\frac{\delta\tau_{U,A}^{1-\eta} + \left(\frac{1-\delta}{2}\right) + \left(\frac{1-\delta}{2}\right)\tau_{U,E}^{1-\eta}}{\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}}\right]^{\frac{\gamma}{1-\eta}} \left(\frac{\iota_A}{\iota_U}\tau_{U,A}\right)^{1-\gamma}.$$

Noticing that $\frac{\iota_E}{\iota_U}\tau_{U,E} = \frac{P_N^E}{P_N^U}$, it is obvious that the relative influence of the terms of trade and the relative prices of non-tradables across countries is determined by the weight of tradables and non-tradables consumption in the consumption index γ and $1-\gamma$. With a much greater weight for the latter as observed in most countries, changes in bilateral real exchange rates are mainly driven by changes in relative prices of non-tradables and to a lesser extent by changes in the terms of trade. Hence, a neglect of non-tradables would be a severe drawback in an analysis of current account rebalancing.

Real effective exchange rates are weighted relative CPIs and can be ex-

[2]For the general case of $\theta \neq 1$ the reader is referred to Appendix B.1.

pressed as weighted bilateral real exchange rates:

$$q^U = \left(q_{U,E}^{\beta-\alpha}\right)\left(q_{U,A}^{1-\beta}\right),$$

$$q^E = \left(q_{U,E}^{\alpha-\beta}\right)\left(q_{E,A}^{1-\beta}\right)$$

and

$$q^A = \left(q_{U,A}^{-\frac{1}{2}}\right)\left(q_{E,A}^{-\frac{1}{2}}\right)$$

In order to derive nominal exchange rates from the above exercise, further assumptions need to be made. Central banks can follow one of two possible strategies in this framework, CPI-targeting (i.e., keeping the overall CPI-index constant over time), or GDP-deflator-targeting (i.e., keeping a weighted average of domestically produced goods prices constant over time). In the first case, nominal exchange rates move one for one with real exchange rates. In the second case, one could specify monetary policy by assuming that central banks fix a geometric average of domestically produced tradables and non-tradables. However, results are quantitatively not very different between the two monetary policy regimes (CPI- and GDP-deflator-targeting), thus there is also no big difference between nominal and real exchange rates, no matter what policy I assume. In the analysis below, I therefore only report results for real exchange rates under the assumption of CPI-targeting.

Demand Functions Nominal demands for non-tradable goods, expressed as functions of tradable goods consumption, are

$$P_N^U Y_N^U = \frac{1-\gamma}{\gamma}\left(\frac{P_N^U}{P_T^U}\right)^{1-\theta} P_T^U C_T^U,$$

$$P_N^E Y_N^E = \frac{1-\gamma}{\gamma}\left(\frac{P_N^E}{P_T^E}\right)^{1-\theta} P_T^E C_T^E$$

and

$$P_N^A Y_N^A = \frac{1-\gamma}{\gamma}\left(\frac{P_N^A}{P_T^A}\right)^{1-\theta} P_T^A C_T^A.$$

For tradables, in turn, these are

$$\begin{aligned} P_U Y_T^U &= \alpha\left(\frac{P_U}{P_T^U}\right)^{1-\eta} P_T^U C_T^U + (\beta-\alpha)\left(\frac{P_U}{P_T^E}\right)^{1-\eta} P_T^E C_T^E \\ &+\frac{1-\delta}{2}\left(\frac{P_U}{P_T^A}\right)^{1-\eta} P_T^A C_T^A \end{aligned}$$

$$\begin{aligned} P_E Y_T^E &= \alpha\left(\frac{P_E}{P_T^E}\right)^{1-\eta} P_T^E C_T^E + (\beta-\alpha)\left(\frac{P_E}{P_T^U}\right)^{1-\eta} P_T^U C_T^U \\ &+\frac{1-\delta}{2}\left(\frac{P_E}{P_T^A}\right)^{1-\eta} P_T^A C_T^A \end{aligned}$$

Walras' law determines the demand function for Asia's tradables.

Because these demand functions are expressed in terms of tradables consumption, they can be related to the regions' current accounts. The current account of region i, CU^i, is defined as tradables output minus tradables consumption plus the income balance, defined as the return r received on the region's net foreign assets F^i. Hence, for the United States and Europe we have

$$CA^U = P_U Y_T^U - P_T^U C_T^U + rF^U$$

and

$$CA^E = P_E Y_T^E - P_T^E C_T^E + rF^E$$

From an accounting perspective, current accounts and stocks of net foreign assets need to add up to zero globally, therefore

$$CA^U + CA^E + CA^A = 0$$

and

$$F^U + F^E + F^A = 0.$$

Consequently, for Asia's current account we have

$$CA^A = -\left(CA^U + CA^E\right) = P_A Y_T^A - P_T^A C_T^A - r\left(F^U + F^E\right).$$

Using these definitions and normalizing all demand functions by the US tradable output $P_U Y_T^U$ we get the five equations shown in Appendix B.1. They fully describe the demand side of the model. Next, I determine the supply side.

3.2.2 The Supply Side

The supply side is introduced by simple Cobb-Douglas production functions for the six goods with labor as the only input,

$$Y_i^j = A_i^j \left(L_i^j\right)^\nu \quad \text{for } i = T, N \text{ and for } j = U, E, A$$

with A_i^j and L_i^j denoting total factor productivity and labor input in region j's sector i while ν is labor's marginal productivity. The nested case of a fixed supply is $\nu = 0$ while $\nu = 1$ denotes the constant returns case. Labor is assumed to be mobile across sectors within regions but immobile across regions. Hence, a single nominal wage rate ω^j, expressed in terms of US dollars, exists for each region j. For simplicity, total labor input in region j, $L^j = L_T^j + L_N^j$, is assumed to be constant over time.

The following relative domestic supply relations are derived from firms' profit maximization:

$$\frac{P_N^U Y_N^U}{P_U Y_T^U} = \left(\frac{A_N^U}{A_T^U} \iota_U \right)^{\frac{1}{1-\nu}} \tag{3.1}$$

for the United States and for Europe and Asia accordingly

$$\frac{P_N^E Y_N^E}{P_E Y_T^E} = \left(\frac{A_N^E}{A_T^E} \iota_E \right)^{\frac{1}{1-\nu}} \tag{3.2}$$

and

$$\frac{P_N^A Y_N^A}{P_A Y_T^A} = \left(\frac{A_N^A}{A_T^A} \iota_A \right)^{\frac{1}{1-\nu}}. \tag{3.3}$$

Hence, the relative supply of non-tradables is a positive function of its relative price and relative total factor productivities.

Tradable output in Europe and Asia relative to US tradable output can be shown to be

$$\frac{P_E Y_T^E}{P_U Y_T^U} = \left[\left(\frac{w^E}{w^U} \right)^{-\nu} \tau_{U,E} \frac{A_T^E}{A_T^U} \right]^{\frac{1}{1-\nu}} \tag{3.4}$$

and

$$\frac{P_A Y_T^A}{P_U Y_T^U} = \left[\left(\frac{w^A}{w^U}\right)^{-\nu} \tau_{U,A} \frac{A_T^A}{A_T^U}\right]^{\frac{1}{1-\nu}} \tag{3.5}$$

Because of differing wages across countries, bilateral relative tradables supply is, in addition to the terms of trade and relative total factor productivities, also a function of relative wages. These in turn are

$$\frac{\omega^E}{\omega^U} = \left(\frac{L^U}{L^E}\right)^{1-\nu} \left[\frac{1+\left(\iota_E \frac{A_N^E}{A_T^E}\right)^{\frac{1}{1-\nu}}}{1+\left(\iota_U \frac{A_N^U}{A_T^U}\right)^{\frac{1}{1-\nu}}}\right]^{1-\nu} \tau_{U,E} \frac{A_T^E}{A_T^U} \tag{3.6}$$

and

$$\frac{\omega^A}{\omega^U} = \left(\frac{L^U}{L^A}\right)^{1-\nu} \left[\frac{1+\left(\iota_A \frac{A_N^A}{A_T^A}\right)^{\frac{1}{1-\nu}}}{1+\left(\iota_U \frac{A_N^U}{A_T^U}\right)^{\frac{1}{1-\nu}}}\right]^{1-\nu} \tau_{U,A} \frac{A_T^A}{A_T^U} \tag{3.7}$$

The supply side is fully described by the relative supply functions (3.1) through (3.5) and the relative wage equations (3.6) and (3.7).

3.2.3 General Equilibrium

In a general equilibrium, goods markets clear in the six markets. For deriving equilibrium conditions, we only need to equate relative demand and supply relations. By doing so, we derive solutions for all relative prices and relative quantities, which are calculated for given current account positions. The resulting equations (shown in Appendix B.2) and the relative wage equations (3.6) and (3.7) describe the general equilibrium.

3.3 Rebalancing of the US Current Account

Having set up the model, it can now be used for simulations of different scenarios in which the US current account deficit is closed. The modelling strategy is to compute two equilibria for every scenario, one with the original global imbalances in which the United States have a current account deficit, and one for which these imbalances are reduced. In most cases, all current accounts are set to zero. Then, the percent changes of relative prices and quantities are computed.

After explaining the calibration of the model in Section 3.3.1, results are summarized along two dimensions. The first dimension, discussed in Section 3.3.2, relates to the comparison with the results presented in Obstfeld and Rogoff, the benchmark with no supply adjustment[3]. The second dimension, presented in Section 3.3.3, relates to the comparison between the two possible exchange rate regimes: the "Global Rebalancing" regime where all exchange rates are freely floating and the "Bretton-Woods-II" regime in which Asia pegs its exchange rate to the US dollar.[4] In a snapshot, results for these two dimensions are summarized in Figures 3.2-3.5, while detailed results are presented in Tables B.1 and B.2 in Appendix B.3.

The two main results from this analysis are (1) that the supply adjustment reduces the exchange rate implications of the re-balancing, thereby shifting the burden of adjustment towards the real economy, while (2) the choice of the exchange rate regime has important implications for the burden sharing between different regions. In particular, Europe is likely to bear the brunt of this burden if Asia keeps its peg with the dollar.

[3] Note that most of Obstfeld and Rogoff's results include valuation effects, that is, the effects of exchange rate changes on the stocks and flows of gross assets and liabilities. These valuation effects, in turn, influence the amount of required trade and price adjustment. It turns out, however, that assuming quite plausible interest rate changes, in particular a reduction in the "exorbitant privilege" (the lower interest rate paid on US liabilities relative to the interest rate received from foreign asset holdings), has the opposite effect of the valuation changes. Hence, these two extensions may well offset each other completely. Therefore, I do not analyse these additional effects and concentrate on the supply side effects.

[4] See Dooley et al. (2003, 2004a-c, 2005a-b) and Caballero et al. (2006, 2007) for discussions about an exchange rate peg or the stable exchange rates between the United States and Asian economies.

Alongside the main specifications, a number of extensions are discussed. First, the sensitivity of the adjustment to the size of the required change of the current account positions is analyzed (Table B.1). This is done by showing results for the case of a reduction to one half of the original current account positions (rather than setting them to zero as in the benchmark scenario). Second, the sensitivity of the adjustment to the time over which this adjustment needs to occur is highlighted (Table B.2). This is done by increasing the elasticities of substitution between different goods. This modelling approach can be justified by assuming that with more time to adjust, more substitutions in response to relative price changes are possible, which can be captured by a larger elasticity of substitution. And finally, the role of a growing Asian labor force is discussed.

3.3.1 Calibration

In order to make results comparable with the benchmark model in Obstfeld and Rogoff (2005), parameters are chosen as in their framework. However, since the time frame involved in a supply adjustment is likely to be larger and hence elasticities larger than in an abrupt rebalancing, bigger elasticities are discussed as well.

The most important parameters are the elasticities of substitution between tradable goods and non-tradable goods, θ, and between tradable goods from different countries, η. Most studies find relatively low values for θ, usually between 0.5 and 1 (see Mendoza, 1991 and Stockman and Tesar, 1995). I follow Obstfeld and Rogoff (2005) who chose $\theta = 1$ at the upper end of this range to capture the short term adjustment scenario, but I also report results for $\theta = 2$ in order to capture longer periods in which adjustment might take place. In the benchmark specification, I choose $\eta = 2$ which is in the middle range of values usually employed and $\eta = 4$ for the slow adjustment scenario.

The share of tradables consumption in total consumption, γ, is set to 0.25, a value that corresponds roughly with the OECD average of tradable output share (see Engler et al., 2007). Therefore, the relative quantities of non-tradables and tradables are set to 3 in all regions in the initial allocation.

The relative tradables quantities across regions are set to 1, and α, β and δ are set to 0.7, 0.8 and 0.7 respectively. Hence, all regions have an equal home-bias in tradables consumption of 0.7[5] while the United States and Europe weigh Asia's tradables somewhat more than Asia weighs their exports. This implies that Asia is assumed to play an important role in world trade.

The elasticity of output with respect to the factor input, ν, is the critical parameter that distinguishes this framework from Obstfeld and Rogoff's benchmark. In that benchmark, this parameter takes on the value of 0, which does not allow any supply adjustment. The results of this benchmark are compared with results when supply is allowed to adjust. As a standard value I choose $\nu = 0.7$, which roughly corresponds to the US labor share. As a robustness check, I present the constant returns to scale case where $\nu = 1$ for some specifications.

The US current account relative to its own tradable output, ca^U, is assumed to be -0.2 in the original allocation from which the adjustment begins. Assuming a tradables share of about 25% in total GDP, this implies a current account to GDP ratio of -0.05. This corresponds to a little less than the actual figure in 2007.

An important element of this model are the relative total labor inputs $\frac{L^i}{L^j}$. Note that although initially one may view this term as endogenous because changes in hours are likely to occur in an adjustment process, consistency requires treating it as constant in the framework I apply. As I abstract from consumers' and workers' intertemporal optimization decisions, I hold total real consumption and total real output constant, and adjust only relative quantities. Hence, total labor supply needs to be constant, too. This allows analyzing sectoral adjustment without modeling total demand and supply.

Two aspects matter for my choice of population figures. First, data on hours worked is available for OECD countries, but not for most developing countries. Hence, relative hours can only be proxied, at least for the US-Asia relationship. Therefore, I use World Development Indicators data

[5]This value is slightly smaller than the one discussed for OECD countries in Obstfeld and Rogoff (2000). However, I follow Obstfeld and Rogoff (2005) with their choice in order to guarantee comparabilita of results.

of the World Bank on relative populations for all three regions in order to guarantee consistency. In the "European" labor force, I include the European Union, Turkey, Switzerland, Canada, Australia and New Zealand. The rationale for this choice is that Obstfeld and Rogoff (2005) include the later four countries for their determination of portfolio shares and because Turkey can well be regarded as part of the wider European economy with its decades old currency union with the European Union. Having flexible exchange rates, this group of countries is likely to be affected similarly in a rebalancing scenario and differentially vis-à-vis the Asian economies, many of which stabilize nominal exchange rates and thereby add to the burden of adjustment on the "European" side.

Second, major Asian countries have a huge share of rural populations which may not be considered as a part of the population relevant for the modern economy and in which substitution between tradable and non-tradable sectors occurs. In the case of China and Thailand, the shares of the urban populations are as low as 44% and 24% respectively in 2007. Hence, I adjust the developing Asian economies' population figures by considering only urban populations. The countries included are China, India, Indonesia, Japan, the Philippines, Vietnam, Thailand, Korea, Malaysia and Singapore, furthermore Taiwan and Hongkong. In order to guarantee consistency, I use urban populations for Europe and the United States as well. It turns out, however, that results are not very sensitive to the exact figure.

In a robustness check, I want to grasp the current population dynamics in Asian societies with a rapid growth of urban populations of up to 4.4% in case of Indonesia and 3.6% in China. This changes the relative population figures over time and therefore the results of the supply adjustment simulations. I provide simulation results only for the longer adjustment scenarios where I computed the changing urban populations over a five-year horizon beginning in 2005, assuming the average annual growth rates of the time between 1990 and 2004. The resulting figures can thus be regarded as projections of relative urban populations in the year 2010.

The model requires values of relative total factor productivities. These are determined for the initial allocation and then assumed to be constant over time. Hence, I abstract from differential productivity developments across sectors and countries over time. For exogenous initial relative outputs and endogenously determined relative prices, the United States' relative total factor productivity is

$$\frac{A_N^U}{A_T^U} = \left(\frac{Y_N^U}{Y_T^U}\right)^{1-\nu} \iota_U^{-\nu}.$$

Other relative total factor productivities are calculated accordingly.

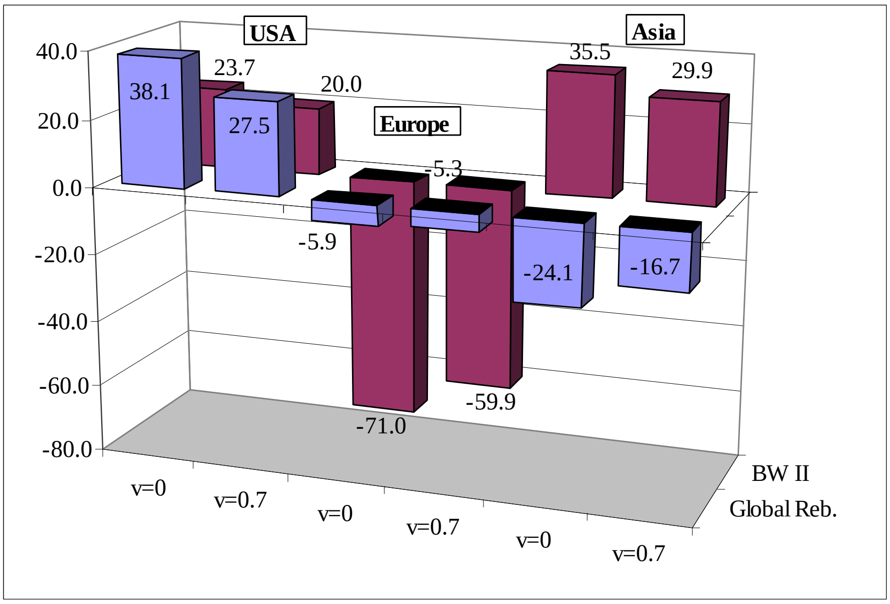
For the international investment positions, the currency denominations thereof and interest return on them I follow Obstfeld and Rogoff (2005). They assume the "exorbitant privilege" with 3.75% interest paid on US dollar denominated assets and 5% on assets denominated in all other currencies. These figures are somewhat smaller than the post-war historical average (Gourinchas and Rey, 2006).

3.3.2 The Global Rebalancing Scenario

The first dimension of the results, the global rebalancing scenario in which all current accounts are reduced to zero, is shown in Table B.1 and highlighted in Figure 3.2 for the real exchange rates (only for $\nu = 0.7$ and for $\nu = 0$). The depreciation of the US dollar falls from 38.1% to 27.5% (for $\nu = 0.7$) and 23% (for $\nu = 1$) respectively when the supply side is allowed to adjust (All values shown are percent changes and calculated as log differences between the initial and the final allocations.). Asia's appreciation, in turn, is significantly reduced, from 24% to 16.7% and 13.5% while Europe's appreciation, already mild without supply response, is further reduced as well.

This reduced real depreciation is achieved through somewhat larger terms of trade deteriorations of the United States vis-à-vis Asia and Europe (Figure 3.3) and a much lower change in the relative non-tradables prices. The larger change in the terms of trade may appear counter-intuitive at first sight. However, in order for a greater quantity of tradable output to be sold in the world market, a greater price change is necessary. This greater terms of trade change per se contributes to a larger real depreciation of the US dollar, but this effect is more than offset by the reduced change of the relative price of

Figure 3.2: Change of REER (in %, short term)



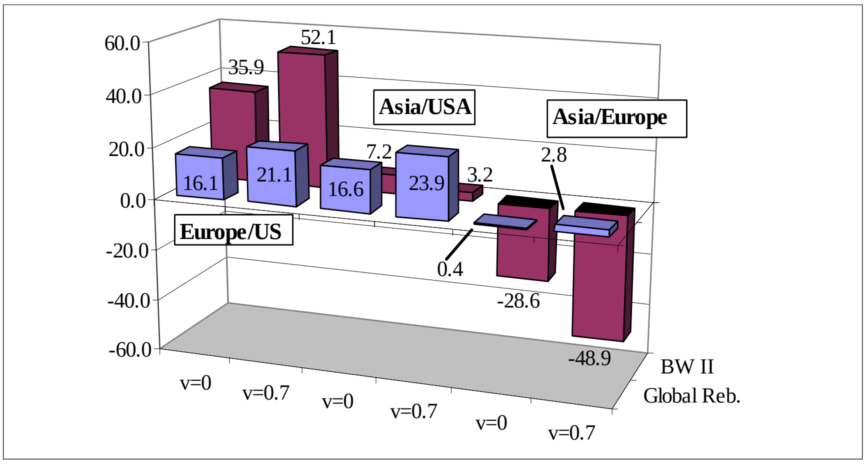
non-tradables, which has a much bigger weight in real exchange rates than the terms of trade due to the large share of non-tradables in the consumption indexes. This underlines the importance of non-tradables in an analysis of current account adjustments and the determination of real exchange rates.

