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The Exchange-Rate Regime and Trade: A New Open-Economy Macroeconomics Perspective with Pass-Through Empirics

THESE

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Alexander MIHAILOV

Licencié en Relations Economiques Internationales
de l'Université d'Economie Nationale et Mondiale de Sofia

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Directeur:

Prof. Philippe Bacchetta
Ecole des HEC, Université de Lausanne

Expert:

Prof. Aude Pommeret
Ecole des HEC, Université de Lausanne

Experts externes:

Prof. Hans Genberg
Université de Genève

Dr. Cédric Tille
Federal Reserve Bank of New York

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Summary of Thesis

Effects of the Exchange-Rate Regime on Trade: The Role of Price Setting In a baseline stochastic new open-economy macroeconomics (NOEM) model, the first chapter of the dissertation revisits the question whether the exchange-rate regime matters for trade. Our main import is to focus the analysis along an explicit microfounded parallel of two alternative invoicing conventions, consumer's currency pricing (CCP) versus producer's currency pricing (PCP), and to uncover the mechanism generating their polar implications for equilibrium consumption allocations across national outputs. Nevertheless, we find that under frictionless trade with symmetry, only money shocks and separable utility, the exchange-rate regime is irrelevant in affecting expected trade-to-output, no matter the price setting assumed. A peg-float comparison remains, however, meaningful under (some degree of) PCP, although not (full) CCP, in terms of the volatility of national trade shares. By shutting down the expenditure-switching channel, a peg then stabilizes equilibrium trade-to-GDP across countries in any state of nature at its expected level. We identify the difference in the impact of exchange-rate regimes on trade share variability as originating in the particular currency denomination of transactions relevant to CCP and PCP and, hence, the exchange-rate pass-through implied by our alternative price-setting assumptions.

When and How Much Does a Peg Increase Trade? The Role of Trade Costs and Import Demand Elasticity To study the effects of the exchange-rate regime on international trade in a more realistic, yet rigorous, analytical set-up, the second chapter extends the NOEM baseline of chapter 1 in two insightful and interrelated ways. We essentially (i) embed trade in similar and different output mixes within a common framework and (ii) focus on the implications of impediments to cross-border transactions, again under alternative CCP vs. PCP invoicing. With costly trade now, as well as given separable utility and symmetry in structure and in the distributions of national money shocks, our principal contribution is to show that with (some degree of) PCP – although not (full) CCP – a peg reduces expected trade, measured in terms of GDP, relative to a float under elastic import demand. Inelastic import demand, possible under the same taste for diversity but dissimilar outputs arising from differences in endowments, reverses this conclusion. In both cases of elastic and inelastic demand for cross-country output, with (some) PCP a peg also stabilizes national trade-to-GDP shares. A simulation based on our extended model of chapter 2 has indicated that how much trade stabilization would be achieved by a shift from a flexible to a fixed exchange-rate regime ultimately depends on both monetary and real trade determinants. Within the perspective of actual-world economies and as a lesson for policy, the degree of trade share variability thus eliminated would be greater for (symmetric) nations, or currency unions, which (i) have a larger proportion of PCP in their (bilateral) trade, (ii) are exposed to higher monetary uncertainty and

– for moderate to high costs of the international exchange of goods – (iii) produce less substitutable outputs and (iv) are located closer to one another or apply weaker (reciprocal) tariff and non-tariff restrictions.