The relative non-tradables price change is a decreasing function of ν. The decline of the US relative non-tradables price falls from -18.5% ($\nu = 0$) to -5.6% ($\nu = 0.7$) and to basically zero for $\nu = 1$. In this latter case the entire adjustment occurs through the quantity adjustment.

The quantity adjustment, in turn, is an increasing function of ν (see Table B.1). The relative quantity of the US non-tradables falls by 13% while it increases by 4.3% and 11.4% in Europe and Asia.

Allowing for price and quantity adjustments does not change the nominal impact (price plus quantity change) compared with the price only adjustment. In case of the US, the fall of the relative size of the non-tradables sector is 18.5% in all three specifications. However, the specifications introduced here highlight the important role of a sectoral re-allocation of production factors. Note that in these specifications the least affected region in terms

Figure 3.3: Change of bilateral terms of trade (in %, short term)



of quantity adjustment is Europe, where the required sectoral re-allocation is extremely low. This will change dramatically in the Bretton-Woods-II scenario.

The relative tradables quantities across regions change remarkably as well. The European and the Asian tradable outputs relative to the US tradables output contracts by 13.1% and 18.3% respectively for $\nu = 0.7$ and by 18.6% and 26.3% respectively for $\nu = 1$. Thus, the European and the Asian exporters suffer from the adjustment in the global rebalancing scenario.

The fourth, fifth and sixth columns of Table B.1 report results for a simulation as above with the only difference that all current accounts are reduced to half their original values, to -0.1 and to 0.025 for the United States and Europe respectively. Here, the price and quantity changes are reduced by half as well, hence percentage changes of endogenous variables are proportional to the needed adjustment analyzed.

In order to analyze an adjustment scenario that occurs over an extended period, the first part of Table B.2 presents simulations where the elasticities of substitution between goods are doubled, θ is set to 2 and η now equals 4.

In all specifications this reduces the percentage changes proportionally by a little more than 50%. The difference between the US real effective exchange rate change in the specifications with and without supply adjustment is less than above but still significant. Asia's and Europe's adjustment in terms of their respective real exchange rates is quite modest here. However, large factor re-allocations remain necessary in both the United States and Asia, indicated by the percentage changes of the relative quantities of non-tradables of around 8%. Europe, on the other hand, remains almost unaffected with an increase of the non-tradables to tradables ratio (Y_N^E/Y_T^E) of 2.6%. Again, this result will turn out to be sensitive to the choice of the exchange rate regime.

The effect of changing relative labor forces is highlighted by a comparison between the second and third columns. In the third column, a change of relative populations is assumed, taking account of the trend of a rapidly increasing urban population in Asia. Taking this less literally, one could regard this as an analysis of the rapid absorption of the rural Chinese population by the expanding industrial sector. In the global rebalancing scenario, the change in the set-up only has a small impact on relative prices and the relative non-tradable quantities. However, the changes of relative tradables output across regions are remarkable. While in the case of constant populations, Europe´s tradables sector grows relative to Asia's (Y_T^A/Y_T^E falls by 3.8%), this ratio increases by 5.9% when population changes are introduced. The gains of the US tradables sector vis-à-vis Asia's tradables sector are reduced and, interestingly, Europe's tradables production falls even more relative to that of the United States. Hence, due to the Asian population dynamics, European exporters bear a greater burden in an adjustment scenario. The intuition behind this result is that, ceteris paribus, Asia's relative wages fall (see the wage equations in Section 3.2), resulting in a shuffling of the burden of adjustment away from Asia and towards Europe.

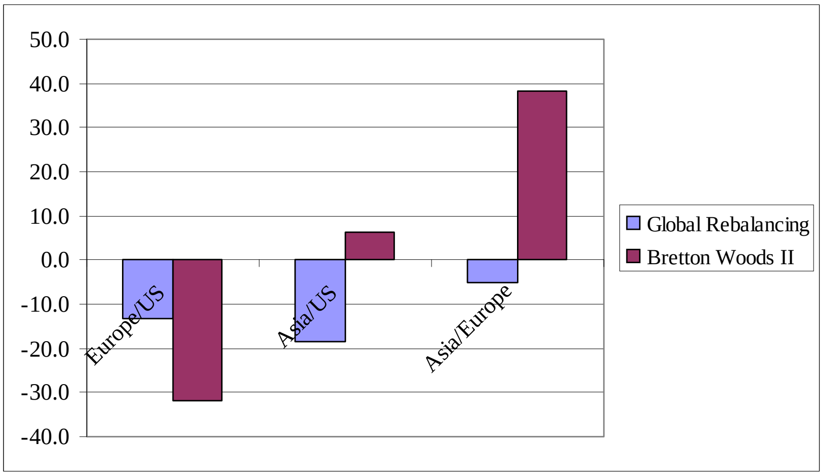
3.3.3 The Bretton-Woods-II scenario

The dramatically different results for a "Bretton-Woods-II" scenario are presented in the second part of Table B.1. Here, Asia's central banks keep their bilateral real exchange rates vis-à-vis the United States fixed. The burden of adjustment on the surplus-side is handed over entirely to Europe, which now experiences a real appreciation of almost 60% vis-à-vis both the United States and Asia for $\nu = 0.7$ (see also Figure 3.2) and somewhat less for $\nu = 1$. At the same time, this effect is again muted through the quantity adjustment.

The change in the terms of trade between the United States and Asia is now quite modest while the gains in competitiveness of both the United States and Asia vis-à-vis Europe are large. The United States' and Asia's terms of trade fall by about 50% (for $\nu = 0.7$) and about 60% (for $\nu = 1$), compared with about 30% when only prices adjust (see also Figure 3.3).

The weaker US and Asian currencies result in a strong deterioration in Europe's export performance. Compared with the Global Rebalancing scenario, Europe's relative to the US tradables output falls by more than 30% for $\nu = 0.7$ rather than 13% (see also Figure 3.4) and by more than 50% for $\nu = 1$. In Asia, the tradables sector continues to grow, a little vis-à-vis the United States and to an enormous extent vis-à-vis Europe.

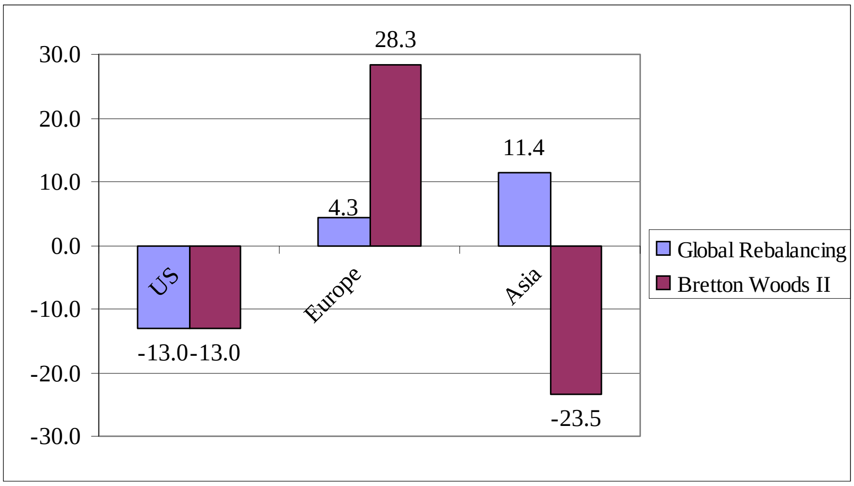
Figure 3.4: Europe's burden: Change of bilateral tradable output (in %, short term)



This picture is reinforced by the change of the non-tradable to tradable output ratio. As can be seen in Figure 3.5, the "burden sharing" between Europe and Asia, with a somewhat bigger burden borne by the Asian economies in the Global Rebalancing scenario, changes completely: the ratio increases by 28.3% in Europe, while it falls by 23.5% in Asia for $\nu = 0.7$ and even more for $\nu = 1$. Thus, under a Bretton-Woods-II scenario, the burden of adjustment in the real economy is handed over entirely to Europe.

Europe's current account surplus of 5% of US tradables output turns into a deficit of almost 43%, which is roughly 11% of US GDP (not shown in the table) and a surplus of equal size in Asia. Hence, global imbalances move from one region to another and aggravate by an enormous extent. This would be a truly alarming scenario for the European economies.

Figure 3.5: Europe's burden: Change in non-tradable to tradable output (in %, short term)



In the last two columns of Table B.1, results for the Bretton-Woods-II setup are presented with the US current account reduced to one half of its original deficit. Like under a Global Rebalancing, this reduces the adjustment of all variables by roughly one half. Hence, the amount by which the US deficit is required to fall matters greatly for the amount of stress it creates for the European economy.

Changing the time horizon of the adjustment has similar effects as in the Global Rebalancing scenario (see Table B.2). All effects are smaller, but in this case the changing population size only has a small impact on relative tradables output.

3.4 Conclusion

This paper presents a simple but flexible theoretical framework that allows a number of specifications under which a rebalancing of the US current account deficit can be analyzed. The precise way of modelling the reversal is to simply assume that the current account needs to shrink by a certain amount over a given period of time. This required adjustment is exogenous in this model, it may be due to some exogenous change in market sentiment towards the United States.

Three aspects are novel to this approach: First, the model captures a three-country world. The differential impact on Europe and Asia is highlighted, rather than only the impact of a reversal of the US current account on the rest of the world as a whole, as in Engler et al. (2007). Second, the supply side is introduced. Hereby, the sectoral re-allocations within countries and across countries are shown, an aspect neglected in the three country model in Obstfeld and Rogoff (2005). Third, the impact of an increasing Asian workforce on the re-balancing scenario is captured through its effect on relative wages.

The core result is that exchange rate policies matter for the distribution of the burden of adjustment. While under flexible exchange rates Europe will hardly be affected by the adjustment, a stabilization of Asian exchange rates vis-à-vis the US dollar will exert massive pressure on Europe's tradables sector. European tradables output will not only contract strongly relative to the US tradables output, but also, to a similar extent, relative to Asian tradables output. In the baseline parameterization, this contraction is more than 30%. The supply adjustment does relieve pressure from European exchange rates, that is, reducing the real appreciation, but the implications for the real economy will be devastating if Asian economies do not let their currencies appreciate against the dollar. The flip side of this contraction of the European tradables sector is that the relative size of the non-tradables sector will grow considerably. In the logic of this model, this requires a re-allocation of production factors.

The simulation results reveal a crucial influence of several key parameters and assumptions on the relative burdens of adjustment each country has to bear. First, demand elasticities matter. The smaller the elasticities of substitution between goods are, the greater the implications for exchange rates and factor re-allocation. Since typical estimates for these elasticities are small, the risks implied by the closing of the US current account are indeed significant. However, if one interprets larger elasticities as parameterizations of longer term adjustment scenarios, the risks might not be as severe as the benchmark specification suggests.

Second, size matters. The more the US deficit needs to shrink, the greater the needed adjustment. It follows that if the US deficit needs to shrink only partially, there is also less to worry about factor re-allocation.

Third, size also matters along another dimension which so far has not been highlighted in the literature: relative populations. The increasing Asian workforce tends to reduce its relative wages and increase its competitiveness. In an adjustment scenario this allows Asia to shift a part of the burden of adjustment towards Europe, whose tradables sector is further suppressed.

Chapter 4

Gains from Migration in a New-Keynesian Model

4.1 Introduction

In recent years researchers have become increasingly aware of the fact that labor migration is not just a once-and-for-all move from one country to another:

> "[.] it has now become a reality that circular, repeat, recurrent, revolving door, multiple, frequent, repetitive, intermittent, seasonal, sojourning, cyclical, recycling, chronic or shuttling migration is a salient trait of migration." (Constant and Zimmermann, 2003a)

Despite a lack of data for a broad evaluation of the phenomenon,[1] some evidence has been brought forward in support of it. For Germany, Constant and Zimmermann (2003a,b) found that more than 60% of immigrants have exited Germany in the sample from 1984-1997 at least once and stayed in the country of origin for at least one year, using a representative GSOEP data

[1] Current data on migration flows are mainly based on census and administrative sources not able to capture the repetitive nature of a great proportion of current migration flows (O'Neil, 2003). Therefore, compilation of more longitudinal data sets will be necessary for an appropriate assessment.

set.[2][3] Major reasons for an increased importance of non-permanent forms of migration relative to permanent migration are improved communication technologies, allowing intensified ties of migrants with source countries, and cheap transportation, making frequent return visits or circular migration patterns easier (O'Neil, 2003).

What could the macroeconomic consequences be when a significant share of a country's labor force emigrates temporarily? This paper will argue that, to the extent that workers' labor supply decisions are guided by working opportunities inside *and* beyond national borders because they allocate their labor supply both abroad and domestically, firms' supply conditions are different than in a purely closed-labor-market economy.[4] In particular, the paper will show that this labor market structure flattens the slope of the Phillips curve, that is, the responsiveness of inflation with respect to changes in the output gap, relative to a setting without migration. The intuition behind this phenomenon is simple: When an economy booms due to productivity or demand shocks, workers will return home from abroad because of improving domestic real wages relative to real wages abroad. All else being equal, this additional labor supply relieves the pressure on wages at home and, therefore, on marginal costs and prices.

The model I employ uses the basic set up of Galí and Monacelli (2005) for a small open economy. The novelty in my framework is that workers are allowed to choose between work at home and abroad, hence migration is analyzed from the perspective of the sending country. I incorporate differing steady state output levels in that the small economy is poorer than the rest of the world on average. In the steady state, this establishes the incentive to migrate and supply labor in two labor markets, those of the domestic and

[2] Furthermore, they found that the frequency of returns depends on the degree to which moving back and forth is restricted or not. Migrants more frequently returned to those countries of origin from which re-entry is easier. This is interpreted as being evidence in favor of a lock-in argument: The risk of not being able to continue to benefit from the higher wages abroad results in less frequent visits and a potentially reduced attachment to the host country. This could be the reason why *"Gastarbeiter"* from Turkey and former Yugoslavia had a much lower return rate than EU-nationals.

[3] For evidence for the UK, see Dustmann and Weiss (2007).

[4] This indicates that I focus on purely economically driven migration and abstract from other motives.

the world economy.

Furthermore, changing cyclical output developments induce cyclical movements of workers across borders. I analyze the differential effects of productivity and demand shocks due to the open labor market setting with a calibration for the Polish economy. This country provides a good example, with its large diaspora and highly mobile workforce. The main result from this exercise is that the increase in domestic output due to a demand shock is substantially higher when workers are allowed to migrate, while the effects of a productivity shock depend largely on the choice of parameters.

Monetary policy plays an important role in this process. If migration is fairly elastic, the central bank can react much less restrictively for a given rate of inflation, that is, more accommodative, to a positive demand shock. This is because firms can tap the pool of returning workers rather than having to compensate workers for reduced leisure. Hence, there is a substitution effect at play between work effort abroad and work effort at home in addition to the closed labor market substitution between leisure and work effort at home. This reduces wage and inflationary pressures and the central bank can allow output to increase by more for a given inflation target. There are therefore significant gains from migration from the perspective of the sending country in the form of output increases compared to a scenario without migration.[5]

However, if migration is symmetric, then the opposite is true as well: When negative demand shocks are associated with large emigration, then the fall in output will be larger and the inflation response smaller than in the scenario without migration.

The welfare implications of open labor markets are analyzed by means of a welfare function that is derived through a second order approximation of the representative household's utility function and by an optimal monetary policy rule for a restricted parameterization. This rule turns out to be identical to the one without migration in that in both cases the central bank perfectly stabilizes the output gap and domestic inflation. Since the welfare function

[5] Since the analysis is within a general equlibrium framework, feedback effects are at play as well. For relatively high goods demand elastcities, the output effect can be so much larger when migration is allowed, that the central bank will have to increase interest rates by more than in the case without migration, given the rule used in the analysis.

is written in terms of the output gap and domestic inflation, there are no welfare implications if the central bank follows this optimal rule. The positive implications of return migration after a positive demand shock described above could thus not be shown to be welfare relevant.

If, however, for some reason that may be exogenous to the model, the central bank follows a non-optimal rule (e.g., a currency peg), then migration can have significant welfare implications. In particular, I show that the weight of domestic inflation relative to the output gap in the welfare function increases when migration is allowed.

How does this relate to the existing literature on the relationship between openness and the Phillips-curve? Loungani et al. (2001) observed that Phillips curves tend to be the flatter the more open an economy is. Razin and Yuen (2002) explained this phenomenon in an open-economy version of the model in Woodford (2003, ch.3) in which the opening of the trade balance and the capital account both flattened the Phillips-curve.[6] Whether the additional opening of the "labor account" works in the same direction, had not been considered in this literature until recently. This work, therefore, contributes to this more general literature on the microfoundations of openness and the Phillips curve. The approach developed in this paper has been adopted by Binyamini and Razin (2007), who analyze migration from the perspective of a receiving country and show that migration also flattens the Phillips curve in that case. Furthermore, Bentolilla et al. (2008) show, in an empirical analysis, that immigration indeed lowered the trade-off in the case of Spain.

The basic structure draws heavily on much older microeconomic literature on temporary migration. A common assumption is location specific

[6] Trade openness reduces the effect of domestic output fluctuations on CPI-inflation relative to an economy that is closed to trade because of a composition effect. The consumption basket in an open economy includes imported goods whose prices are, by construction, not affected by domestic output changes because marginal costs for their production are not affected. The CPI therefore reacts less. Open capital markets affect the Phillips-curve because risk sharing breaks up the link between production and consumption in the closed economy. When output changes, consumption does not automatically change. For that reason, the marginal rate of substitution between consumption and leisure, and thereby the real wage, marginal costs and inflation are less affected.

preferences (e.g. in Hill, 1987, Djajic and Milbourne, 1988, Raffelhüschen, 1992). Migrants emigrate only when they are compensated for being away from home, therefore, they have a higher relative preference to work at home rather than abroad. Furthermore, the usually much higher purchasing power of the host country's currency in the home country's economy is another driving force for emigration, remittances and return migration (Dustmann, 1995,1997).[7] In the present analysis, I introduce only the location specific preferences and simply assume that the representative household only consumes the domestic consumption bundle.

This paper fills a gap in the literature between the microeconomic literature, focused on the partial equilibrium, and macroeconomic open economy approaches that generate insights in a general equilibrium framework, in particular, on the implications for the central bank and interest rates. The latter effects are far-reaching, in particular for receiving countries, because they put into question political conclusions derived from observations of falling wages due to immigration.

What is crucial for my model to be empirically valid is a link between migration flows and wages at business cycle frequencies. If migration is supposed to have any significant impact, this will be reflected in real wage changes. A link between emigration and wages has indeed been shown for Mexico and Poland, two important sending countries (Hanson, 2006; Aydemir and Borjas, 2006; Mishra, 2007 Budnik, 2008) where emigration increases wages of those staying behind. Whether a cyclical spell of return migration or immigration has an effect on wages, has not yet been shown for sending countries, to my knowledge.

This paper is structured as follows. Section 4.2 presents the representative household's decision problem, thereby first introducing the standard model and then presenting the way migration can be incorporated into this decision problem. Section 4.3 turns to the decision of the firm, where I again formulate the standard case and then introduce the way migration and pro-

[7] Further motives put forward but unrelated to the present analysis are credit market rationing in sending countries (Mesnard, 2004), higher returns to human capital, acquired in the host country, in the sending country (Dustmann, 1995, 1997).

duction are related. Sections 4.4 and 4.5 describe the aggregate demand and aggregate supply sides respectively. The discussion of the aggregate supply relation, that is, the Phillips-curve, provides the core of the analysis and the main results. Section 4.6 derives the optimal monetary policy and the welfare function, while Section 4.7 discusses the simulations of demand and productivity shocks. Section 4.8 concludes.

4.2 The Representative Household

The representative household maximizes his utility function, taking account of his budget constraint. He works both at home and abroad with a relative preference to work at home. That means he "suffers" more when working abroad than at home, or can be described as "homesick". This is reflected in a wedge between the contribution to his disutility of labor of an hour worked for a domestic firm relative to an hour worked for a firm in the rest of the world.

He is assumed to consume only domestically, that is, he remits all his earnings from abroad back home indicating his preference to consume at home, a standard assumption in the return migration literature. The representative agent's Euler equation is the basis of a dynamic IS-equation.

Section 4.2.1 first derives goods demand functions and relative prices in a standard New-Keynesian open economy model. Then, Section 4.2.2 introduces the specifics of a migrant household and the resulting first order conditions.

4.2.1 The Standard Model

Utility function and budget constraint The representative agent in the small open economy maximizes the following utility function,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ u\left(C_t\right) - f\left(N_{H,t}, N_{M,t}\right) \right\} \tag{4.1}$$

where E_0 are the household's rational expectations in $t = 0$, β is the discount factor with $\beta < 1$, $u(.)$ and $f(.)$ are the additively separable utility functions of consumption and labor respectively. $N_{H,t}$ and $N_{M,t}$ are the household's labor inputs in the domestic economy and abroad and are explained in more detail below. The domestic consumption index is C_t,

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} \left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

with $C_{H,t}$ as an index for domestic consumption of domestically produced goods $C_{H,t}(j)$ with $j \in [0,1]$:

$$C_{H,t} \equiv \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

$C_{F,t}$ is an index for domestic consumption of foreign goods produced in country $i \in [0,1]$, $C_{i,t}$:

$$C_{F,t} \equiv \left(\int_0^1 \left(C_{i,t}\right)^{\frac{\gamma-1}{\gamma}} di\right)^{\frac{\gamma}{\gamma-1}}$$

$C_{i,t}$, in turn, is an index of goods produced in country i, $C_{i,t}(j)$ with $j \in [0,1]$:

$$C_{i,t} \equiv \left(\int_0^1 C_{i,t}(j)^{\frac{\varepsilon^*-1}{\varepsilon^*}} dj\right)^{\frac{\varepsilon^*}{\varepsilon^*-1}}$$

α is an indicator of the degree of openness of the domestic economy and indicates (inversely) the degree of home-bias in consumption preferences, ε, ε^*, η and γ are the elasticities of substitution within the respective indices.