The Empirical Range of Pass-Through in US, German and Japanese Macrodata The objective of the last, empirical chapter of the dissertation is to pursue certain implications of the analytical framework developed in the two preceding, theoretical chapters. Chapters 1 and 2 have shown why from an economy-wide viewpoint the assumption of CCP vs. PCP is of an essential nature. The reason is that full CCP completely reverses a central result in the Keynesian international macroeconomics tradition, namely the expenditure-switching effect. A monetary expansion that depreciates the national currency leads under full CCP to an improvement (not deterioration, as under full PCP) in the inflating country's terms of trade and ultimately depresses (and does not stimulate) real economic activity. It is clear, however, that in reality CCP and PCP will coexist in the prices of exported as well as imported products, and the extent of CCP (or, inversely, PCP) would thus largely determine the empirical range of pass-through from nominal exchange rate (NER) changes to import, producer, consumer and export prices of a given country. In the third chapter of the dissertation, building on recent empirical studies, our interest is therefore to measure econometrically and to compare the range of aggregate pass-through during the last two decades of the 20th century in the three largest national economies in the world, i.e. the United States (US), Germany and Japan. A key contribution is that, unlike earlier research, we focus on monthly data to comply with the relevant span of real-world price level stickiness and NER fluctuations but at the same time discuss how our quantification differs from analogous quarterly estimates. Another import is that we take robustness seriously and obtain our results employing a battery of alternative specifications of preliminary tests and of OLS, orthogonalized and – notably – generalized VARs based on various combinations of proxies. An overall conclusion is that the empirical range of exchange rate pass-through varies across (i) economies, (ii) data frequencies, (iii) periods of time, (iv) methods of estimation, (v) aggregate price measures, (vi) stages along the pricing chain and (vii) horizons of analysis. Any generalization thus needs to be careful, yet abstracting from specificity, we would stress at least three rather robust findings from our empirical analysis. First, in the three countries we examined pass-through on import prices has considerably declined in the 1990s relative to the 1980s; but pass-through on export prices has, in essence, remained the same; as far as consumer prices are concerned, pass-through seems to be nowadays practically negligible over all horizons of up to one year. Second, the econometric method and the measurement proxy used matter for the precise magnitudes and time patterns, yet they often – but not always – accord on the general trends. Third, the US is quite a particular economy, with import and, hence, consumer price levels that are amazingly insensitive to US dollar depreciations. Our results have also confirmed that the use of monthly data is quite central when it comes to measuring pass-through more precisely. This is not surprising, since pass-through has to do with reactions of monopolistically competitive price-setters to (i) exchange rate movements (ii) under sticky prices. On both counts, quarterly observations would miss much of the "action". Accordingly, from performing the same calculations with monthly as well as with (corresponding) quarterly data, we establish that when passing from the higher to the lower frequency a lot of interesting dynamics is lost, due to certain averaging out of shorter-run price adjustments to changes in exchange rates.

Chapter 1

Effects of the Exchange-Rate Regime on Trade: The Role of Price Setting

1.1 Introduction

The present chapter belongs to the rapidly growing new open-economy macroeconomics (NOEM) literature.[1] Our objective is to revisit, within this sticky-price optimizing approach and explicitly accounting for monetary uncertainty in general equilibrium, the classic subject of exchange rate and trade determination. In particular, we here reconsider in a fully-symmetric NOEM context and under alternative price-setting conventions the question whether the exchange-rate regime matters for international trade. Comparing *consumer's* currency pricing (CCP) with *producer's* currency pricing (PCP), we are able to answer in what sense this is the case. In a self-contained theoretical analysis that explicitly parallels a CCP to a PCP model version, we derive from first (micro-)principles important (macro-)outcomes. Some of them are novel, while the positive and normative implications of other have been debated for long, but largely within ad-hoc frameworks in the Mundell-Fleming-Dornbusch tradition.

More precisely, this chapter builds on the stochastic representative agent set-up under CCP and frictionless trade in highly substitutable national outputs proposed in Bacchetta and van Wincoop (1998, 2000 a). As noted by these authors, their "benchmark monetary model" – together with the similar ones developed in Obstfeld and Rogoff (1998, 2000) under PCP, we would add – is intended as a starting point in modern research on monetary policy in open economies. The main contribution of the quoted studies, which we pursue here as well, is to recast traditional comparisons of exchange-rate arrangements in a general equilibrium setting that explicitly considers the role of macroeconomic uncertainty under nominal rigidity. We further down ex-

[1] As defined and classified in the recent survey by Lane (2001). A narrower and more technical summary of the basic NOEM methodology is also provided in Sarno (2001).

plore Bacchetta and van Wincoop's (2000 a) single-period benchmark also under PCP, focusing our attention on trade prices and flows. In essence, we thus compare the equilibrium outcomes of a baseline stochastic NOEM framework under polar invoicing practices in cross-border transactions[2], namely CCP vs. PCP. A theoretical parallel of these extremes allows us to draw some clear-cut, mostly qualitative conclusions on the effects of the exchange-rate regime – modelled simply as float vs. peg – on relative prices, consumption and labor/leisure choices and, finally, trade.

Our principal import is to demonstrate that price-setting assumptions, fundamental in any open-economy model with nominal stickiness, affect in a crucial way optimal consumption allocations under (even only) monetary uncertainty and, consequently, any microfounded analysis of international trade. In a preview of our results we can state that, irrespective of the invoicing assumed, the exchange-rate regime does not matter for the *expected level* of trade-to-output, which is always 1 given symmetry and frictionless trading. Yet under PCP, but not CCP, it matters for the *volatility* of national trade shares. A peg would thus stabilize, under PCP, the equilibrium trade share in each country across states of nature at its expected level. This latter level coincides with the one under CCP, which in that case is the same ex-ante as ex-post. We identify the difference in the effects of the exchange-rate regime on equilibrium trade flows as originating in the particular currency denomination of transactions, hence, the implied *exchange-rate pass-through* and, finally, *expenditure switching*. In our symmetric framework, this major channel of international spillover of monetary shocks is absent under CCP and float. As to the PCP model version, a peg effectively shuts it down, by equalizing at the neutral unitary level the relative price of foreign goods in terms of domestic analogues which households in both countries face.

We would not survey here the voluminous literature, classic as well as modern, on the subject we are interested in. We briefly discuss instead only those lines of relevant research that have strongly influenced our motivation and modelling strategy for the present chapter. In doing so, we also highlight in each of the next two subsections two essential features of our set-up, which would have important implications in any open-economy model with price rigidity.

1.1.1 Monetary Uncertainty in General Equilibrium

Monetary uncertainty generating exchange-rate risk is inherent in issues related to international trade, welfare and macroeconomic policy in which risk-averse agents are involved. To be properly studied, such issues have therefore to be cast in general

[2] Friberg (1998) points out to the fact that the currency of *price setting*, the currency of *invoicing* and the currency of *payment*, although theoretically corresponding to three distinct stages of a typical international trade transaction and hence potentially different, practically coincide "with few known exceptions". Therefore in what follows we use "invoicing" and "price setting" interchangeably (without talking at all about the "currency of payment").

equilibrium frameworks that are *explicitly stochastic*.[3] That is why we have purposefully chosen to follow a recent approach in NOEM theoretical modelling, introduced by Obstfeld and Rogoff (1998, 2000) and Bacchetta and van Wincoop (1998, 2000 a). It extends the deterministic "redux" exchange rate model of Obstfeld and Rogoff (1995, 1996: Chapter 10) and its variations in Corsetti and Pesenti (1997, 2001 a, b, 2002). To our knowledge, the "redux" model was the first microfounded open-economy general-equilibrium framework with rigid prices and monopolistic competition designed to explain exchange-rate dynamics. Traditional research on exchange-rate regimes was either general-equilibrium but flexible-price,[4] or sticky-price but ad-hoc.[5] If the impact of uncertainty on exchange rates and, hence, trade and consumption flows was at all considered, analysis was restricted to partial-equilibrium models, as duly pointed out in Bacchetta and van Wincoop (2000 a).[6]

To allow for analytical solutions, the explicitly stochastic NOEM literature has been technically implemented under simplifying assumptions. Log-normal processes for shocks and, consequently, for the endogenous variables as well as specific utility functions are usually imposed, e.g. in Obstfeld and Rogoff (2000). Often, it is also assumed that the Law of One Price (LOP) and, hence, Purchasing Power Parity (PPP) hold[7] so that the real exchange rate (RER) is constant. To benefit from the insights provided by an analytical solution, we likewise limit our set-up to a single period with only monetary uncertainty, as in Bacchetta and van Wincoop's (2000 a) benchmark and many other NOEM papers. Yet we do not restrict attention to neither a CCP nor a PCP-LOP-PPP model version but rather provide an analytical comparative account of both. Furthermore, we need not specialize, for our purposes here, to a log-normal distribution of disturbances or to a particular class of utility. With respect to the stochastic processes, it proves sufficient to require no more than a jointly *symmetric* distribution for the national money stock growth rates. As to the utility function, we assume that it is well-behaved and separable. These features make our analysis somewhat less restrictive than related earlier work.

1.1.2 Alternative Price Setting in Open Economies

Another important development in NOEM research has been to incorporate considerations of the earlier international trade literature, such as Helpman and Razin (1984) to mention an outstanding example, regarding alternative price setting. Contributions in this particular direction have been due to Betts and Devereux (1996, 2000), Bacchetta

[3] Earlier models usually considered impulse responses to just a *single (one-time) shock* in an otherwise completely deterministic setting. Accordingly, although sometimes named "stochastic", they are essentially not.

[4] E.g. Helpman and Razin (1979, 1982, 1984), Helpman (1981) and Lucas (1982).

[5] Here one could enumerate papers in the Mundell-Fleming-Dornbusch tradition of the 1960s and 1970s.

[6] See the references cited in their footnote 7, p. 1096. Good surveys can be found in Côté (1994) and in Glick and Wihlborg (1997).