The consumer faces the period budget constraint

$$\begin{aligned} W_t N_{H,t} + \epsilon_t W_{M,t} N_{M,t} + D_t \geq & \int_0^1 P_{H,t}(j) C_{H,t}(j) dj \\ & + \int_0^1 \int_0^1 P_{i,t}(j) C_{i,t}(j) dj di + E_t \left\{Q_{t,t+1} D_{t+1}\right\} \end{aligned} \tag{4.2}$$

where W_t is the domestic nominal hourly wage; $W_{M,t}$ is the world average of the wages the migrant faces in the rest of the world (discussed below); ϵ_t is the nominal effective exchange rate; D_t is the nominal pay-off of the portfolio in period t; $Q_{t,t+1}$ is a stochastic discount factor; $P_{H,t}(j)$ is the price of domestically produced good j; and $P_{i,t}(j)$ is the price of good j produced in country i.

Let us now turn to the goods demand functions and the respective price indexes.

Demand functions and price indexes From the consumption indexes, the demand functions for the individual goods can be derived. They are as follows:

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon} C_{H,t} \quad \text{and} \qquad C_{i,t}(j) = \left(\frac{P_{i,t}(j)}{P_{i,t}}\right)^{-\varepsilon^*} C_{i,t} \qquad (4.3)$$

where

$$P_{H,t} \equiv \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}} \qquad \text{and} \quad P_{i,t} \equiv \left(\int_0^1 P_{i,t}(j)^{1-\varepsilon^*} dj\right)^{\frac{1}{1-\varepsilon^*}}$$

Aggregation of these demand functions over all goods j delivers

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj = P_{H,t} C_{H,t}$$

and

$$\int_0^1 P_{i,t}(j) C_{i,t}(j) dj \quad = \quad P_{i,t} C_{i,t}$$

respectively. Furthermore, expressed as functions of the domestic and foreign indexes, the demand functions are

$$C_{i,t} = \left(\frac{P_{i,t}}{P_{F,t}}\right)^{-\gamma} C_{F,t} \qquad (4.4)$$

$$\text{with } P_{F,t} \equiv \left(\int_0^1 P_{i,t}^{1-\gamma} di\right)^{\frac{1}{1-\gamma}}$$

Aggregating these over all countries i, gives $\int_0^1 P_{i,t}C_{i,t}di = P_{F,t}C_{F,t}$. Finally, because

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad \text{and} \quad C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{4.5}$$

$$\text{with } P_t \equiv \left[(1-\alpha)\left(P_{H,t}\right)^{1-\eta} + \alpha\left(P_{F,t}\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

gives $P_{H,t}C_{H,t} + P_{F,t}C_{F,t} = P_tC_t$, allowing the period budget constraints to be re-written as

$$W_tN_{N,t} + \epsilon_t W_{M,t}N_{M,t} + D_t \;\; \geq \;\; P_tC_t + E_t\left\{Q_{t,t+1}D_{t+1}\right\} \tag{4.6}$$

In Section 4.4, the demand functions for individual goods expressed in terms of total consumption are needed. They can be derived by combining (4.3), (4.4) and (4.5):

$$C_{H,t}(j) = (1-\alpha)\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon}\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{4.7}$$

$$C_{i,t}(j) = \alpha\left(\frac{P_{i,t}(j)}{P_{i,t}}\right)^{-\varepsilon^*}\left(\frac{P_{i,t}}{P_{F,t}}\right)^{-\gamma}\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \tag{4.8}$$

Next, let us turn to the relationship between the prices, inflation, the terms of trade and the real exchange rate.

Relative prices and inflation The *bilateral terms of trade* $S_{i,t} = \frac{P_{i,t}}{P_{H,t}}$ are defined as the relative price of country i´s and the domestic economy´s goods. The *effective terms of trade* S_t are given by

$$\begin{aligned} S_t &\equiv \frac{P_{F,t}}{P_{H,t}} \\ &= \left(\int_0^1 S_{i,t}^{1-\gamma} di\right)^{\frac{1}{1-\gamma}} \end{aligned} \quad (4.9)$$

which, in the symmetric case, is approximately

$$\widehat{s}_t = \int_0^1 \widehat{s}_{i,t} di$$

where lower case letters indicate logarithms, and hats over lower case letters indicate percent deviations from the respective steady state values. Symmetry is a reasonable and simplifying assumption as long as the focus of the analysis is not structural differences between countries. With rich and poor countries and asymmetric incentives to move across borders (i.e., no incentive for rich countries' workers and a strong incentive for poor countries' workers, as is introduced below), symmetry is no longer a reasonable assumption. For simplicity, I assume two different types of countries, rich and poor, with each group having a common average steady state level for the terms of trade. If, in addition, the weight of the poor group approaches zero in the calculation of the effective terms of trade, then the above approximation remains valid. This may be a reasonable approach for poor countries trading mainly with rich countries and little with other poor countries. It will be shown in the Appendix C.2 that the terms of trade are not necessarily equal to one in the steady state. The precise value, rather, depends on the choice of parameters.

The consumer price index P_t can be approximated by

$$\begin{aligned} \widehat{p}_t &= \frac{1-\alpha}{1-\alpha+\alpha S^{1-\eta}}\widehat{p}_{H,t} + \frac{\alpha}{(1-\alpha)S^{\eta-1}+\alpha}\widehat{p}_{F,t} \\ \widehat{p}_t &= \widehat{p}_{H,t} + \alpha_S \widehat{s}_t \end{aligned} \quad (4.10)$$

where $\alpha_S \equiv \frac{\alpha}{(1-\alpha)S^{\eta-1}+\alpha}$ and where variables with capital letters and without indexes are steady state values. This implies that the level of the steady state terms of trade influence the reaction of the domestic price level on terms of trade fluctuations. For example, if $S > 1$ and if the elasticity of substitution between domestic and foreign goods is smaller than one, any terms of trade change has a larger effect on the price index. For the symmetric case of $S = 1$ and for $\eta = 1$, however, $\alpha_S = \alpha$.

From (4.10), it follows that *domestic inflation*, defined as the rate of change of the domestic goods prices, $\pi_{H,t} \equiv p_{H,t} - p_{H,t-1}$, is related to *CPI inflation* according to

$$\pi_t = \pi_{H,t} + \alpha_S \Delta s_t \tag{4.11}$$

The *law of one price* (LOOP) holds at all times, that is, $P_{i,t}(j) = \epsilon_{i,t} P^i_{i,t}(j)$ for all $i, j \; \epsilon \; [0, 1]$ where $\epsilon_{i,t}$ is the bilateral nominal exchange rate between country i and the domestic country, defined as the price of country i's currency in terms of the domestic currency, and $P^i_{i,t}(j)$ is the price of country i's good j expressed in country i's, the producer's currency. With this assumption and the definition of $P_{i,t}$ one obtains $P_{i,t} = \epsilon_{i,t} P^i_{i,t}$, where $P^i_{i,t} \equiv \left(\int_0^1 P^i_{i,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$. Substituting the definition of the LOOP into the definition of $P_{F,t}$, assuming again two types of countries (rich and poor) with a common average value of P_i in the steady state, and neglecting the values of the poor countries one obtains through log-linearization:

$$\begin{aligned} p_{F,t} &= \int_0^1 p_{i,t} di \\ &= \int_0^1 (e_{i,t} + p^i_{i,t}) di \\ &= e_t + p^*_t \end{aligned} \tag{4.12}$$

where $e_t \equiv \int_0^1 e_{i,t} di$ is the log *nominal effective exchange rate,* $p^i_{i,t} \equiv \int_0^1 p^i_{i,t}(j) dj$ is the log domestic price index of country i in its own currency, and $p^*_t \equiv \int_0^1 p^i_{i,t} di$ is the log *world price index.* Note that for the rest of the world as a whole, the distinction between the domestic and the consumer price index fades because $\alpha \to 0$.

From (4.9) and (4.12), I derive a relationship between the terms of trade and the nominal exchange rate:

$$s_t = e_t + p_t^* - p_{H,t} \tag{4.13}$$

Defining the *bilateral real exchange rate with country i* as $RER_{i,t} \equiv \frac{\epsilon_{i,t}P_t^i}{P_t}$ and the (log) real effective exchange rate $reer_t \equiv \log REER_{i,t} \equiv \int_0^1 rer_{i,t}di$, and using (4.13) and (4.10) gives a relationship between the real effective exchange rate and the terms of trade:

$$\begin{aligned} reer_t &= \int_0^1 (e_{i,t} + p_{i,t}^i - p_t)di \\ &= e_t + p_t^* - p_t \\ &= s_t + p_{H,t} - p_t \\ &= (1 - \alpha_S)s_t \end{aligned} \tag{4.14}$$

Having introduced goods demand functions and relative prices which were, so far, unaffected by the migration decision, I now turn to the specifics of the migrant household.

4.2.2 The Representative Household and Migration

In order to derive the household's optimal allocation of consumption, hours abroad and at home, I employ the following period utility function:

$$u(C_t) - f(N_{H,t}, N_{M,t}) \equiv \frac{e^{d_t}C_t^{1-\sigma}}{1-\sigma} - \frac{\left(N_t^H + \phi N_t^M\right)^{1+\varphi}}{1+\varphi} \tag{4.15}$$

where e^{d_t} is a domestic demand shock, assumed to follow an AR-process in logs, that is, $d_t = \rho_d d_{t-1} + \varepsilon_t^d$ with $E_t\left\{\varepsilon_{t+1}^d\right\} = 0$. The disutility of labor function has two arguments: The labor supplied domestically, $N_{H,t}$, and the labor supplied abroad, $N_{M,t}$. The latter of the two is multiplied by the factor $\phi > 1$, indicating his relative preference for working at home rather than working abroad, or "home sickness". $N_{H,t}$ and $N_{M,t}$ are indexes explained in more detail in Section 4.3 and are constrained to be non-negative.

Foreign labor is not allowed to migrate to the small open economy, hence the utility functions of households abroad assign a value of either infinity or zero to ϕ. In the first case ($\phi = 0$ in the rest of the world), one would simply assume that it is not possible for households to migrate to the domestic economy. In the second case ($\phi = \infty$ in the rest of the world), one would assume that it is not regarded as desirable to migrate.

The world average nominal wage $W_{M,t}$ that the household faces when working abroad will be assumed to be exogenous. This may be an appropriate assumption for a small open economy where the migrants are price takers in the labor market of their host country. For a large host country with several small countries jointly providing a large group of imigrants, this assumption would certainly have to be relaxed in order to allow for changes of the foreign wage due to changes in supplied hours.

Maximizing (4.1) w.r.t. C, N_H and N_M, subject to (4.6) and taking account of (4.15), one gets the marginal rates of substitution equated to the respective real wages and, in case of the foreign wage in terms of the domestic goods prices, adjusted for the home-sickness coefficient ϕ:

$$e^{-d_t} C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{4.16}$$

$$e^{-d_t} C_t^{\sigma} N_t^{\varphi} \phi = \frac{\epsilon_t W_{M,t}}{P_t} \tag{4.17}$$

where $N_t = N_{H,t} + \phi N_{M,t}$ is the argument of the disutility of labor function. From this, it follows that $\frac{W_t}{P_t} \leq \frac{\epsilon_t W_{M,t}}{P_t}$, that is, the purchasing power of the foreign wages in the domestic economy is larger than the one of domestic wages. To be more precise, the wedge in domestic earnings and those from abroad is $\phi = \frac{\epsilon_t W_{M,t}}{W_t}$. Therefore, with the world nominal wage assumed to be exogenous for the domestic economy, the exchange rate and the domestic nominal wage rate are endogenously determined to keep the wedge constant for a given value of ϕ.

From the first order condition w.r.t. D_t, one obtains the intertemporal optimality condition

$$\beta \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+1}}\right) e^{d_{t+1}-d_t} = Q_{t+1} \tag{4.18}$$

which, when taking conditional expectations on both sides, yields the standard stochastic Euler equation:

$$\beta R_t E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+1}} e^{d_{t+1}-d_t} \right\} = 1$$

where $R_t^{-1} = E_t \{Q_{t,t+1}\}$ is the domestic currency price of a one-period riskless bond.

An international risk sharing relationship can be derived by relating the domestic and foreign Euler equations. Assuming perfect securities markets, an intertemporal equilibrium condition for country i, analogous to equation (4.18) of the form

$$\beta E_t \left\{ \left(\frac{C^i_{t+1}}{C^i_t}\right)^{-\sigma} \frac{P^i_t}{P^i_{t+1}} \frac{\epsilon^i_t}{\epsilon^i_{t+1}} e^{d^*_{t+1}-d^*_t} \right\} = Q_{t,t+1} \tag{4.19}$$

has to hold, where ϵ^i_t is the nominal effective exchange rate of country i and where d^*_t is a demand shock that, for simplicity, is assumed to be the same for all countries except the domestic economy. Equating (4.18) and (4.19), gives a relationship linking domestic and country i's consumption,

$$C_t = \vartheta_i C^i_t \left(RER_{i,t}\right)^{\frac{1}{\sigma}} \left(e^{d_t-d^*_t}\right)^{\frac{1}{\sigma}} \tag{4.20}$$

where $\vartheta_i \equiv \frac{C_0}{C^i_0} RER_{i,0}^{-\frac{1}{\sigma}}$, under the assumption that $d_0 = d^*_0 = 0$. The term ϑ_i is an initial condition for relative consumption at time zero in the absence of shocks. Assuming symmetric initial conditions across countries, $\vartheta_i = 1$, Galí and Monacelli (2005) showed that this would lead to a symmetric steady state where $C = C^i = C^*$, and where C^* is an index of world consumption, and $REER_t = S_t = 1$.

Here, however, I deviate from this assumption and allow that on average $\vartheta_i < 1$, that is, the domestic economy started with below country i's level of consumption. The asymmetric initial condition can be interpreted as an unsymmetric distribution of wealth across countries that suppresses domestic relative to other countries' consumption even today. For simplicity I assume that $\vartheta_i = \vartheta$ for all i. In Appendix C.2, I show that this assumption affects the steady state of the terms of trade.

Taking logs on both sides of (4.20) and integrating over i gives

$$\begin{aligned} c_t &= \log\vartheta + c_t^i + \frac{1}{\sigma} rer_{i,t} + \frac{1}{\sigma}(d_t - d_t^*) \\ &= \log\vartheta + c_t^* + \frac{1}{\sigma} reer_t + \frac{1}{\sigma}(d_t - d_t^*) \\ &= \log\vartheta + c_t^* + \frac{1-\alpha_s}{\sigma} s_t + \frac{1}{\sigma}(d_t - d_t^*) \end{aligned}$$

where $c_t^* = \int_0^1 c_{i,t} di$. This is an international risk sharing condition that relates domestic and foreign consumption. A wedge is created between the two by the initial condition, the terms of trade and asymmetric demand shocks, that is, $d_t - d_t^* \neq 0$.[8]

In summary, the optimality conditions (apart from the budget constraints) take the following log-linearized form:

$$w_t - p_t = \sigma c_t + \varphi n_t - d_t \tag{4.21}$$

$$w_{M,t} - p_t + e_t = \sigma c_t + \varphi n_t + \log\phi - d_t \tag{4.22}$$

$$c_t = E_t\{c_{t+1}\} - \frac{1}{\sigma}\left(r_t - E_t\{\pi_{t+1}\} - \rho\right) + (1-\rho_d) d_t \tag{4.23}$$

$$c_t = \log\vartheta + c_t^* + \frac{1-\alpha_s}{\sigma} s_t + \frac{1}{\sigma}(d_t - d_t^*) \tag{4.24}$$

[8] Alternatively, the uncovered interest parity could be derived as a risk sharing condition. In any country i, an analogous relationship to $R_t^{-1} = E_t\{Q_{t,t+1}\}$ has to hold and because of complete international securities markets, one has $\epsilon_{i,t}\left(R_t^i\right)^{-1} = E_t\{Q_{t,t+1}\epsilon_{i,t+1}\}$. Combining these two equations, log-linearizing and aggregating over all i, gives $r_t - r_t^* = E_t\{\Delta e_{t+1}\}$, the uncovered interest parity condition.

where $e_t \equiv \log \epsilon_t$, $\rho \equiv \beta^{-1} - 1$ is the subjective rate of time preference and $\pi_t \equiv p_t - p_{t-1}$ is defined as the CPI inflation rate.

4.3 Firms

Domestic firms employ domestic labor and set prices in a forward-looking way with price staggering à la Calvo (1983), allowing the derivation of a New-Keynesian Phillips-curve in Section 4.5. The rest of the world is modeled in a mainly analogous manner, with the main difference that workers from the rest of the world are not assumed to work in the domestic small economy. Section 4.3.1 derives the standard model of firms in the open economy, while Section 4.3.2 introduces migration.

4.3.1 The Standard Model

The domestic firm $j \in [0, 1]$ produces with the linear production function

$$Y_t(j) = A_t N_{H,t}(j)$$

where $a_t \equiv \log A_t$ follows an AR(1) process $a_t = \rho_a a_{t-1} + \varepsilon_t$ with $E_t \{\varepsilon_{t+1}\} = 0$. From this, and the definitions $Y_t \equiv \left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$ and $N_{H,t} \equiv \int_0^1 N_{H,t}(j) dj$, the following first order approximation to an aggregate production relationship can be derived:

$$N_{H,t} = \frac{Y_t Z_t}{A_t} \tag{4.25}$$

where $Z_t \equiv \left(\int_0^1 \frac{Y_t(j)}{Y_t} dj \right)$. Galí and Monacelli (2005) further show that equilibrium variations in $z_t \equiv \log Z_t$ around the perfect foresight steady state are of second order. Therefore, up to a first order approximation

$$y_t = a_t + n_{H,t} \tag{4.26}$$

can be written for aggregate production.

Variable costs, in terms of domestic prices, are common across domestic firms and given by $w_t - p_{H,t} + y_t - a_t$. Domestic real marginal costs are thus given by

$$mc_t = w_t - p_{H,t} - a_t \tag{4.27}$$

With Calvo-type price-setting (Calvo, 1983), a measure $1-\theta$ of randomly-selected firms sets new prices every period with the probability of being selected independent of the time elapsed since prices were last adjusted. The optimal price-setting rule can then be approximated by

$$\overline{p}_{H,t} = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t \left(mc_{t+k} + p_{H,t} \right)$$

where $\overline{p}_{H,t}$ denotes the optimal newly-adjusted log price and $\mu \equiv \log(\varepsilon/(\varepsilon - 1))$ denotes the optimal mark-up in the steady state. Therefore, firms set their prices in a forward-looking manner equal to a weighted average of the expected discounted marginal costs, plus a mark-up.

In an analogous way, world output is produced: Individual country i produces with production function $y_t^i = a_t^i + n_t^i$ where $a_t^i = \rho_{a^i} a_{t-1}^i + \varepsilon_t^i$ with $E_t \left\{ \varepsilon_{t+1}^i \right\} = 0$ and $E_t \left\{ \varepsilon_{t+1}^i \varepsilon_{t+1}^j \right\} = 0 \; \forall \; i,j$, implying marginal costs of $mc_t^i = w_t^i - p_{H,t}^i - a_t^i$. Integrating these relationships over all countries, results in the world production and marginal cost functions:

$$\begin{aligned} y_t^* &\equiv \int_0^1 y_t^i di = \int_0^1 a_t^i di + \int_0^1 n_t^i di \equiv a_t^* + n_t^* \\ mc^* &\equiv \int_0^1 mc_t^i di = \int_0^1 w_t^i di - \int_0^1 p_{H,t}^i di - \int_0^1 a_t^i di \equiv w_t^* - p_t^* - a_t^* \end{aligned}$$

where asterisks indicate world averages.

4.3.2 Production and Migrant Labor

Having established the standard decision of firms, I now show how labor migration can be introduced into this framework in a very general way. To that end, I show how migrant labor is related to the production side of the economy and how this, in turn, is related to the household's preferences.

I assume that the migrant's labor input does not appear in the world production function. This means that changes in N_M will not result in measurable changes of world output. This is reasonable for the small country/rest-of-the-world setting. However, I assume that changes in world output and in world productivity have non-negligible effects on N_M through an assumed correlation between output and productivity of the world economy, and the sectors employing migrant workers. Rather than modelling N_M explicitly in the world production function, I assume that the first effect increases the migrant's labor input abroad, while the second decreases it. Furthermore, I assume that migrant labor hours are a negative function of domestic output, that is, domestic output growth induces migrants to return, while they are a positive function of domestic productivity shocks, indicating that when set free domestically, labor partly moves abroad.

Therefore, I can describe N_M as a function of four factors:

$$N_M = N_M(\overset{-}{Y}, \overset{+}{A}, \overset{+}{Y^*}, \overset{-}{A^*}) \tag{4.28}$$

The plus and minus signs indicate the signs of the first derivatives of N_M with respect to the respective variables. I further assume that these partial derivatives are additively separable.

These assumptions are necessary in order to establish a link between domestic and foreign business cycles due to exogenous shocks on the one hand and the migrant's decision with respect to his place of work on the other hand. The reason for choosing this general rather than a specific functional form is that I want to illustrate in a transparent way which relationships between these variables are required in order to derive the conclusions below. In an empirical analysis, one could then directly check whether these relationships can be verified. In a future theoretical analysis with more specific functional forms, one would then need to make sure that these relationships are indeed fulfilled.

Applying a Taylor expansion to this function around the steady state, gives

$$\widehat{n}_{M,t} = \frac{\partial N_{M,t}}{\partial Y_t}\frac{Y}{N_M}\widehat{y}_t + \frac{\partial N_{M,t}}{\partial A_t}\frac{A}{N_M}a_t + \frac{\partial N_{M,t}}{\partial Y_t^*}\frac{Y^*}{N_M}\widehat{y}_t^* + \frac{\partial N_{M,t}}{\partial A_t^*}\frac{A^*}{N_M}a_t^*$$

What is of ultimate interest here, however, is the relationship between output and productivity fluctuations on the one hand and the overall disutility of labor on the other hand. Approximated around the steady state, the argument in the disutility of labor function $N_t = N_{H,t} + \phi N_{M,t}$ is

$$\widehat{n}_t = \nu\widehat{n}_{Ht} + (1-\nu)\widehat{n}_{M,t}$$

where $\nu = \frac{N_H}{N} < 1$. Plugging the above result and equation (4.26) into this approximation, I can relate the disutility of labor to domestic and foreign output fluctuations, and to domestic and foreign productivity shocks as follows:

$$\begin{aligned}\widehat{n}_t &= \nu\widehat{y}_t - \nu a_t + \\ &\quad (1-\nu)\left[\frac{\partial N_{M,t}}{\partial Y_t}\frac{Y}{N_M}\widehat{y}_t + \frac{\partial N_{M,t}}{\partial A_t}\frac{A}{N_M}a_t + \frac{\partial N_{M,t}}{\partial Y_t^*}\frac{Y^*}{N_M}\widehat{y}_t^* + \frac{\partial N_{M,t}}{\partial A_t^*}\frac{A^*}{N_M}a_t^*\right] \\ \widehat{n}_t &= (\nu - \zeta_Y)\,\widehat{y}_t - (\nu - \zeta_A)\,a_t + \zeta_{Y^*}\widehat{y}_t^* - \zeta_{A^*}a_t^* \qquad (4.29)\end{aligned}$$

where $\zeta_X \equiv \left|\frac{\partial N_{M,t}}{\partial X_t}\frac{X}{N_M}\frac{\phi N_M}{N}\right|$ is defined as the elasticity of the argument of the disutility of labor function, N_t, with respect to changes in variable X. For example, ζ_Y is the elasticity by which N_t reacts to changes in domestic output due to the reduced labor input abroad. The term $(\nu - \zeta_Y)$ needs to be restricted to positive values to avoid N_t to become negative (see Appendix C.3).

In a closed labor market setting, where the $\zeta_X = 0$ for $X = Y, A, Y^*$ and A^* and $\nu = 1$, this equation reduces to the relationship between labor input and output derived from the aggregate production function, $\widehat{n}_t = \widehat{y}_t - a_t$. Here, however, purely domestic variations of economic activity and productivity only partially affect the disutility of labor when the "labor account" is open because $(\nu - \zeta_Y) < 1$ and $(\nu - \zeta_A) < 1$.

Two effects contribute to weaken the link between domestic output and productivity on the one hand and the disutility of labor on the other hand. First, in the deterministic steady state, a fraction $1 - \nu$ of hours worked constitute a factor input abroad. This fraction is unaffected by fluctuations of the domestic variables y_t and a_t. Only the fraction ν is affected. Second, when favorable domestic conditions, that is, positive deviations of output from the steady state, result in return migration, this return migration constitutes a substitution of hours worked domestically for hours worked abroad. To that extent an increased domestic labor input leaves the disutility of labor unaffected. In the model, this is introduced through the elasticity ζ_Y. These two effects are the reason for the reduction of the slope of the Phillips-curve as shown below.

Furthermore, world output and productivity affect the disutility of labor because of their impact on the migrant's hours worked.

4.4 Aggregate Demand

I now derive the domestic equilibrium by establishing a goods market clearing condition that relates domestic output to domestic and foreign consumption. In this relationship, a wedge between domestic output and consumption is created by fluctuations in the terms of trade and a relative demand shock that result in changing relative demand for domestically produced goods. This condition will be used to derive an intertemporal Euler equation in terms of the output gap. The external equilibrium is determined by the net export equation. It turns out that migration affects the demand side of the model only through the steady state's impact on the dynamics.

In a goods market equilibrium, domestic supply has to equal domestic and foreign demand. In Appendix C.1, this is explicitly derived and approximated around the steady state. The resulting equilibrium is

$$\widehat{y}_t = \widehat{c}_t + \frac{\alpha \varpi_S}{\sigma} \widehat{s}_t - \frac{\alpha}{\sigma} l(S) \left[d_t - d_t^* \right] \tag{4.30}$$

where I made use of the substitutions

$$\begin{aligned} l(S) &\equiv \left[(1-\alpha)\vartheta S^{\eta-\gamma} reer(S)^{\frac{1}{\sigma}-\eta} + \alpha\right]^{-1} \\ reer(S) &\equiv REER \\ \varpi_S &\equiv [\sigma\gamma + (1-\alpha_S)(\sigma\eta - 1)]\, l(S) + \sigma\eta \left[\frac{\alpha_s}{\alpha} - l(S)\right] \end{aligned}$$

Therefore, the terms of trade and asymmetric demand shocks $d_t - d_t^* \neq 0$ cause wedges between output and consumption in a small open economy. The size of these effects depends on parameters, the steady state and the initial condition ϑ.[9]

Condition (4.30) holds for every country i, therefore $\widehat{y}_t^i = \widehat{c}_t^i + \frac{\alpha\varpi_S}{\sigma}\widehat{s}_t^i$. Aggregation over all countries results in the world market clearing condition:

$$y_t^* \equiv \int_0^1 y_t^i di = \int_0^1 c_t^i di \equiv c_t^* \tag{4.31}$$

where y_t^* and c_t^* are indexes for log world output and consumption. Combining this with (4.30) and (4.24) gives

$$\widehat{y}_t = \widehat{y}_t^* + \sigma_{\alpha,s}^{-1}\widehat{s}_t + \frac{1-\alpha l(S)}{\sigma}(d_t - d_t^*) \tag{4.32}$$

where $\sigma_{\alpha,s}^{-1} = \frac{(1-\alpha_S)+\alpha\varpi_S}{\sigma}$.

Finally, combining (4.30) with the domestic Euler equation (4.23) and the conditional expectations of both sides of equation (4.11) gives the Euler equation in terms of domestic output,

$$\begin{aligned} \widehat{y}_t &= E_t\{\widehat{y}_{t+1}\} - \frac{1}{\sigma_{\alpha,s}}(\widehat{r}_t - E_t\{\pi_{H,t+1}\}) + \alpha\Theta_{y^*} E_t\left\{\Delta\widehat{y}_{t+1}^*\right\} \\ &\quad -\Theta_d d_t + \Theta_{d^*} d_t^* \end{aligned}$$

[9] Note that $l(S) = 1$ and $\varpi_S = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$ for $S = \vartheta = 1$, which is the solution for the symmetric case.

where I made use of the substitutions

$$\begin{aligned}
\Theta_{y^*} &\equiv (\omega_S - \frac{\alpha_S}{\alpha}) \\
\Theta_d &\equiv \left[\frac{\alpha\Theta_{y^*}}{\sigma}\sigma_{\alpha,s}\left(1-\alpha l(S)\right) + \alpha l(S) - \sigma\right]\frac{1-\rho_c}{\sigma_{\alpha,s}} \\
\Theta_{d^*} &\equiv \left[\frac{\alpha\Theta_{y^*}}{\sigma}\sigma_{\alpha,s}\left(1-\alpha l(S)\right) + \alpha l(S)\right]\frac{1-\rho_c^*}{\sigma_{\alpha,s}}
\end{aligned}$$

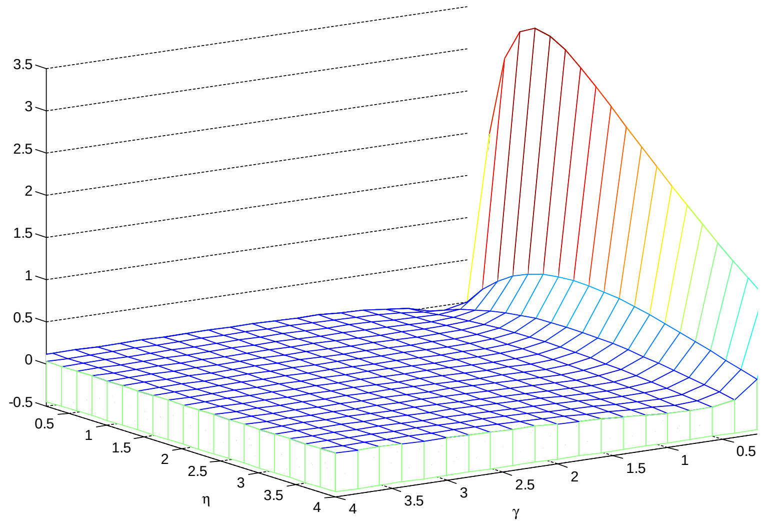
$\sigma_{\alpha,s}^{-1}$ is the intertemporal elasticity of substitution.[10] The inflation rate that matters for the Euler-equation expressed in terms of output in an open economy setting is the domestic inflation rate rather than the CPI rate.

How does migration affect the steady state and thereby the dynamics of the model? In Appendix C.2, I show how emigration affects the unique steady state for output and the terms of trade. The intuition is that, ceteris paribus, an increase in hours worked abroad (i.e., an increase of emigration) increases the marginal disutility from labor, driving up the real wage and thereby reducing S. This deteriorates firms' international competitiveness and reduces output. Therefore, in an analysis of the model's dynamic behavior in the migration case relative to the no-migration benchmark, like the one presented below, output is clearly smaller while the terms of trade improved, that is, S is smaller.

Figure 4.1 sheds light on the magnitude of the impact of the change in the steady state terms of trade due to migration on the demand side of the economy. The figure shows the difference in $\sigma_{\alpha,s}$ when S is set to the arbitrary number of 1 and when it is arbitrarily set to 2 for a wide range of the elasticities η and γ. This change could be due to emigration, which reduces S as mentioned above. The other parameters are chosen as in the calibration presented below for the Polish economy. The figure shows that for a large fraction of the $\eta-\gamma-$space there is no large difference. For the special case when $\eta = \gamma = \sigma = 1$ (for which I will compute the optimal policy below), there is no difference at all because $\varpi_S = 1$ and $\sigma_{\alpha,s} = 1$, so that the steady state does not affect the demand side in this case. Only for values

[10]This equation nests the symmetric benchmark for $S = 1$, where $\Theta_{y^*} \equiv \omega_S - 1$.

Figure 4.1: Change in $\sigma_{\alpha,s}$ when S reduced from 2 to 1 ($\sigma = 1$, $\alpha = 0.4$, $\vartheta = 0.1$)



of γ close to zero is there a large impact on $\sigma_{\alpha,s}$. But in today's globally integrated goods markets, it is unrealistic to assume a price elasticity of almost zero between goods from different countries. I thus regard the figure as an indication that, in this model, with this parameterization for a country like Poland, migration has at most a minor impact on the aggregate demand side.[11]

Below, the aggregate supply side is expressed in terms of inflation and output gap fluctuations x_t, that is, the difference between actual and the natural rate of output, rather than output fluctuations $\widehat{y}_t$. The output gap is derived in detail below and it can be shown that, in turn, the Euler equation can be rewritten as

$$x_t = E_t \left\{x_{t+1}\right\} - \frac{1}{\sigma_{\alpha,s}}(\widehat{r}_t - E_t \left\{\pi_{H,t+1}\right\} - \widehat{r}_t^n) \tag{4.33}$$

[11]Note also, that the graph displays a very large change in the steady state terms of trade, which might be far from realistic. In reality, the actual impact should be even smaller than displayed here.

with the natural rate of interest

$$\widehat{r}_t^n = -\Gamma_a a_t + \Gamma_{\Delta y^*} E\left\{\Delta \widehat{y}_{t+1}^*\right\} - \Gamma_{a^*} a_t^* + \Gamma_d d_t + \Gamma_{d^*} d_t^*$$

and where

$$\begin{aligned}
\Gamma_a &= \left(\frac{1+\varphi\left(\nu-\zeta_A\right)}{\sigma_{\alpha,s}+\varphi\left(\nu-\zeta_Y\right)}\sigma_{\alpha,s}\right)(1-\rho_a) \\
\Gamma_{\Delta y^*} &= \left(\alpha\Theta_{y^*}\sigma_{\alpha,s} - \frac{\sigma-\sigma_{\alpha,s}+\varphi\zeta_{Y^*}}{\sigma_{\alpha,s}+\varphi\left(\nu-\zeta_Y\right)}\sigma_{\alpha,s}\right) \\
\Gamma_{a^*} &= \left(\frac{\varphi\zeta_{A^*}\sigma_{\alpha,s}}{\sigma_{\alpha,s}+\varphi\left(\nu-\zeta_Y\right)}\right)(1-\rho_{a^*}) \\
\Gamma_d &= \left[\sigma + \frac{\sigma_{\alpha,s}}{\sigma}\left(1-\alpha l(S)\right)\frac{\varphi\left(\nu-\zeta_Y\right)}{\sigma_{\alpha,s}+\varphi\left(\nu-\zeta_Y\right)} - 1\right](1-\rho_d) \\
\Gamma_{d^*} &= \left[\left(1-\frac{\sigma_{\alpha,s}}{\sigma}\left(1-\alpha l(S)\right)\right)\left(\frac{\varphi\left(\nu-\zeta_Y\right)}{\sigma_{\alpha,s}+\varphi\left(\nu-\zeta_Y\right)}\right)\right](1-\rho_{d^*})
\end{aligned}$$

The open labor market structure thus affects the real rate of interest through multiple channels. It is affected by demand and productivity shocks and fluctuations in world output.

Net exports are determined by output, consumption and the terms of trade, too. Expressed in terms of domestic output in the steady state, net exports are

$$nx_t \equiv \frac{1}{Y}\left(Y_t - \frac{P_t}{P_{H,t}}C_t\right)$$

Up to a first order approximation, this is

$$\widehat{nx}_t = \widehat{y}_t - (1-nx)\widehat{c}_t - (1-nx)\alpha_S\widehat{s}_t$$

4.5 Aggregate Supply

4.5.1 The Standard Model

As shown by Galí and Monacelli (2005), the *domestic* inflation dynamics in this model are analogous to CPI-inflation dynamics in a closed-economy:

$$\pi_{H,t} = \beta E_t \{\pi_{H,t+1}\} + \lambda \widehat{mc}_t \tag{4.34}$$

where $\lambda \equiv \frac{(1-\beta\theta)(1-\theta)}{\theta}$. Marginal costs, in turn, are proportional to the output gap x_t which is defined as the difference between (log) domestic output y_t and its natural level y_t^n, that is, the equilibrium output in the absence of nominal rigidities. The standard aggregate supply relation, the Phillips-curve, is therefore

$$\pi_{H,t} = \beta E_t \{\pi_{H,t+1}\} + \kappa x_t$$

The slope of the Phillips-curve, κ, is thus the crucial parameter for the effects of output gap fluctuations on inflation. How migration affects this trade-off will be explained in the next Section. To that end, the marginal cost function and the Phillips-curve are derived in detail.

4.5.2 Aggregate Supply and Migration

The channel through which migration affects domestic inflation is its effect on marginal costs. If output expands and migrants are attracted back to the domestic economy, then marginal costs and domestic inflation react less. The formal argument is summarized and proven in the following two Propositions and the intuition explained thereafter.

Proposition 1 *The open labor market structure reduces the effects of output expansions on domestic marginal cost fluctuations $\widehat{mc}_t$ relative to the closed labor market setup for reasonable parameterizations.*

Proof. *From (4.27), (4.21) and (4.10) I get*

$$\begin{aligned} mc_t &= w_t - p_{H,t} - a_t \\ &= (w_t - p_t) + (p_t - p_{H,t}) - a_t \\ &= \sigma c_t + \varphi n_t + \alpha_S s_t - a_t - d_t \end{aligned} \tag{4.35}$$

which, when evaluated in the neighborhood of the steady state, is

$$\begin{aligned}
\widehat{mc}_t &= \sigma\widehat{c}_t + \varphi\widehat{n}_t + \alpha_S\widehat{s}_t - a_t - d_t \\
&= \sigma\widehat{y}_t^* + (1-\alpha_S)\widehat{s}_t + d_t - d_t^* + \varphi\widehat{n}_t + \alpha_S\widehat{s}_t - a_t - d_t \\
&= \sigma\widehat{y}_t^* + \widehat{s}_t + \varphi\left[(\nu - \zeta_Y)\,\widehat{y}_t - (\nu - \zeta_A)\,a_t + \zeta_{Y^*}\widehat{y}_t^* - \zeta_{A^*}a_t^*\right] \\
&\quad - a_t - d_t^* \\
&= (\sigma_{\alpha,s} + \varphi\,(\nu - \zeta_Y))\,\widehat{y}_t - (1 + \varphi\,(\nu - \zeta_A))\,a_t \\
&\quad + (\sigma - \sigma_{\alpha,s} + \varphi\zeta_{Y^*})\widehat{y}_t^* - \varphi\zeta_{A^*}a_t^* \\
&\quad - d_t^* - (1 - \alpha l(S))\,\frac{\sigma_{\alpha,s}}{\sigma}\,(d_t - d_t^*) \\
&= (\sigma_{\alpha,s} + \varphi\,(\nu - \zeta_Y))\,\widehat{y}_t - (1 + \varphi\,(\nu - \zeta_A))\,a_t \\
&\quad + (\sigma - \sigma_{\alpha,s} + \varphi\zeta_{Y^*})\widehat{y}_t^* - \varphi\zeta_{A^*}a_t^* \\
&\quad - (1 - \alpha l(S))\frac{\sigma_{\alpha,s}}{\sigma}d_t + \left((1 - \alpha l(S))\frac{\sigma_{\alpha,s}}{\sigma} - 1\right)d_t^* \qquad (4.36)
\end{aligned}$$

where I inserted (4.31), (4.24), (4.32) and (4.29). In contrast, in the closed labor market setting I have

$$\begin{aligned}
\widehat{mc}_t &= (\sigma_{\alpha,s} + \varphi)\,\widehat{y}_t - (1+\varphi)a_t + (\sigma - \sigma_{\alpha,s})\widehat{y}_t^* \qquad (4.37) \\
&\quad - (1 - \alpha l(S))\frac{\sigma_{\alpha,s}}{\sigma}d_t + \left((1 - \alpha l(S))\frac{\sigma_{\alpha,s}}{\sigma} - 1\right)d_t^*
\end{aligned}$$

Comparing coefficients on output fluctuations $\widehat{y}_t$, one can see that in the migration case, the coefficient is smaller because $\nu - \zeta_Y < 1$ and because, as shown above, $\sigma_{\alpha,s}$ changes little for a reasonable parameter choice in the presence of migration. Therefore, the impact of output expansions on marginal costs in the open labor market setting is smaller than in the case of no migration. ■

The intuition behind this result is as follows: In a scenario WITHOUT migration, given productivity, an increase in output requires an increase in labor input. This incurs an increased disutility from labor because leisure needs to be reduced. Consequently, the real wage and real marginal costs increase, the magnitude of this effect is $\varphi\widehat{y}_t$. Migration reduces this effect because in this case there is a substitution out of labor abroad, rather than out of leisure. Workers skip one job (abroad) for another (at home). Therefore, there is a reduced impact on the disutility of labor when output expands at home. The term $-\varphi\zeta_Y\widehat{y}_t$ takes account of the disutility of labor reducing effect due to return migration, while $\varphi\nu\widehat{y}_t$ takes account of the fact that only a fraction of the disutility of labor argument is affected by domestic labor input.

I now turn to the New-Keynesian Phillips-curve. In order to derive it, I need equations (4.34) and (4.36), and an expression for the output gap x_t. This is derived by setting marginal costs equal to its flexible price value $-\mu$ so that $\widehat{mc}_t = 0$ in (4.36), and solving for output:

$$\begin{aligned}\widehat{y}_t^n \;=\; & \left(\frac{1+\varphi(\nu-\zeta_A)}{\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y)}\right)a_t - \left(\frac{\sigma-\sigma_{\alpha,s}+\varphi\zeta_{Y^*}}{\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y)}\right)\widehat{y}_t^* \\ & + \left(\frac{\varphi\zeta_{A^*}}{\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y)}\right)a_t^* \\ & + \left(\frac{(1-\alpha l(S))\frac{\sigma_{\alpha,s}}{\sigma}}{\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y)}\right)d_t - \left(\frac{(1-\alpha l(S))\frac{\sigma_{\alpha,s}}{\sigma}-1}{\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y)}\right)d_t^* \quad (4.38)\end{aligned}$$

With this, and because

$$\widehat{y}_t = \left(\frac{1}{\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y)}\right)\widehat{mc}_t + \widehat{y}_t^n$$

the relationship between marginal costs and the output gap is approximated by:

$$\widehat{mc}_t = (\sigma_{\alpha,s}+\varphi(\nu-\zeta_Y))\,x_t \quad (4.39)$$

Proposition 2 extends the reasoning of Proposition 1 to the Phillips-curve:

Proposition 2 *The open labor market structure reduces the effect of output gap changes on increases of domestic inflation relative to a closed labor market structure. In other words, the Phillips-curve becomes flatter.*

Proof. *Combining (4.39) with (4.34), gives the open economy New Keynesian Phillips-curve in terms of the output gap,*

$$\pi_{H,t} = \beta E_t \{\pi_{H,t+1}\} + \kappa^{open} x_t \tag{4.40}$$

where

$$\kappa^{open} = \lambda (\sigma_{\alpha,s} + \varphi (\nu - \zeta_Y))$$

is the slope factor of the Phillips-curve in the open labor market setting. In contrast, in the closed labor-market, this same calculation yields

$$\kappa^{closed} = \lambda (\sigma_{\alpha,s} + \varphi)$$

Because $(\nu - \zeta_Y) < 1$ *and because* $\sigma_{\alpha,s}$ *is basically unchanged for reasonable parameterizations, I have*

$$\kappa^{open} < \kappa^{closed}$$

Therefore, the effect of output gap variations on the domestic inflation rate is smaller when the labor market is open, that is, the Phillips-curve becomes flatter. ■

What's the mechanism behind this phenomenon? As pointed out above, when output expands in the domestic economy, workers return from abroad and thereby serve as an extra, "cheap" pool for the additional labor, which is needed for the expansion as an input to production. This pool is "cheap" in the sense that the alternative in the closed labor market setting is a reduction of leisure, while returning emigrants substitute labor at home for labor abroad. To the extent that output expansions at home are fed by this substitution effect, the disutility of labor does not increase and the real wage, marginal costs, prices and inflation increase less as well.

Tables 4.1 and 4.2 shed light on the dimension of this effect for various parameterizations of κ^{open}. The columns in Table 4.1 indicate possible fractions of the labor force that work abroad in the steady state, that is, $\frac{N_M}{N_M+N_H} * 100$. The rows indicate various values for the wage gap between the

Table 4.1: Phillips-curve slope coefficient

	Share of labor force abroad			
ϕ	*5%*	*10%*	*20%*	*30%*
3	0.32	0.29	0.25	0.21
5	0.28	0.24	0.19	0.15
10	0.25	0.19	0.14	0.11
20	0.20	0.15	0.11	0.09

Note: $\frac{\partial N_M}{\partial Y}\frac{Y}{N_M} = 0.1,\ \eta = \gamma = \sigma = 1,\ \alpha = 0.4,$
$\beta = 0.99,\ \theta = 0.75$ *and* $S = 1$
Benchmark without migration: $\kappa^{closed} = 0.34$

home country and abroad ϕ. Results are shown for an elasticity with that the stock of migrants abroad reacts to domestic output changes, $\frac{\partial N_M}{\partial Y}\frac{Y}{N_M}$, equal to 0.1. Further assumptions are as follows: $\eta = \gamma = \sigma = 1$ is the parameterization for which a welfare function is derived analytically below; $\alpha = 0.4$ is the degree of trade openness of Poland, the country for which the model is calibrated below; $\theta = 0.75$ is consistent with an average duration of prices of one year; $\beta = 0.99$ and $S = 1$. ϑ, the initial condition, does not affect the slope of the Phillips-curve for this particular parameter choice because $\sigma_{\alpha,s} = \sigma = 1$. The benchmark κ^{closed} is 0.34.

One can see in the table that the larger the share of migrant labor hours in total hours and the larger the wage differential, the lower is the impact of output gap fluctuations on domestic inflation.[12] For $\phi = 5$ and a fraction of the labor force abroad of 10%, the slope coefficient falls by almost a quarter to 0.24. An output gap of 1% would imply a response of domestic inflation of 0.24% rather than 0.34% in this case.

[12]Increasing the return elasticity $\frac{\partial N^M}{\partial Y}\frac{Y}{N^M}$ further reduces the slope coefficient as well. However, $\nu - \zeta_Y$ quickly becomes negative, which I excluded by assumption in order to prevent the argument in the disutility of labor function to turn negative. Therefore, I do not present results for higher return elasticities.

Table 4.2 shows the same calculation with the only difference that the elasticities of substitution between goods, γ and η, are increased to 2. The benchmark value of κ^{closed} is now 0.30. The reduction of the slope of the Phillips curve is even more severe in this case. The return migration interacts with the degree of substitutability of the demand for goods.

Table 4.2: Phillips-curve slope coefficient with high demand elasticity

	Share of labor force abroad			
ϕ	*5%*	*10%*	*20%*	*30%*
3	0.28	0.25	0.21	0.17
5	0.24	0.20	0.14	0.11
10	0.20	0.15	0.10	0.07
20	0.16	0.11	0.07	0.05

Note: $\frac{\partial N_M}{\partial Y}\frac{Y}{N_M} = 0.1,\ \ \eta = \gamma = 2,\ \sigma = 1,\ \vartheta = 0.1,$
$\alpha = 0.4,\ \beta = 0.99,\ \theta = 0.75$ *and* $S = 1$
Benchmark without migration: $\kappa^{closed} = 0.30$

4.6 Welfare Analysis

In order to derive implications of migration for monetary policy and social welfare, the optimal monetary policy and a utility based welfare function are now derived. This analysis is analytically possible only for the restricted parameterization of $\sigma = \eta = \gamma = 1$.

First, the optimal allocation from the social planner's perspective is derived. This result is used to determine an optimal subsidy that makes the flexible price allocation the optimal one as is a common approach in the literature. The subsidy eliminates the distortion of the monopolistic market structure while taking into account the open economy characteristics.

With the optimality of the flexible price allocation, the only distortion remaining is the stickyness of prices. Consequently, the optimal monetary policy is shown to be the one that replicates this optimal allocation. As it turns out, this implies full stabilization of both the ouput gap and the domestic rate of inflation. Furthermore, the optimal rule that accomplishes this optimum is the same as the one without migration.

Lastly, I derive a welfare function that allows the determination of welfare losses that are incurred by non-optimal monetary policies. These rules might be pursued because of other policy goals that are exogenous to this model. Since the opening of the "labor account" does not change the optimal monetary policy rule, there are no welfare implications of migration under the optimal policy. However, under non-optimal rules, migration matters in that the weight of the output gap falls relative to domestic inflation in the welfare function. This last result corresponds to the finding of Binyamini and Razin (2007).

4.6.1 Optimal Allocation and Policies

The efficient allocation from the social planner's perspective is derived by maximizing the representative household's utility function $U(C_t, N_t)$ under the following constraints:

1. technological constraint $Y_t = A_t N_{H,t}$
2. the relationship $N_{M,t} = N_M(Y_t, ., .)$
3. risk sharing condition (4.24) in combination with (4.31),

   i.e., $C_t = \vartheta Y_t^* S_t^{1-\alpha} e^{(d_t - d_t^*)}$
4. market clearing condition (C.2)

$$\begin{aligned} Y_t &= \left(\frac{P_{H,t}}{P_t}\right)^{-1} C_t \left[(1-\alpha) + \alpha \left(\vartheta e^{d_t - d_t^*}\right)^{-1}\right] \\ &= S^{\alpha} C_t \left[(1-\alpha) + \alpha \left(\vartheta e^{d_t - d_t^*}\right)^{-1}\right] \end{aligned}$$

Note that for the last constraint, the CPI for $\eta = 1$ is $P_t = (P_{H,t})^{1-\alpha} (P_{F,t})^{\alpha}$ implying $\frac{P_t}{P_{H,t}} = S^{\alpha}$.

In Appendix C.3, I show that in the optimal allocation

$$N_t = \left(\frac{1-\alpha}{\nu - \zeta_Y} \right)^{\frac{1}{1+\varphi}}$$

under the assumption that the term $\nu - \zeta_Y$ is constant. This implies that in the optimum, the argument of the disutility of labor function is constant. Note that for N_t to be non-negative, $\nu - \zeta_Y$ needs to be restricted to positive values.

This result will now be used to determine the optimal allocation under flexible prices. Under flexible prices, the equilibrium satisfies

$$1 - \frac{1}{\varepsilon} = MC_t^n.$$

In Appendix C.3, I further show that this can be rewritten as

$$1 - \frac{1}{\varepsilon} = (1-\tau) \left(N_t^n\right)^{\varphi} N_{H,t}^n \left[(1-\alpha) e^{d_t} + \alpha \vartheta^{-1} e^{d_t^*} \right]^{-1}$$

where I introduced the production subsidy τ, which the social planner can use to implement the optimal allocation in the flexible price equilibrium.

Using the optimal argument of the disutility of labor function, gives

$$1 - \frac{1}{\varepsilon} = (1-\tau) \left(\frac{1-\alpha}{\nu - \zeta_Y} \right)^{\frac{\varphi}{1+\varphi}} N_{H,t}^n \left[(1-\alpha) e^{d_t} + \alpha \vartheta^{-1} e^{d_t^*} \right]^{-1}$$

As discussed above, domestic output in the flexible price equilibrium is determined by the exogenous shocks and foreign output. Thereby, the domestic employment level $N_{H,t}^n$ is uniquely pinned down as well (and, because of the constant optimal value of N_t, also $N_{M,t}^n$). The subsidy can therefore be set such that employment $N_{H,t}$ is at its optimum for $d_t = d_t^* = 0$. Therefore, the social planner needs to set τ so that the equation

$$N_{H,t}^{n} = \frac{\left(1-\frac{1}{\varepsilon}\right)\left(\frac{1-\alpha}{\nu-\zeta_Y}\right)^{\frac{-\varphi}{1+\varphi}}\left[(1-\alpha)+\alpha\vartheta^{-1}\right]}{1-\tau}$$

is fulfilled. Thereby, the planner guarantees the efficiency of the flexible price allocation in the absence of shocks.

With the flexible price equilibrium being optimal, the optimal output gap is zero, that is, $x_t = 0$ at all times. Given the Phillips curve, the optimal monetary policy is then one that perfectly stabilizes domestic inflation, that is, $\pi_{H,t} = 0$. The optimal monetary policy is thus the same as in Galí and Monacelli (2005). These authors show that a unique equilibrium of that kind can be achieved through the policy rule

$$r_t = r_t^n + \phi_\pi \pi_{H,t} + \phi_x x_t \tag{4.41}$$

under the condition

$$\kappa(\phi_\pi - 1) + (1-\beta)\phi_x > 0$$

for non-negative values of $\phi_\pi$and ϕ_x as shown by Bullard and Mitra (2002).

The optimal monetary policy rule is thus not affected by the open labor market structure. From this perspective, the social planner does not need to change monetary policy when labor migration is allowed. The only thing that is different is the optimal subsidy τ.

4.6.2 The Welfare Function

From a welfare perspective, how costly is a deviation from the optimal policy just described? One could imagine a scenario in which the social planner has other policy goals that are exogenous from the perspective of this model. This could be an exchange rate peg that is introduced in preparation to the introduction of a foreign currency such as the euro. A welfare function that allows to assess the costs of such a policy would therefore be desirable for a policy maker.

In Appendix C.4, I derive the following welfare function as a second order Taylor approximation of the representative household's utility function around the flexible price equilibrium:

$$W = -\frac{1}{2}(1-\alpha)\sum_{t=0}^{\infty}\beta^t\left\{\left(\frac{\nu}{\nu-\zeta_Y}\frac{\varepsilon}{\lambda}\pi_{H,t}^2 + (1+\varphi)(\nu-\zeta_Y)x_t^2\right)\right\}$$

Taking unconditional expectations on both sides and assuming $\beta \to 1$, the expected welfare loss becomes a function of the volatilities of domestic inflation and the output gap:

$$EW = -\frac{1}{2}(1-\alpha)\left(\frac{\nu}{\nu-\zeta_Y}\frac{\varepsilon}{\lambda}var(\pi_{H,t}) + (1+\varphi)(\nu-\zeta_Y)\,var(x_t)\right)$$

The open labor market terms are ν and ζ_Y. The following consequences for this welfare metric stand out for the open labor market setting compared to a closed labor market environment. Because

1. $\nu - \zeta_Y < 1$, output gap fluctuations reduce welfare by less and
2. $\frac{\nu}{\nu-\zeta_Y} > 1$, inflation fluctuations affect welfare more negatively.

The intuition for the first result derives from the risk aversion with respect to employment fluctuations. A positive output gap implies an increase in domestic employment, which reduces utility. With return migration, the household is able to smooth this effect on disutility through a substitution of a job abroad for a job at home.

The second result states that the negative effect of inflation on welfare is amplified by migration. Inflation reduces welfare because of the inefficiency that results from output dispersion across goods and the corresponding price dispersion across goods due to price stickyness (Woodford, 2003, ch. 6). When workers are allowed to migrate, the link between the output fluctuations and prices becomes weaker: Any given inflation rate is associated with a larger output dispersion. This larger output dispersion decreases welfare at a given inflation rate, the costs of inflation increase.

From this analysis, it follows that when the central bank follows the optimal rule and thereby perfectly stabilizes both domestic inflation and the output gap, there are no welfare implications of migration. In the simulation exercises presented in the next Section, there are thus no welfare consequences in the respective specifications. However, the dynamic behavior of output, employment, etc., are affected by migration and are therefore of interest from a policy perspective.

4.7 Simulation

In order to illustrate the dynamics of the model, I present a simulation exercise for the differential impact of demand and supply shocks in the closed and the open labor market setting. A quite robust result is that output expands more after a positive demand shock in a scenario with migration, compared to the scenario of closed labor markets. Whether or not there is a difference for productivity shocks depends on the parameter choice.

Parameters are chosen to mimic the structure of the Polish economy. Poland has several characteristics that make it a candidate country for which the mechanics underlying this model may apply, in particular after joining the European Union and the opening of the British, Irish and Swedish labor markets for Polish workers. I assume ϕ to be 5, proxying the wage differential between Poland and the EU15. The share of emigrant hours in total hours is assumed to be 15%, a conservative estimate of the large Polish diaspora, while the elasticity by which N_M reacts to changes in domestic output is set to 0.1. This last figure is a guess because of a lack of empirical estimates. The curvature parameter of the disutility of labor function, φ, is assumed to be 3, as in Galí and Monacelli (2005), in order to make results comparable.

Setting α to 0.4 is roughly in line with the country's imports to GDP ratio. The initial condition ϑ is assumed to be 0.1, somewhat below the ratio of Poland's real GDP per capita to the EU15's at the beginning of the transition period in 1989, and is increased to 1 in a robustness check to illustrate the impact of this asymmetry. As above, θ is set to 0.75, which is consistent with an average duration of prices of one year, and $\beta = 0.99$, implying a real rate of interest of about 4% in the steady state.

In the baseline specification for which the optimal monetary policy was derived above, η, γ and σ are all set to 1. In a robustness check, η and γ are increased to 2 to check the role of these elasticities of substitution in the adjustment process. This range of values are in line with Obstfeld and Rogoff's (2005) discussion of the literature on trade elasticities. For trade equations with aggregate data and for calibrated dynamic general equilibrium models, typical estimates for trade elasticities are 1 or even less, while for estimates with disaggregated data, 2 is a rather conservative value. Choosing 1 and 2 can therefore be regarded as a compromise.

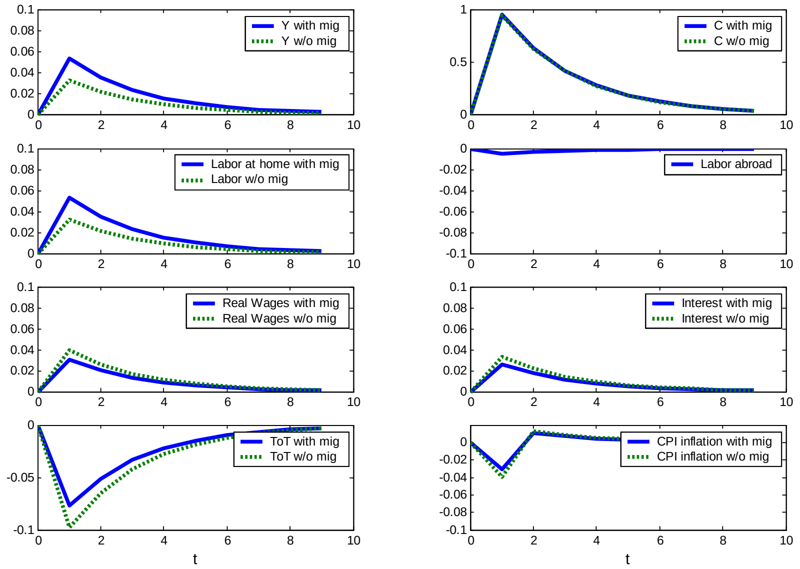
The steady state terms of trade are set to 2 for the closed labor market setting and to 1 for open labor markets. The precise figures are somewhat arbitrary, but without further assumptions, realistic numbers cannot be obtained. However, in the baseline specification with $\eta = \gamma = \sigma = 1$, the steady state is not affected at all. But for $\eta = \gamma = 2$, this is not the case and both the steady state and the dynamics are affected. In order to assess the impact of the change in the steady state on the dynamics, I also present a simulation with an unchanged steady state in a robustness check. As it turns out, the differential dynamics in the open/closed labor market setting are smaller than in the setting with different steady states.

These assumptions imply Phillips-curve slope coefficients κ^{open} of 0.21 and 0.17 for η and γ equal to 1 and 2 respectively, which is 38% and 43% less than the benchmarks without migration κ^{closed} of 0.34 and 0.30 respectively. In all the specifications below, I assume that the central bank follows the rule (4.41), which is the optimal rule for the parameter choice $\eta = \gamma = \sigma = 1$.

4.7.1 Demand Shock

First, I analyze the effects of a domestic demand shock. Figure 4.2 shows the impulse responses of key model variables to a unit demand shock d_t with $\rho_d = 0.66$ in a baseline specification. Output and domestic employment move 63% more when people are allowed to re-migrate after the demand shock, compared with the benchmark in which migration is not allowed. The exact coefficients on impact are 0.053 and 0.033 respectively. Therefore, the differential output effect is remarkably large, even though the elasticity of

Figure 4.2: Demand shock: Baseline ($\eta = \gamma = \sigma = 1$, $\vartheta = 0.1$ *and* $S = 1$ ($S = 2$) *with migration (w/o migration)*)

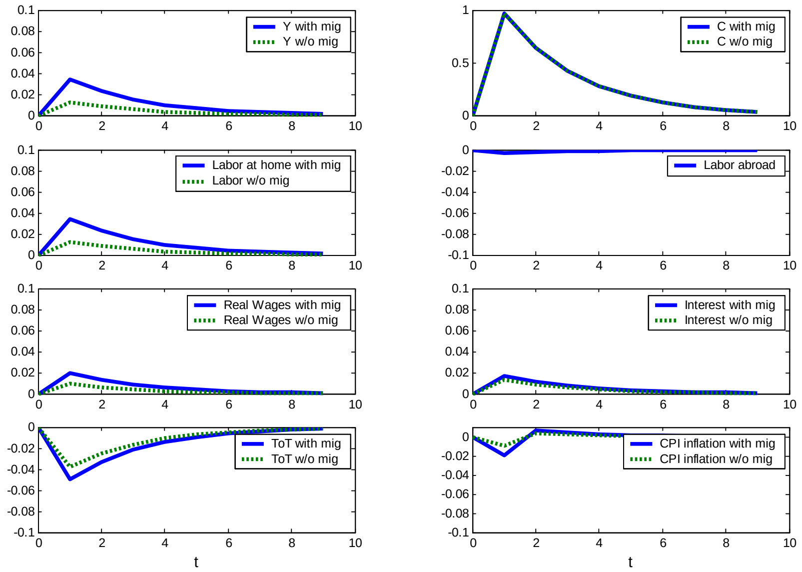


re-migration is assumed to be reasonably low, and consequently only a small fraction of the emigrated labor actually returns.

This exercise thus verifies the theoretical reasoning of Section 4.5 for an empirically plausible parameter choice. The re-migrating labor reduces the pressure on marginal costs, domestic prices and thereby domestic inflation, which ceteris paribus allows a greater output expansion at the zero domestic inflation rate prevailing throughout. This can be seen when comparing equations (4.36) and (4.37) under the assumption that the central bank keeps marginal costs constant: The smaller impact on marginal costs of a given output expansion allows a greater output response after the demand shock.

The demand shock increases relative demand for domestic output, thereby appreciating the terms of trade (s_t falls). This, in turn, increases the real wage (here expressed as the nominal wage relative to the CPI) because the import prices fall in line with net exports (not shown). Both the terms of trade and the real wage improve less when migration is allowed. In this specification and in most others presented below, there is no measurable differential impact on consumption after the demand shock. Consumption is thus mainly driven by the shock itself and little affected by the model inherent dynamics.

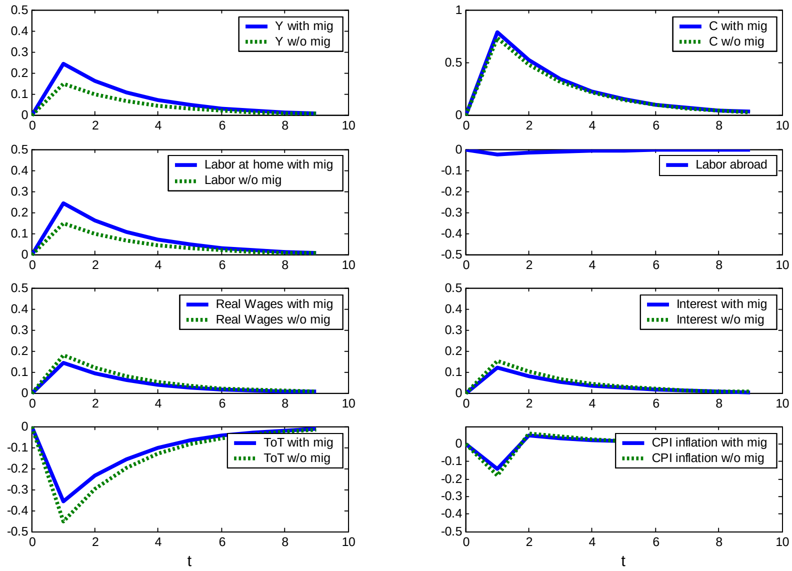
Figure 4.3: Demand shock: High substitution elasticity ($\eta = \gamma = 2$, $\sigma = 1$, $\vartheta = 0.1$ *and* $S = 1$ ($S = 2$) *with migration (w/o migration)*)



There is an important conclusion for monetary policy here. The appreciating currency corresponds to an increase in the interest rate, given that the interest parity condition holds. The differential effect through the open labor market is that the central bank reacts less restrictive after the demand shock when it follows its optimal rule. This is because the inflationary pressure is muted through the returning migrants. One interpretation of this effect is that the central bank supports and amplifies the expansionary effect of the demand shock because migrants allow a less inflationary growth of output.

A first robustness check is presented in Figure 4.3. Here, I increase the elasticities of substitution between domestic and foreign goods and between goods from different countries γ and η to 2. The output expansion is lower in both specifications, but the differential impact in the migration setting is much larger. The output expansion on impact is 173% larger than the benchmark without migration. The appreciation of the terms of trade and the real wage increase is larger when workers re-migrate, while the impact on consumption remains indistinguishable.

Figure 4.4: Demand shock: Same initial condition ($\eta = \gamma = \sigma = 1$, $\vartheta = 1$ *and* $S = 1$ $(S = 2)$ *with migration (w/o migration)*)



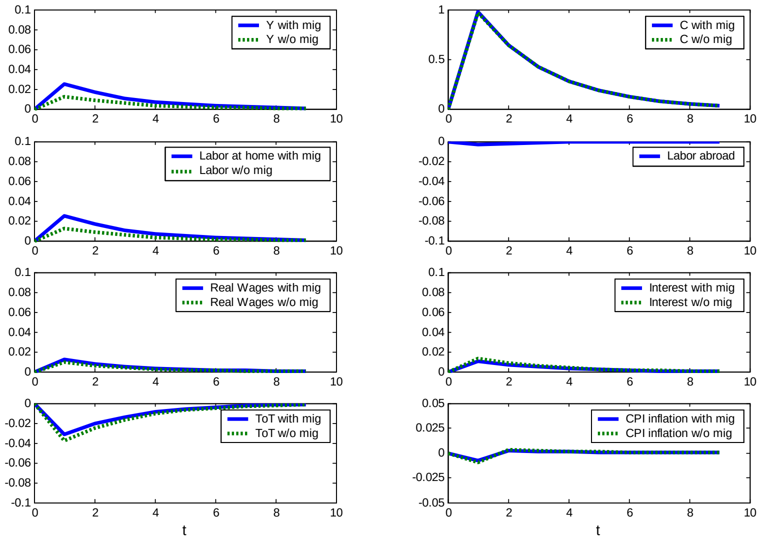
The conclusion for monetary policy is somewhat different here than in the baseline specification. First of all, the central bank follows the same rule as above, but in this case one cannot be sure that this is indeed the optimal rule because this could be verified in the framework above only for the parameterization of $\eta = \gamma = 1$. However, the much larger relative output expansion in the migration case results in a stronger increase in interest rates than in the case without migration. The reason for this result is that here the benign effect of migration on inflation is more than offset by the so much stronger reaction of output. The net effect is that the central bank needs to react more restrictive when migration is allowed. Consequently, the simple conclusion with respect to monetary policy from the baseline specification (i.e., that the central bank can amplify the expansionary demand effect) needs to be qualified within a general equilibrium framework.

The next robustness check (Figure 4.4) highlights the role of the initial condition ϑ for the dynamics. Up to now, the value was set to 0.1, which assumed the country to have been much poorer initially. Here, instead, I assume symmetric initial conditions, that is, $\vartheta = 1$. The most important difference is the size of the fluctuations, which are much larger compared to the specification above (note the change of the scale in this Figure compared to the previous ones). Furthermore, with the open labor market, the output effect is again 63% larger than with a closed labor market. The coefficients are 0.24 in case of migration and 0.15 in the case without migration. A rich country thus benefits more from a demand shock in terms of output and has an even bigger gain in absolute terms from migration than a poor one. This is a surprising result. However, when demand elasticities are higher, this result does not prevail. Gains from migration are higher for a poor country when γ and η are set to 2.[13]

In the last robustness check (Figure 4.5), the elasticities of substitution η and γ are again 2, but now the steady state terms of trade are assumed to be 2 in both specifications. Hence the impulse response functions for the closed labor market are the same here as the one presented in Figure 4.3 while impulse responses for the migration case now uses a different steady state than before. This is supposed to highlight the extent to which the different dynamics are due to the change in the steady state or to the differing labor market structures. Here the difference in the impact on output is smaller, indicating that the reduction of the size of the steady state output and the improvement in the terms of trade due to the out-migration, increases the differential reaction. The underlying mechanism of a benign effect of the returning migrants on output thus proves to be a very robust result.

[13]Graphs for this specification are not shown, but are available from the author upon request.

Figure 4.5: Demand shock: Same steady state ($\eta = \gamma = 2$, $\sigma = 1$, $\vartheta = 0.1$ *and* $S = 2$ *with and w/o migration*)



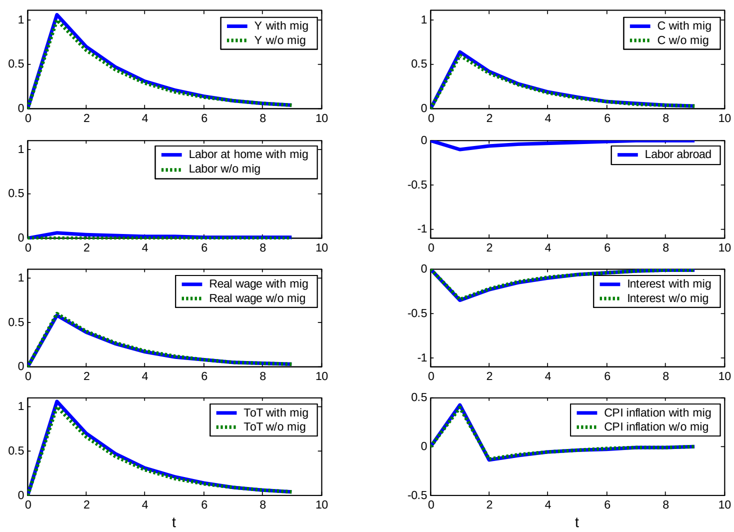
4.7.2 Productivity Shock

I now turn to impulse responses due to a unit productivity shock with $\rho_a = 0.66$. The benchmark parameterization is the same as for the demand shock. Furthermore $\frac{\partial N_{M,t}}{\partial A_t} \frac{A}{N_M}$, and thereby ζ_A, was set to zero. As can be seen from Figure 4.6, the effects on output and the other variables shown are indistinguishable between the two set ups. In both cases, the central bank accomodates the productivity increase by a reduction of the interest rate in order to stabilize marginal costs. Thereby the currency depreciates and output, consumption, the real wage and employment expand.

But why is there no difference? The reason is that two effects offset each other. This can be seen from equation (4.36) when setting all variables except output and productivity to zero. Marginal costs do not change because of the assumed monetary policy rule, therefore, this equation becomes

$$\widehat{mc}_t = 0 = (\sigma_{\alpha,s} + \varphi(\nu - \zeta_Y))\,\widehat{y}_t - (1 + \varphi(\nu - \zeta_A))\,a_t$$

Figure 4.6: Productivity shock: Baseline ($\eta = \gamma = \sigma = 1$, $\vartheta = 0.1$ *and* $S = 1$ $(S = 2)$ *with migration (w/o migration)*)

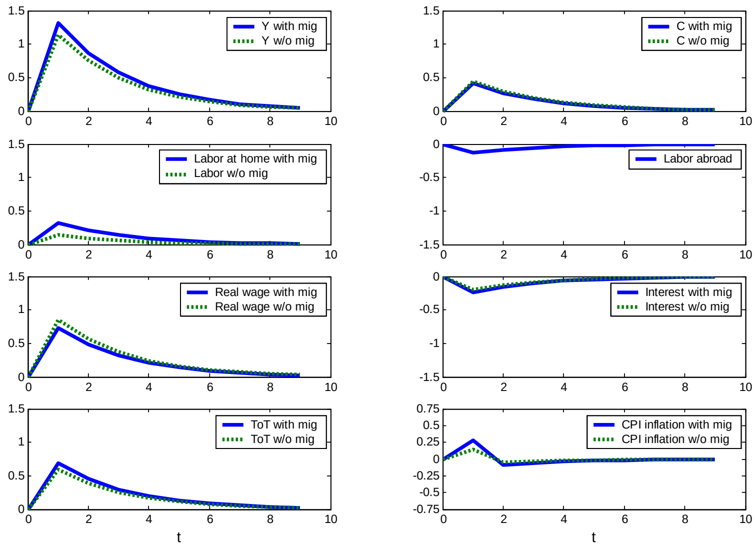


In the open labor market setting both coefficients on output $\widehat{y}_t$ and productivity a_t are reduced: The latter describes the reduced effect on marginal costs after the productivity shock because only a fraction of the labor force is affected. Thereby, the disutility of labor is, ceteris paribus, only partially reduced given output. The marginal rate of substitution between labor and consumption and the real wage are less affected, and there remains less room for an output expansion at constant marginal costs. This would be reinforced if $\frac{\partial N_{M,t}}{\partial A_t}\frac{A}{N_M} > 0$ and $\zeta_A > 0$, that is, if emigration occurred due to the domestic productivity shock. The coefficient on $\widehat{y}_t$, on the other hand, is reduced too. The increased output that is made possible through the reduced interest rate and the depreciating currency has a lower effect on marginal costs in the open labor market structure. Therefore, the output expansion needs to be larger to keep marginal costs constant given productivity.

In summary, the two effects together imply that a lower output expansion is needed to keep marginal costs constant, but since any given output expansion has a lower effect on marginal costs when labor markets are open, a greater output expansion is needed to keep marginal costs constant. With this parameterization, there is obviously no output gain from migration after the productivity shock.

The analysis changes when the elasticities of substitution are increased to 2 (Figure 4.7). The reduced interest rate and the depreciated currency

Figure 4.7: Productivity shock: High substitution elasticity ($\eta = \gamma = 2$, $\sigma = 1$, $\vartheta = 0.1$ *and* $S = 1$ ($S = 2$) *with migration (w/o migration)*)



now have a much greater effect on demand for domestic goods (note the change of the scale in this Figure compared to the previous one). Domestic employment and output expand more than in the case of low elasticities. More remarkably, there is now a difference in the two labor market settings: Output expands by almost 16% more when labor markets are open, while the domestic employment change is 230% higher. This is made possible by a stronger monetary policy response, accompanied by a bigger depreciation of the currency and return migration that dampens the real wage increase. At the same time, the consumption changes are almost the same in both specifications.

The reason for the different outcomes is that the greater response of demand for domestic goods due to the higher demand elasticities makes the increased labor demand large enough to increase the domestic labor input above the steady state level. When labor demand is strong, as it is in this case, the beneficial effect of returning labor is obviously strongest. Therefore, there is room for gains from migration in terms of bigger output expansions when elasticities of substitution between domestic and foreign goods are "high".

Robustness checks with analogous parameterizations as for the demand shocks confirm the results of the specifications above with insignificant differences. Graphs are available from the author upon request.

4.8 Conclusion

This paper presents a New Keynesian business cycle model that allows for labor to be supplied both domestically and abroad. This modification to an otherwise standard set up takes account of the observed labor movements across borders in many countries. Allowing migrants to cross broders in response to asymmetric business cycles has several important implications for the structure of the domestic economy.

First, the Phillips curve becomes flatter. When emigrants return when output expands, firms do not need to compensate workers for foregone leisure as they skip one job (abroad) for another job (at home). As a consequence, there is less pressure on wages, marginal costs and prices.

Second, the optimal monetary policy rule derived is the same as in the case of no migration but the welfare loss implied by deviations from the optimal rule is different. According to the optimal monetary policy rule, that is derived from the perspective of a social planner, both the output gap and domestic inflation need to be fully stabilized. However, according to the welfare function, which is derived as a second order approximation to the representative household's utility function, deviations from this optimal rule are shown to reduce welfare differently when migration is allowed. Domestic inflation volatility is penalized more while output gap volatility is penalized less.

The effect of output gap volatility on welfare is due to the property that workers are able to reduce the adverse effects of output volatility on disutility from labor by adjusting their labor input domestically and abroad. The negative effect of domestic inflation on welfare is explained by the fact that for a given volatility of inflation, there will be a higher inefficient variability of output across goods due to price stickyness when migration is allowed. The reason for this is the weakened link between output variation and inflation because of migration. The benign effect of migration on inflation thus exacerbates the adverse welfare effects of any given volatility of inflation.

Third, domestic demand shocks are shown to have a greater impact on domestic output in the set up with migration. When output expands due to the demand shock and migrants are attracted to the domestic economy, the pressure on marginal costs and inflation is lower. Consequently, output can expand more until inflation increases to the point at which the central bank no longer tolerates it.

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Appendix A

Appendix to Chapter 2

A.1 Equilibrium

The equilibrium is fully described by the following four equations and the real exchange rate:

$$\begin{aligned} 1 &= \frac{\alpha}{\alpha+(1-\alpha)\tau^{1-\eta}}(1+if-ca) \\ &+\frac{1-\alpha^*}{\alpha^*\tau^{1-\eta}+1-\alpha^*}\left[\tau^{\frac{1}{1-\beta}}\left(\frac{\varpi^*}{\varpi}\right)^{\frac{\beta}{\beta-1}}\left(\frac{A_F}{A_H}\right)^{\frac{1}{1-\beta}}-if+ca\right] \end{aligned} \tag{A.1}$$

$$\iota=\left[\frac{A_H}{A_N}\left(\frac{1-\gamma}{\gamma}\left(\alpha+(1-\alpha)\tau^{1-\eta}\right)^{\frac{\theta-1}{1-\eta}}(1+if-ca)\right)^{1-\beta}\right]^{\frac{1}{\beta+(1-\beta)\theta}} \tag{A.2}$$

$$\begin{aligned} \iota^* &= \left[\frac{A_F}{A_N^*}\left(\frac{1-\gamma}{\gamma}\left(\alpha^*+(1-\alpha^*)\tau^{\eta-1}\right)^{\frac{\theta-1}{1-\eta}}\right)^{1-\beta}\right]^{\frac{1}{\beta+(1-\beta)\theta}} \\ &* \left[1+\left(\frac{\varpi^*}{\varpi}\right)^{\frac{\beta}{1-\beta}}\left(\frac{A_F}{A_H}\right)^{\frac{1}{\beta-1}}\tau^{\frac{1}{\beta-1}}(-if+ca)\right]^{\frac{1-\beta}{\beta+(1-\beta)\theta}} \end{aligned} \tag{A.3}$$

$$\frac{\varepsilon\varpi^*}{\varpi} = \left(\frac{L}{L^*}\right)^{1-\beta} \left[\frac{1+\left(\iota^*\frac{A_N^*}{A_F}\right)^{\frac{1}{1-\beta}}}{1+\left(\iota\frac{A_N}{A_H}\right)^{\frac{1}{1-\beta}}}\right]^{1-\beta} \tau\frac{A_F}{A_H} \tag{A.4}$$

$$\begin{aligned} q \;=\; & \left(\frac{\alpha^*\tau^{1-\eta}+(1-\alpha^*)}{\alpha+(1-\alpha)\tau^{1-\eta}}\right)^{\frac{1}{1-\eta}} \\ & * \left(\frac{\gamma+(1-\gamma)\left(\alpha^*+(1-\alpha^*)\tau^{\eta-1}\right)^{\frac{\theta-1}{1-\eta}}\iota^{*1-\theta}}{\gamma+(1-\gamma)\left(\alpha+(1-\alpha)\tau^{1-\eta}\right)^{\frac{\theta-1}{1-\eta}}\iota^{1-\theta}}\right)^{\frac{1}{1-\theta}} \end{aligned} \tag{A.5}$$

where ca and if denote the current account and income balance as a share of tradable output respectively.

A.2 Extensions

Table A.1: No home bias: Changes of REER and terms of trade

		Real depreciation		**TOT depreciation**		**ROW/US quantity**
θ	η	**w/o supply**	**supply**	**w/o supply**	**supply**	**supply**
0.5	2	53	25	8	17	-21
1	2	24	17	8	13	-12
1	3	22	12	5	8	-12
2	2	12	11	8	11	-6
2	3	11	8	5	7	-7

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

Table A.2: Alternative labor share: Changes of REER and terms of trade

		Real Depreciation			**TOT Depreciation**			**ROW/US Quantity**		
θ	η					β				
		0.65	0.75	1	0.65	0.75	1	0.65	0.75	1
0.5	1	34	31	26	24	25	26	-21	-23	-27
1	2	25	24	21	20	21	23	-12	-14	-18
1	3	17	16	13	12	13	14	-12	-14	-18
2	2	18	18	17	18	18	20	-5	-6	-10
2	3	12	12	11	11	11	12	-6	-7	-12
1	1000	6	5	0	0	0	0	-61	-70	-93

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

Table A.3: Alternative labor share: Changes in US and ROW price and quantity of non-tradables relative to tradables

		US						**ROW**					
		Price			**Quantity**			**Price**			**Quantity**		
θ	η							β					
		0.65	0.75	1	0.65	0.75	1	0.65	0.75	1	0.65	0.75	1
0.5	2	-10	-7	0	-18	-20	-23	3	2	0	5	5	6
1	2	-7	-5	0	-12	-14	-19	2	1	0	3	4	5
1	3	-7	-5	0	-12	-14	-19	2	1	0	3	4	5
2	2	-3	-3	0	-6	-8	-12	1	1	0	2	2	4
2	3	-4	-3	0	-7	-9	-15	1	1	0	2	2	4
1	1000	-7	-5	0	-12	-14	-19	2	1	0	3	4	6

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

Table A.4: Other elasticities: Changes of REER and terms of trade

		Real depreciation		**TOT depreciation**		**ROW/US quantity**
θ	η	**w/o supp.**	**supp.**	**w/o supp.**	**supp.**	**supp.**
0.5	0.5	356	743	200	734	-174
0.5	1	111	90	49	79	-31
1	1	65	64	50	64	-14
1	0.5	228	310	200	327	-30
2	0.5	174	171	200	194	1

Note: Changes in percent. θ refers to the elasticity of substitution between tradables and non-tradables, η refers to the elasticity of substitution between domestic and foreign tradables.

Appendix B

Appendix to Chapter 3

B.1 Demand Side

The bilateral real exchange rates in the general case of $\theta \neq 1$ are

$$q_{U,E} = \frac{\left[\alpha\tau_{U,E}^{1-\eta} + (\beta-\alpha) + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{1}{1-\eta}}}{\left[\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{1}{1-\eta}}} * \frac{\left[\gamma + (1-\gamma)\left[\alpha + (\beta-\alpha)\tau_{U,E}^{\eta-1} + (1-\beta)\tau_{E,A}^{1-\eta}\right]^{\frac{\theta-1}{1-\eta}}\iota_E^{1-\theta}\right]^{\frac{1}{1-\theta}}}{\left[\gamma + (1-\gamma)\left[\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{\theta-1}{1-\eta}}\iota_U^{1-\theta}\right]^{\frac{1}{1-\theta}}}$$

and

$$q_{U,A} = \frac{\left[\delta\tau_{U,A}^{1-\eta} + \left(\frac{1-\delta}{2}\right) + \left(\frac{1-\delta}{2}\right)\tau_{U,E}^{1-\eta}\right]^{\frac{1}{1-\eta}}}{\left[\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{1}{1-\eta}}} * \frac{\left[\gamma + (1-\gamma)\left[\delta + \left(\frac{1-\delta}{2}\right)\tau_{U,A}^{\eta-1} + \left(\frac{1-\delta}{2}\right)\tau_{E,A}^{\eta-1}\right]^{\frac{\theta-1}{1-\eta}}\iota_A^{1-\theta}\right]^{\frac{1}{1-\theta}}}{\left[\gamma + (1-\gamma)\left[\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{\theta-1}{1-\eta}}\iota_U^{1-\theta}\right]^{\frac{1}{1-\theta}}}.$$

The demand side is fully described by the following equations. For the United States we have

$$
\begin{aligned}
1 = {} & \alpha\left(\alpha+(\beta-\alpha)\tau_{U,E}^{1-\eta}+(1-\beta)\tau_{U,A}^{1-\eta}\right)^{-1}\left(1+rf^{U}-ca^{U}\right) \\
& +(\beta-\alpha)\left(\alpha\tau_{U,E}^{1-\eta}+(\beta-\alpha)+(1-\beta)\tau_{U,A}^{1-\eta}\right)^{-1} \\
& *\left(\frac{P_E Y_T^E}{P_U Y_T^U}+rf^{E}-ca^{E}\right) \\
& +\frac{1-\delta}{2}\left(\delta\tau_{U,A}^{1-\eta}+\left(\frac{1-\delta}{2}\right)+\left(\frac{1-\delta}{2}\right)\tau_{U,E}^{1-\eta}\right)^{-1} \\
& *\left(\frac{P_A Y_T^A}{P_U Y_T^U}-r\left(f^{U}+f^{E}\right)+ca^{U}+ca^{E}\right)
\end{aligned}
\tag{B.1}
$$

with $f^U = F^U/P_U Y_T^U$, $ca^U = CA^U/P_U Y_T^U$, $f^E = F^E/P_U Y_T^U$ and $ca^E = CA^E/P_U Y_T^U$. For Europe we get

$$
\begin{aligned}
\frac{P_E Y_T^E}{P_U Y_T^U} = {} & \alpha\left[\alpha+(\beta-\alpha)\tau_{U,E}^{\eta-1}+(1-\beta)\tau_{E,A}^{1-\eta}\right]^{-1} \\
& *\left(\frac{P_E Y_T^E}{P_U Y_T^U}+\left(rf^{E}-ca^{E}\right)\right) \\
& +(\beta-\alpha)\left[\alpha\tau_{U,E}^{\eta-1}+(\beta-\alpha)+(1-\beta)\tau_{E,A}^{1-\eta}\right]^{-1} \\
& *\left(1+rf^{U}-ca^{U}\right) \\
& +\frac{1-\delta}{2}\left[\delta\tau_{E,A}^{1-\eta}+\left(\frac{1-\delta}{2}\right)\tau_{U,E}^{\eta-1}+\left(\frac{1-\delta}{2}\right)\right]^{-1} \\
& *\left(\frac{P_A Y_T^A}{P_U Y_T^U}+\left(-r\left(f^{U}+f^{E}\right)+ca^{U}+ca^{E}\right)\right),
\end{aligned}
\tag{B.2}
$$

and for non-tradables

$$\frac{P_N^U Y_N^U}{P_U Y_T^U} = \frac{1-\gamma}{\gamma}\left[\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{1-\theta}{\eta-1}} \iota_U^{1-\theta} * \left(1 + rf^U - ca^U\right), \tag{B.3}$$

$$\frac{P_N^E Y_N^E}{P_E Y_T^E} = \frac{1-\gamma}{\gamma}\left[\alpha + (\beta-\alpha)\tau_{U,E}^{\eta-1} + (1-\beta)\tau_{E,A}^{1-\eta}\right]^{\frac{1-\theta}{\eta-1}} \iota_E^{1-\theta} * \left(1 + \frac{P_U Y_T^U}{P_E Y_T^E}\left(rf^E - ca^E\right)\right) \tag{B.4}$$

and

$$\frac{P_N^A Y_N^A}{P_A Y_T^A} = \frac{1-\gamma}{\gamma}\left(\left[\delta + \left(\frac{1-\delta}{2}\right)\tau_{U,A}^{\eta-1} + \left(\frac{1-\delta}{2}\right)\tau_{E,A}^{\eta-1}\right]^{\frac{-1}{1-\eta}} \iota_A\right)^{1-\theta} * \left(1 + \frac{P_A Y_T^A}{P_U Y_T^U}^{-1}\left[-r\left(f^U + f^E\right) + ca^U + ca^E\right]\right) \tag{B.5}$$

B.2 Equilibrium

The general equilibrium conditions derived from equations (3.1) to (3.5) and (B.1) to (B.5) are as follows:

$$\iota_U = \left(\frac{A_T^U}{A_N^U}\right)^{\frac{1}{\nu+(1-\nu)\theta}} * \left[\frac{1-\gamma}{\gamma}\left[\alpha + (\beta-\alpha)\tau_{U,E}^{1-\eta} + (1-\beta)\tau_{U,A}^{1-\eta}\right]^{\frac{1-\theta}{\eta-1}}\left(1 + rf^U - ca^U\right)\right]^{\varkappa},$$

$$\begin{aligned}
\iota_E &= \left(\frac{A_T^E}{A_N^E}\right)^{\frac{1}{\nu+(1-\nu)\theta}} \\
&* \left[\frac{1-\gamma}{\gamma}\left[\alpha+(\beta-\alpha)\tau_{U,E}^{\eta-1}+(1-\beta)\left(\frac{\tau_{U,A}}{\tau_{U,E}}\right)^{1-\eta}\right]^{\frac{1-\theta}{\eta-1}}\right]^{\varkappa} \\
&* \left[\left(1+\left[\left(\frac{w^E}{w^U}\right)^{-\nu}\tau_{U,E}\frac{A_T^E}{A_T^U}\right]^{\frac{-1}{1-\nu}}\left(rf^E-ca^E\right)\right)\right]^{\varkappa}
\end{aligned}$$

and

$$\begin{aligned}
\iota_A &= \left(\frac{A_T^A}{A_N^A}\right)^{\frac{1}{\nu+(1-\nu)\theta}} \\
&* \left[\frac{1-\gamma}{\gamma}\left[\delta+\left(\frac{1-\delta}{2}\right)\tau_{U,A}^{\eta-1}+\left(\frac{1-\delta}{2}\right)\left(\frac{\tau_{U,A}}{\tau_{U,E}}\right)^{\eta-1}\right]^{\frac{1-\theta}{\eta-1}}\right]^{\varkappa} \\
&* \left[\left(1+\left[\left(\frac{w^A}{w^U}\right)^{-\nu}\tau_{U,A}\frac{A_T^A}{A_T^U}\right]^{\frac{-1}{1-\nu}}\left[-r\left(f^U+f^E\right)+ca^U+ca^E\right]\right)\right]^{\varkappa}
\end{aligned}$$

where $\varkappa \equiv \frac{1-\nu}{\nu+(1-\nu)\theta}$ and which in the case of $\theta = 1$ simplify to

$$\iota_U = \frac{A_T^U}{A_N^U}\left[\frac{1-\gamma}{\gamma}\left(1+rf^U-ca^U\right)\right]^{1-\nu},$$

$$\iota_E = \frac{A_T^E}{A_N^E}\left[\frac{1-\gamma}{\gamma}\left(1+\left[\left(\frac{w^E}{w^U}\right)^{-\nu}\tau_{U,E}\frac{A_T^E}{A_T^U}\right]^{\frac{-1}{1-\nu}}\left(rf^E-ca^E\right)\right)\right]^{1-\nu}$$

and

$$\begin{aligned}
\iota_A &= \frac{A_T^A}{A_N^A} \\
&* \left[\frac{1-\gamma}{\gamma}\left(1+\left[\left(\frac{w^A}{w^U}\right)^{-\nu}\tau_{U,A}\frac{A_T^A}{A_T^U}\right]^{\frac{-1}{1-\nu}}\left[-r\left(f^U+f^E\right)+ca^U+ca^E\right]\right)\right]^{1-\nu}
\end{aligned}$$

Furthermore, we have

$$\begin{aligned}
1 &= \alpha\left(\alpha+(\beta-\alpha)\tau_{U,E}^{1-\eta}+(1-\beta)\tau_{U,A}^{1-\eta}\right)^{-1}\left(1+rf^U-ca^U\right) \\
&+(\beta-\alpha)\left(\alpha\tau_{U,E}^{1-\eta}+(\beta-\alpha)+(1-\beta)\tau_{U,A}^{1-\eta}\right)^{-1} \\
&*\left(\left[\left(\frac{w^E}{w^U}\right)^{-\nu}\tau_{U,E}\frac{A_T^E}{A_T^U}\right]^{\frac{1}{1-\nu}}+rf^E-ca^E\right) \\
&+\frac{1-\delta}{2}\left(\delta\tau_{U,A}^{1-\eta}+\left(\frac{1-\delta}{2}\right)+\left(\frac{1-\delta}{2}\right)\tau_{U,E}^{1-\eta}\right)^{-1} \\
&*\left(\left[\left(\frac{w^A}{w^U}\right)^{-\nu}\tau_{U,A}\frac{A_T^A}{A_T^U}\right]^{\frac{1}{1-\nu}}-r\left(f^U+f^E\right)+ca^U+ca^E\right)
\end{aligned}$$

and

$$\begin{aligned}
&\left[\left(\frac{w^E}{w^U}\right)^{\nu}\left(\tau_{U,E}\frac{A_T^E}{A_T^U}\right)^{-1}\right]^{\frac{1}{\nu-1}} \\
= \; &\alpha\left[\alpha+(\beta-\alpha)\tau_{U,E}^{\eta-1}+(1-\beta)\left(\frac{\tau_{U,A}}{\tau_{U,E}}\right)^{1-\eta}\right]^{-1} \\
&*\left(\left[\left(\frac{w^E}{w^U}\right)^{\nu}\left(\tau_{U,E}\frac{A_T^E}{A_T^U}\right)^{-1}\right]^{\frac{1}{\nu-1}}+\left(rf^E-ca^E\right)\right) \\
&+(\beta-\alpha)\left[\alpha\tau_{U,E}^{\eta-1}+(\beta-\alpha)+(1-\beta)\left(\frac{\tau_{U,A}}{\tau_{U,E}}\right)^{1-\eta}\right]^{-1}\left(1+rf^U-ca^U\right) \\
&+\frac{1-\delta}{2}\left[\delta\left(\frac{\tau_{U,A}}{\tau_{U,E}}\right)^{1-\eta}+\left(\frac{1-\delta}{2}\right)\tau_{U,E}^{\eta-1}+\left(\frac{1-\delta}{2}\right)\right]^{-1} \\
&*\left(\left[\left(\frac{\omega^A}{\omega^U}\right)^{-\nu}\tau_{U,A}\frac{A_T^A}{A_T^U}\right]^{\frac{1}{1-\nu}}-r\left(f^U+f^E\right)+ca^U+ca^E\right)
\end{aligned}$$

B.3 Simulations

Table B.1: Current account rebalancing in the short run

		Global Rebalancing			Global Rebalancing (ca's halved)			Bretton-Woods-II			BW-II (ca's halved)	
		$\nu = 0$	$\nu = 0.7$	$\nu = 1$	$\nu = 0$	$\nu = 0.7$	$\nu = 1$	$\nu = 0$	$\nu = 0.7$	$\nu = 1$	$\nu = 0$	$\nu = 0.7$
REER	U	38.1	27.5	23.0	19.5	13.8	11.4	23.7	20.0	18.6	13.3	10.9
	E	-5.9	-5.3	-5.0	-2.7	-2.5	-2.4	-71.0	-59.9	-55.9	-39.9	-32.8
	A	-24.1	-16.7	-13.5	-12.7	-8.5	-6.7	35.5	29.9	28.0	20.0	16.4
bilateral RER	U-E	33.0	24.6	21.0	16.6	12.2	10.4	71.0	59.9	55.9	39.9	32.8
	U-A	40.6	29.0	24.0	21.0	14.6	11.9	0.0	0.0	0.0	0.0	0.0
	E-A	7.6	4.4	3.0	4.3	2.3	1.5	-71.0	-59.9	-55.9	-39.9	-32.8
Terms of Trade	U-E	16.1	21.1	23.3	8.3	10.6	11.5	35.9	52.1	62.6	19.7	28.2
	U-A	16.6	23.9	27.1	8.5	12.0	13.5	7.2	3.2	-0.7	3.5	1.4
	E-A	0.4	2.8	3.8	0.2	1.4	1.9	-28.6	-48.9	-63.3	-16.2	-26.8
Rel. tradable output	U-E	0.0	-13.1	-18.6	0.0	-6.5	-9.2	0.0	-31.8	-50.3	0.0	-17.5
	U-A	0.0	-18.3	-26.3	0.0	-9.2	-13.1	0.0	6.3	13.0	0.0	3.1
	E-A	0.0	-5.3	-7.6	0.0	-2.8	-3.9	0.0	38.1	63.2	0.0	20.6
Rel. price of non-tradables	U	-18.5	-5.6	0.0	-8.8	-2.6	0.0	-18.5	-5.6	0.0	-8.8	-2.6
	E	6.2	1.8	0.0	3.4	0.9	0.0	33.2	12.1	0.0	20.7	7.2
	A	16.1	4.9	0.0	9.0	2.6	0.0	-27.6	-10.1	0.0	-13.3	-4.8
Rel. non-tradable output	U	0.0	-13.0	-18.5	0.0	-6.2	-8.8	0.0	-13.0	-18.5	0.0	-6.2
	E	0.0	4.3	6.1	0.0	2.3	3.1	0.0	28.3	46.4	0.0	16.8
	A	0.0	11.4	16.4	0.0	6.1	8.6	0.0	-23.5	-39.8	0.0	-11.2

Note: In the Bretton-Woods-II scenario the US current account is set to zero in the second period while the European economies absorb the entire Asian surplus. The European deficits in the three specifications are 37.7%, 42.6% and 47.8% of US tradable output respectively. Under Bretton-Woods-II and a reduction of the US deficit to one half of the original deficit Europe's deficit increases to 16.3% and 18.5%.

Table B.2: Current account rebalancing in the medium run

		Global Rebalancing			Bretton-Woods-II		
		$\nu = 0$	$\nu = 0.7$	$\nu = 0.7^*$	$\nu = 0$	$\nu = 0.7$	$\nu = 0.7^*$
REER	U	16.9	12.9	12.3	10.5	9.2	9.3
	E	-2.2	-2.0	-3.2	-31.6	-27.6	-27.7
	A	-11.0	-8.1	-6.9	15.8	13.8	13.9
bilateral RER	U-E	14.3	11.2	11.6	31.5	27.6	27.8
	U-A	18.2	13.7	12.7	0.0	0.0	0.0
	E-A	3.8	2.5	1.1	-31.6	-27.6	-27.8
Terms of Trade	U-E	7.1	8.5	8.9	16.0	21.1	21.3
	U-A	7.4	9.6	8.2	3.2	1.9	1.1
	E-A	0.3	1.1	-0.7	-12.8	-19.1	-20.2
Rel. tradable output	U-E	0.0	-8.4	-11.0	0.0	-20.7	-23.3
	U-A	0.0	-12.2	-5.1	0.0	3.9	9.7
	E-A	0.0	-3.8	5.9	0.0	24.6	33.1
Rel. price of non-tradables	U	-8.2	-3.7	-3.7	-8.2	-3.7	-3.8
	E	2.5	1.1	1.0	14.8	7.9	7.8
	A	7.4	3.3	3.4	-12.2	-6.3	-5.4
Rel. non-tradable output	U	0.0	-8.5	-8.6	0.0	-8.7	-8.8
	E	0.0	2.6	2.4	0.0	18.3	18.2
	A	0.0	7.8	8.0	0.0	-14.7	-12.5

Note: The European current account deficits in the three Bretton-Woods-II scenarios are 35.5%, 39.1% and 38.2%

* *Simulations with changing relative populations.*

Appendix C

Appendix to Chapter 4

C.1 Goods Market Equilibrium

The domestic demand was derived above and given in equation (4.7):

$$C_{H,t}(j) = (1-\alpha)\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon}\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{C.1}$$

For the derivation of foreign demand, a demand function for domestic good j analogous to equation (4.8) needs to be derived. Because of the LOOP, I have

$$P_{H,t}(j) = \epsilon_{i,t} P^i_{H,t}(j)$$

where $P^i_{H,t}(j)$ is the price of the domestically produced good j expressed in terms of country i's currency units. Furthermore, when defining $P^i_{H,t} = \left(\int_0^1 P^i_{H,t}(j)^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}$ as the index of domestically produced goods in terms of country i's currency units, one can easily check that

$$P_{H,t} = \epsilon_{i,t} P^i_{H,t}$$

Country i's demand for good i, $C^i_{H,t}(j)$, is then:

$$C^i_{H,t}(j) = \alpha\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon}\left(\frac{P_{H,t}}{\epsilon_{i,t} P^i_{F,t}}\right)^{-\gamma}\left(\frac{P^i_{F,t}}{P^i_t}\right)^{-\eta} C^i_t$$

with P_t^i and C_t^i defined as country i's consumer price and consumption indexes, the former expressed in its own currency. Integrating this over all countries, gives total foreign demand:

$$\int_0^1 C_{H,t}^i(j)di = \alpha \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon} \int_0^1 \left(\frac{P_{H,t}}{\epsilon_{i,t}P_{F,t}^i}\right)^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} C_t^i di$$

Total demand is therefore

$$\begin{aligned} Y_t(j) &= C_{H,t}(j) + \int_0^1 C_{H,t}^i(j)di \\ &= (1-\alpha)\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon}\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \\ &\quad +\alpha\left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon} \int_0^1 \left(\frac{P_{H,t}}{\epsilon_{i,t}P_{F,t}^i}\right)^{-\gamma}\left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} C_t^i di \end{aligned}$$

Plugging this into the aggregate output relation, making use of the international risk sharing condition (4.20) and the definition of $RER_{i,t}$, gives

$$\begin{aligned} Y_t &\equiv \left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}} \\ &= (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha \int_0^1 \left(\frac{P_{H,t}}{\epsilon_{i,t}P_{F,t}^i}\right)^{-\gamma}\left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} C_t^i di \\ &= \left(\frac{P_{H,t}}{P_t}\right)^{-\eta}\left[(1-\alpha)C_t + \alpha\int_0^1 \left(\frac{\epsilon_{i,t}P_{F,t}^i}{P_{H,t}}\right)^{\gamma-\eta} RER_{i,t}^{\eta} C_t^i di\right] \\ &= \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \\ &\quad * \left[1-\alpha+\alpha\vartheta^{-1}\left(e^{d_t-d_t^*}\right)^{-\frac{1}{\sigma}} \int_0^1 \left(\frac{\epsilon_{i,t}P_{F,t}^i}{P_{H,t}}\right)^{\gamma-\eta} RER_{i,t}^{\eta-\frac{1}{\sigma}} di\right] \end{aligned}$$

$$\begin{aligned} Y_t &= \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \\ &* \left[1-\alpha+\alpha\vartheta^{-1}\left(e^{d_t-d_t^*}\right)^{-\frac{1}{\sigma}}\int_0^1 \left(S_t^i S_{i,t}\right)^{\gamma-\eta} RER_{i,t}^{\eta-\frac{1}{\sigma}}di\right] \end{aligned} \tag{C.2}$$

making use of the fact that $\frac{\epsilon_{i,t}P_{F,t}^i}{P_{H,t}} = S_t^i S_{i,t}$ with S_t^i defined as country i's effective terms of trade. Loglinearizing, assuming that $S^i = S^* = 1$, $\int_0^1 \widehat{s}_t^i di = 0$, $S_i = S$ and $RER_i = REER$ in the steady state gives

$$\begin{aligned} Y_t - Y &= -\eta\left(\frac{P_H}{P}\right)^{-\eta-1} C\left[...\right]\left(\frac{1}{P}dP_H - \frac{P_H}{P^2}dP\right) + \left(\frac{P_H}{P}\right)^{-\eta}\left[...\right]dC_t \\ &-\frac{1}{\sigma}(e^0)^{-\frac{1}{\sigma}-1}\left(\frac{P_H}{P}\right)^{-\eta} C\alpha\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}(d_t-d_t^*) \\ &+(\gamma-\eta)\left(\frac{P_H}{P}\right)^{-\eta} C\alpha\vartheta^{-1}S^{\gamma-\eta-1}REER^{\eta-\frac{1}{\sigma}}\int_0^1 dS_{i,t}di \\ &+\left(\eta-\frac{1}{\sigma}\right)\left(\frac{P_H}{P}\right)^{-\eta} C\alpha\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}-1}\int_0^1 dRER_{i,t}di \end{aligned}$$

$$\begin{aligned} \frac{Y_t - Y}{Y} &= -\eta\left(\widehat{p}_{H,t} - \widehat{p}_t\right) + \widehat{c}_t \\ &- \frac{\frac{\alpha}{\sigma}\left(\frac{P_H}{P}\right)^{-\eta} C\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}}{\left(\frac{P_H}{P}\right)^{-\eta} C\left[(1-\alpha)+\alpha\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}\right]}(d_t-d_t^*) \\ &+ \frac{\alpha(\gamma-\eta)\left(\frac{P_H}{P}\right)^{-\eta} C\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}}{\left(\frac{P_H}{P}\right)^{-\eta} C\left[(1-\alpha)+\alpha\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}\right]}\int_0^1 \widehat{s}_{i,t}di \\ &+ \frac{\alpha\left(\eta-\frac{1}{\sigma}\right)\left(\frac{P_H}{P}\right)^{-\eta} C\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}}{\left(\frac{P_H}{P}\right)^{-\eta} C\left[(1-\alpha)+\alpha\vartheta^{-1}S^{\gamma-\eta}REER^{\eta-\frac{1}{\sigma}}\right]}\int_0^1 \widehat{rer}_{i,t}di \end{aligned}$$

$$\begin{aligned}
\widehat{y}_t &= \alpha_s \eta \widehat{s}_t + \widehat{c}_t \\
&- \frac{\alpha}{\sigma}\left[(1-\alpha)\vartheta S^{-\gamma+\eta} REER^{-\eta+\frac{1}{\sigma}} + \alpha\right]^{-1}(d_t - d_t^*) \\
&+ \alpha(\gamma-\eta)\left[(1-\alpha)\vartheta S^{-\gamma+\eta} REER^{-\eta+\frac{1}{\sigma}} + \alpha\right]^{-1}\widehat{s}_t \\
&+ \alpha\left(\eta - \frac{1}{\sigma}\right)\left[(1-\alpha)\vartheta S^{-\gamma+\eta} REER^{-\eta+\frac{1}{\sigma}} + \alpha\right]^{-1}\widehat{reer}_t
\end{aligned}$$

$$\begin{aligned}
\widehat{y}_t &= \widehat{c}_t + \frac{\alpha}{\sigma}\left[\eta\sigma k(S) + \sigma(\gamma-\eta)l(S) + (1-\alpha_S)(\sigma\eta - 1)l(S)\right]\widehat{s}_t \\
&- \frac{\alpha}{\sigma} l(S)\left[d_t - d_t^*\right] \\
\widehat{y}_t &= \widehat{c}_t + \frac{\alpha}{\sigma}\left[(\sigma\gamma + (1-\alpha_S)(\sigma\eta-1))\, l(S) + \sigma\eta(k(S) - l(S))\right]\widehat{s}_t \\
&- \frac{\alpha}{\sigma} l(S)\left[d_t - d_t^*\right] \\
\widehat{y}_t &= \widehat{c}_t + \frac{\alpha\varpi_S}{\sigma}\widehat{s}_t - \frac{\alpha}{\sigma} l(S)\left[d_t - d_t^*\right]
\end{aligned}$$

with the substitutions

$$\begin{aligned}
k(S) &\equiv \left[(1-\alpha)S^{\eta-1} + \alpha\right]^{-1} \\
l(S) &\equiv \left[(1-\alpha)\vartheta S^{\eta-\gamma} reer(S)^{\frac{1}{\sigma}-\eta} + \alpha\right]^{-1} \\
reer(S) &\equiv REER \\
\varpi_S &\equiv \left[\sigma\gamma + (1-\alpha_S)(\sigma\eta - 1)\right] l(S) + \sigma\eta\left[k(S) - l(S)\right]
\end{aligned}$$

C.2 Steady State

In the steady state, output and the terms of trade are uniquely pinned down by two equations with values determined by the relative labor market conditions facing the representative worker.

From equation (C.2), I derive the goods market clearing condition in the steady state,

$$Y = h(S)^{\eta} C\left[(1-\alpha) + \alpha\vartheta^{-1} S^{\gamma-\eta} reer(S)^{\eta-\frac{1}{\sigma}}\right]$$

making use of the risk sharing condition (4.37), the fact that $S^i = S^* = 1$,

$S_i = S$ and $RER_i = REER$ $\forall i$ in the steady state and the substitutions

$$\frac{P}{P_H} = \left[(1-\alpha) + \alpha S^{1-\eta}\right]^{\frac{1}{1-\eta}} \equiv h(S)$$

and $REER = \frac{S}{h(S)} \equiv reer(S)$. Note that $h(S) > 0$ and $reer(S) > 0$, $h'(S) > 0$ and $reer'(S) > 0$ and $h(1) = reer(1) = 1$.

Furthermore, in the steady state, the risk sharing condition, taking account of international goods market clearing, $C^* = Y^*$, is

$$C = \vartheta Y^* reer(S)^{\frac{1}{\sigma}}$$

Combining this with the goods market clearing condition gives

$$\begin{aligned} Y &= h(S)^{\eta} \vartheta Y^* reer(S)^{\frac{1}{\sigma}} \left[(1-\alpha) + \alpha \vartheta^{-1} S^{\gamma-\eta} reer(S)^{\eta - \frac{1}{\sigma}}\right] \\ &= Y^* \left[(1-\alpha)\vartheta h(S)^{\eta} reer(S)^{\frac{1}{\sigma}} + \alpha S^{\gamma-\eta} h(S)^{\eta} reer(S)^{\frac{1}{\sigma}} reer(S)^{\eta - \frac{1}{\sigma}}\right] \\ &= Y^* \left[(1-\alpha)\vartheta S^{\eta} reer(S)^{\frac{1}{\sigma}-\eta} + \alpha S^{\gamma-\eta} h(S)^{\eta} reer(S)^{\eta}\right] \\ &= Y^* \left[(1-\alpha)\vartheta S^{\eta} reer(S)^{\frac{1}{\sigma}-\eta} + \alpha S^{\gamma}\right] \\ &\equiv Y^* v(S) \end{aligned} \tag{C.3}$$

with $v(S) > 0$ and $v'(S) > 0$. The intuition behind this equation is the following: In the steady state, a more depreciated currency results in a greater demand for domestic goods. Note that $v(1) < 1$, implying $Y < Y^*$ even if $S = 1$ when $\vartheta < 1$. This means that for a country that was initially poorer than the rest of the world, output remains smaller in the steady state because consumption and thereby domestic demand remains suppressed. Moreover, output is uniquely determined when the steady state terms of trade are known. This means that up to some upper limit, values of $S > 1$ are possible, which would be in line with typical observations of developing countries' terms of trade.

For the second equation to determine the unique steady states of output and the terms of trade, I rewrite the domestic labor market clearing condition:

$$\begin{aligned} C^{\sigma} N^{\varphi} &= \frac{W}{P} \\ &= A \frac{W}{P_H A} \frac{P_H}{P} \\ &= A \frac{1}{h(S)} MC \end{aligned}$$

In the steady state, I have $MC = 1 - \frac{1}{\varepsilon}$. Therefore, and because of the risk sharing condition, I get

$$\begin{aligned} (\vartheta Y^*)^{\sigma} \, reer(S) \left(\frac{Y}{A} + \phi N^M \right)^{\varphi} &= A \frac{1}{h(S)} \left(1 - \frac{1}{\varepsilon} \right) \\ Y &= A \left[\left(\frac{A \frac{1}{h(S)} \left(1 - \frac{1}{\varepsilon}\right)}{(\vartheta Y^*)^{\sigma} \, reer(S)} \right)^{\frac{1}{\varphi}} - \phi N^M \right] \\ Y &= A \left[\left(\frac{A \left(1 - \frac{1}{\varepsilon}\right)}{(\vartheta Y^*)^{\sigma} \, S} \right)^{\frac{1}{\varphi}} - \phi N^M \right] \\ Y &= k(S) \end{aligned} \quad \text{(C.4)}$$

with $k'(S) < 0$. Output is thus negatively related to the terms of trade. The intuition behind this relationship is that an increase in S increases consumption through the risk sharing condition, thereby reducing the incentive to work. Labor input and output fall.

Jointly with (C.3), I have a system of two equations in the two unknowns Y and S, given parameters, N_M and productivity A. Because in (C.3) Y is strictly increasing while in (C.4) Y is strictly decreasing in S, there is a unique solution for Y and S. In the fully symmetric, no-migration benchmark model, this unique solution is determined by $S = 1$ and $Y = Y^*$ (Galí and Monacelli, 2005). The original asymmetry ($\vartheta < 1$) tends to reduce output in the first equation, while increasing it in the second. These shifts drive up the terms of trade in the steady state above one. The effect of emigration, that is, an increase in N_M, is to lower $k(S)$ and shift (C.4) down, that is, reducing Y and, in conjunction with equation (C.3), reduce S. Consequently, the model is flexible enough to be calibrated such that output is below the world average while the terms of trade can be allowed to be above and below 1 in the steady state.

C.3 Optimal Allocation

Here, I derive the optimal allocation and the flexible price equilibrium presented in Section 4.6.1. To that end, the third and the fourth constraints are combined. I rewrite the fourth constraint

$$Y_t = S^{\alpha} C_t \left[(1-\alpha) + \alpha\vartheta^{-1}\left(e^{d_t - d_t^*}\right)^{-1}\right]$$

$$\Leftrightarrow S_t = Y_t^{\frac{1}{\alpha}} C_t^{\frac{-1}{\alpha}} \left[(1-\alpha) + \alpha\vartheta^{-1}\left(e^{d_t - d_t^*}\right)^{-1}\right]^{\frac{-1}{\alpha}}$$

and plug it into the third:

$$\begin{aligned} C_t &= \vartheta Y_t^* \left(Y_t^{\frac{1-\alpha}{\alpha}} C_t^{\frac{-1+\alpha}{\alpha}} \left[(1-\alpha) + \alpha\vartheta^{-1}\left(e^{d_t - d_t^*}\right)^{-1}\right]^{\frac{-1+\alpha}{\alpha}} \right) e^{(d_t - d_t^*)} \\ C_t^{1+\frac{1-\alpha}{\alpha}} &= \vartheta Y_t^* Y_t^{\frac{1-\alpha}{\alpha}} \left[(1-\alpha) + \alpha\vartheta^{-1}\left(e^{d_t - d_t^*}\right)^{-1}\right]^{\frac{-1+\alpha}{\alpha}} e^{(d_t - d_t^*)} \\ C_t &= \left(\vartheta Y_t^*\right)^{\alpha} Y_t^{1-\alpha} \left[(1-\alpha) + \alpha\vartheta^{-1}\left(e^{d_t - d_t^*}\right)^{-1}\right]^{-1+\alpha} \left(e^{(d_t - d_t^*)}\right)^{\alpha} \quad \text{(C.5)} \end{aligned}$$

Next, I replace the arguments in the period utility function,

$$\begin{aligned} U(C_t, N_t) &= e^{d_t} \log C_t - \frac{\left(N_{H,t} + \phi N_{M,t}\right)^{1+\varphi}}{1+\varphi} \\ U(Y_t, Y_t^*) &= e^{d_t} \log \left\{ \left(\vartheta Y_t^*\right)^{\alpha} Y_t^{1-\alpha} \left[(1-\alpha) + \alpha\vartheta^{-1}\left(e^{d_t - d_t^*}\right)^{-1}\right]^{-1+\alpha} \left(e^{(d_t - d_t^*)}\right)^{\alpha} \right\} \\ &\quad - \frac{\left(\frac{Y_t}{A_t} + \phi N_M(Y_t, Y_t^*, A_t, A_t^*)\right)^{1+\varphi}}{1+\varphi} \end{aligned}$$

and optimize that equation:

$$
\begin{aligned}
\frac{U_N}{U_C} &= \frac{(1-\alpha)\left(\vartheta Y_t^*\right)^\alpha Y_t^{-\alpha}\left[(1-\alpha)+\alpha\vartheta^{-1}\left(e^{d_t-d_t^*}\right)^{-1}\right]^{-1+\alpha}\left(e^{(d_t-d_t^*)}\right)^\alpha}{\frac{1}{A_t}+\phi\frac{\partial N_{M,t}}{\partial Y_t}} \\
N_t^\varphi C_t &= \frac{(1-\alpha)\left(\vartheta Y_t^*\right)^\alpha Y_t^{1-\alpha}\left[(1-\alpha)+\alpha\vartheta^{-1}\left(e^{d_t-d_t^*}\right)^{-1}\right]^{-1+\alpha}\left(e^{(d_t-d_t^*)}\right)^\alpha}{\left(\frac{N_{H,t}}{Y_t}+\phi\frac{\partial N_{M,t}}{\partial Y_t}\right)Y_t} \\
N_t^\varphi C_t &= \frac{(1-\alpha)C_t}{N_{H,t}+\phi\frac{\partial N_{M,t}}{\partial Y_t}Y_t} \\
N_t^{1+\varphi} &= \frac{1-\alpha}{\frac{N_{H,t}}{N_t}+\frac{\partial N_{M,t}}{\partial Y_t}\frac{Y_t}{N_{M,t}}\frac{\phi N_{M,t}}{N_t}} \\
N_t &= \left(\frac{1-\alpha}{\nu_t-\zeta_{Y,t}}\right)^{\frac{1}{1+\varphi}}
\end{aligned}
$$

This is the optimal allocation from the planner's perspective. The term $(\nu_t-\zeta_{Y,t})$ is proportional to the change in the argument in the disutility of labor function. Assuming this to be constant, that is, $\nu_t-\zeta_{Y,t}=\nu-\zeta_Y$, there is now a unique and constant optimal value of N_t, rather than a constant optimal N_H, as in Galí and Monacelli (2005).

The flexible price equilibrium satisfies

$$
\begin{aligned}
1-\frac{1}{\varepsilon} &= MC_t^n \\
&= \frac{1-\tau}{A_t}\frac{W_t^n}{P_{H,t}^n} \\
&= \frac{1-\tau}{A_t}e^{-d_t}C_t^n\left(N_t^n\right)^\varphi\frac{P_t^n}{P_{H,t}^n} \\
&= \frac{1-\tau}{A_t}e^{-d_t}C_t^n\left(N_t^n\right)^\varphi\left(S_t\right)^\alpha \\
&= \frac{1-\tau}{A_t}e^{-d_t}C_t^n\left(N_t^n\right)^\varphi Y_t^n\left(C_t^n\right)^{-1}\left[(1-\alpha)+\alpha\vartheta^{-1}\left(e^{d_t-d_t^*}\right)^{-1}\right]^{-1} \\
&= \frac{1-\tau}{A_t}\left(N_t^n\right)^\varphi Y_t^n\left[(1-\alpha)e^{d_t}+\alpha\vartheta^{-1}\left(e^{d_t-d_t^*}\right)^{-1}e^{d_t}\right]^{-1} \\
&= (1-\tau)\left(N_t^n\right)^\varphi N_{H,t}^n\left[(1-\alpha)e^{d_t}+\alpha\vartheta^{-1}e^{d_t^*}\right]^{-1}
\end{aligned}
$$

C.4 Welfare Function

In order to derive the welfare function in terms of the output gap and inflation, the utility function needs to be rewritten. It is approximated by a second order Taylor expansion around the flexible price equilibrium (the natural rate), and the resulting terms replaced by the output gap and domestic inflation.

For the utility of consumption with $\sigma = 1$, one can write

$$\log C_t = c_t^n + \widetilde{c}_t$$

where the tilde indicates the log deviation of this variable from the natural level. $\widetilde{c}_t$ can be replaced by an expression that is proportional to the output gap. Taking logs of equation (C.5) and approximating this around the natural level, gives

$$\widetilde{c}_t = \alpha x_t^* + (1-\alpha) x_t$$

Assuming the rest of the world to perfectly stabilize its output gap, consumption utility is

$$\begin{aligned} \log C_t &= c_t^n + \widetilde{c}_t \\ &= c_t^n + (1-\alpha) x_t \end{aligned} \tag{C.6}$$

For the disutility of labor function, the approximation around the natural rate is:

$$\frac{N_t^{1+\varphi}}{1+\varphi} = \frac{(N^n)^{1+\varphi}}{1+\varphi} + (N^n)^{1+\varphi}\left(\widetilde{n}_t + \frac{1}{2}(1+\varphi)\widetilde{n}_t^2\right) + o\left\|a\right\|^3$$

Approximated around the natural rate, the argument in the disutility of labor function $N_t = N_t^H + \phi N_t^F$ is

$$\widetilde{n}_t = \nu \widetilde{n}_t^H + (1-\nu)\widetilde{n}_t^M$$

where $\nu = \frac{N^H}{N} < 1$. N_t^H can be approximated as

$$\widetilde{n}_t^H = x_t + z_t$$

(see Galí and Monacelli, 2005) while hours abroad are

$$\widetilde{n}_t^M = \frac{\partial N_{M,t}}{\partial Y_t}\frac{Y_t^n}{N_{M,t}^n}x_t + \frac{\partial N_{M,t}}{\partial Y_t^*}\frac{Y_t^*}{N_{M,t}^n}x_t^*$$

Assuming the rest of the world to perfectly stabilize the output gap x_t^*, this equation reduces to

$$\widetilde{n}_t^M = \frac{\partial N_{M,t}}{\partial Y_t}\frac{Y_t^n}{N_{M,t}^n}x_t$$

Combining these last three results, gives

$$\begin{aligned}
\widetilde{n}_t &= \nu\widetilde{n}_t^H + (1-\nu)\widetilde{n}_t^M \\
&= \nu\left(x_t + z_t\right) + (1-\nu)\left(\frac{\partial N_{M,t}}{\partial Y_t}\frac{Y_t^n}{N_{M,t}^n}x_t\right) \\
&= \nu\left(x_t + z_t\right) + \frac{\partial N_{M,t}}{\partial Y_t}\frac{Y_t^n}{N_{M,t}^n}\frac{\phi N_{M,t}}{N_t}x_t \\
&= \left(\nu - \zeta_Y\right)x_t + \nu z_t
\end{aligned}$$

Finally, this can be inserted into the approximation of the disutility of labor function from above:

$$\begin{aligned}
\frac{N_t^{1+\varphi}}{1+\varphi} &= \frac{\left(N^n\right)^{1+\varphi}}{1+\varphi} + \left(N^n\right)^{1+\varphi}\left(\widetilde{n}_t + \frac{1}{2}(1+\varphi)\widetilde{n}_t^2\right) + o\left\|a\right\|^3 \\
&= \frac{\left(N^n\right)^{1+\varphi}}{1+\varphi} \\
&\quad + \left(N^n\right)^{1+\varphi}\left(\left(\nu - \zeta_Y\right)x_t + \nu z_t + \frac{1}{2}(1+\varphi)\left(\nu - \zeta_Y\right)^2 x_t^2\right) \\
&\quad + o\left\|a\right\|^3
\end{aligned} \tag{C.7}$$

where $o\left\|a\right\|^3$ are terms of order 3 or higher in the bound $\left\|a\right\|$ on the size of the relevant shocks.

The approximations (C.6) and (C.7) taken together are now

$$
\begin{aligned}
U(C_t, N_t) &= \log C_t - \frac{N_t^{1+\varphi}}{1+\varphi} \\
&= c_t^n + (1-\alpha)x_t - \frac{(N_t^n)^{1+\varphi}}{1+\varphi} \\
&\quad - (N_t^n)^{1+\varphi}\left((\nu-\zeta_Y)\,x_t + \nu z_t + \frac{1}{2}(1+\varphi)\,(\nu-\zeta_Y)^2\,x_t^2\right) + o\left\|a\right\|^3 \\
&= \left((1-\alpha - \frac{1-\alpha}{\nu-\zeta_Y}\,(\nu-\zeta_Y)\right)x_t \\
&\quad -\frac{1-\alpha}{\nu-\zeta_Y}\left(\nu z_t + \frac{1}{2}(1+\varphi)\,(\nu-\zeta_Y)^2\,x_t^2\right) + \text{t.i.p.} + o\left\|a\right\|^3 \\
&= -(1-\alpha)\left(\frac{\nu}{\nu-\zeta_Y}z_t + \frac{1}{2}(1+\varphi)\,(\nu-\zeta_Y)\,x_t^2\right) + \text{t.i.p.} + o\left\|a\right\|^3
\end{aligned}
$$

where t.i.p. are terms that are independent from policies.

Finally, the welfare function is the discounted sum of the period utility functions:

$$
\begin{aligned}
W &= -(1-\alpha)\sum_{t=0}^{\infty}\beta^t\left\{\left(\frac{\nu}{\nu-\zeta_Y}z_t + \frac{1}{2}(1+\varphi)\,(\nu-\zeta_Y)\,x_t^2\right)\right\} \\
&\quad + \text{t.i.p.} + o\left\|a\right\|^3
\end{aligned}
$$

In order to replace the dispersion term z_t, Galí and Monacelli (2005) showed that it is proportional to the variance of domestic prices,

$$z_t = \frac{\varepsilon}{2}var_i\left\{p_{H,t}(i)\right\} + o\left\|a\right\|^3$$

and because

$$\sum_{t=0}^{\infty}\beta^t var_i\left\{p_{H,t}(i)\right\} = \frac{1}{\lambda}\sum_{t=0}^{\infty}\beta^t\left\{\pi_{H,t}^2\right\}$$

(see Woodford, 2003, ch. 6), it gives

$$
\begin{aligned}
W &= -\frac{1}{2}(1-\alpha)\sum_{t=0}^{\infty}\beta^{t}\left\{\left(\frac{\nu}{\nu-\zeta_{Y}}\frac{\varepsilon}{\lambda}\pi_{H,t}^{2}+(1+\varphi)(\nu-\zeta_{Y})\,x_{t}^{2}\right)\right\} \\
&\quad +\text{t.i.p.}+o\left\|a\right\|^{3}
\end{aligned}
$$

This is the welfare function in Section 4.6.2.