[7] In Obstfeld and Rogoff (1995, 1996: Chapter 10, 1998, 2000) and Devereux (2000), among others.

and van Wincoop (1998, 2000 a, b, 2001), Devereux and Engel (1998, 1999, 2000), Devereux (2000) and Engel (2000). Extending the original Obstfeld-Rogoff – Corsetti-Pesenti framework of nonsegmented markets, these authors introduced international market segmentation in the goods market and what they usually call *pricing-to-market* (PTM)[8] behavior of monopolistically competitive firms, engaging at the same time in microfounded welfare comparisons of exchange-rate regimes. PTM is often denoted local currency pricing (LCP),[9] but to avoid ambiguity we would rather use a terminology that is hopefully more precise in our context: *producer*'s currency pricing (PCP) and *consumer*'s currency pricing (CCP).[10]

With regard to the literature cited in the preceding paragraph, our study is justified at least in the following three aspects. First, we examine the effects of the exchange-rate regime on *trade* prices and quantities, whereas attention in most quoted papers has been focused on welfare issues. Indeed, international trade has been covered only marginally in NOEM. But it is important to understand the mechanism of its determination, the more so under the alternative invoicing possible in open economies. There is a purely *theoretical* reason why it is important to also look at trade: namely, because the underlying relative prices and the subsequent flows of goods predetermine – through microfounded consumption and leisure choices – the ultimate equilibrium allocations of these welfare ingredients, themselves sensitive to the specification of utility. Moreover, and as a consequence of not undertaking welfare analysis, we are able to allow for a more general utility function, although separable in consumption and leisure. Second, there is another, *policy-oriented* perspective on the role of the exchange-rate regime in trade determination: in fact, much has been debated on the trade implications of a monetary union within the context of a united Europe. In an attempt to extend NOEM research in a direction that throws more light on the theory that should underpin such prominent but perhaps thus far somewhat misleading public discussion, we consider it worthwhile to address analytically the present topic. And third, under uncertainty and in cash-in-advance (CiA) sticky-price frameworks – as emphasized in the insightful methodological books by Magill and Quinzii (1996) and Walsh (1998), among others – the assumed timing of decisions and price-setting behavior are crucial to model outcomes, which materializes in the *polar* pass-through implications of our two model versions. In highlighting these aspects and, more importantly, their interaction in a microfounded two-country economy that makes an explicit *parallel* between CCP and PCP invoicing and helps understand the effects of the exchange-rate regime on trade consists the main novelty of our approach.

The chapter is further down organized as follows. Section 1.2 outlines the stochastic

[8] A term coined by Krugman (1987).

[9] A coinage due to Devereux (1997) to refer to the *special* case of PTM where prices are always set in the currency of the destination market.

[10] Since we do not explicitly distinguish an intermediary import/export sector in the two-country economy we study, as Tille (2000 b) has first done within NOEM, CCP and PCP are equivalent here to, respectively, *importer*'s (buyer's) and *exporter*'s (seller's) currency pricing.

NOEM model of exchange rate and trade determination we employ. The third section studies, under *float* and symmetry, the role which alternative price setting plays in agents' optimization and in deriving equilibrium relationships. Section 1.4 then focuses on the effects of the exchange-rate regime on international relative prices and trade flows, by discussing if and how a *peg* would change the float allocations of the preceding section. Section 1.5 concludes and Appendix A contains the proofs of propositions.

1.2 A Simple Stochastic NOEM Model of Trade

The present section serves to introduce the model we study. In it, we describe the *basic* set-up that underlies both our model versions. The essential differences between the *CCP vs. PCP* cases, originating in the relevant currency denomination of the goods sold abroad under market segmentation and reflected in our invoicing-specific notation, are highlighted in the next section.

1.2.1 Basic Set-Up

The artificial economy we analyze exists in a single period[11] and is made up of two countries, *H(ome)* and *F(oreign)*, assumed of equal size. A continuum of differentiated *brands* belonging to the same good *type* is available for consumption. These highly substitutable brands are indexed by i if made in H and by i^* if made in F. Each such brand is produced and sold by a single monopolistically competitive firm, also indexed by i in H and i^* in F. Firms in Home are uniformly distributed on the unit interval $[0, 1]$. Likewise, firms in Foreign produce on $(1, 2]$.

To obtain (short-run) money non-neutrality, we assume sticky prices motivated by menu costs.[12] Moreover, monopolistic competition enables each firm to optimally choose the price(s) at which it sells its product. Prices are set in advance, i.e. in our *ex-ante* state 0 (*before* monetary uncertainty has been resolved), and remain valid until the end of the period, i.e. for the *ex-post* state $s \in S$ we consider (*after* shocks in H and F have been observed).[13] Preannounced prices result, in turn, in demand-

[11] Extension to sequential dynamics is straightforward: it will only violate ex-ante symmetry right after the first period and thus require recursive simulation. However, since the relevant measure of variables under uncertainty is their *expected* level, with which we are concerned here, simulating and summing over a sufficiently large number of *periods* will essentially replicate the analytically derived results over multiple *states* of nature we provide further down.

[12] As first suggested by Mankiw (1985). To recall a classic result in Lucas (1982), with perfectly flexible prices the exchange-rate regime does not matter, even under uncertainty, for optimal real allocations. As to the locus of rigidity, some authors prefer to model sticky (nominal or real) wages, following Taylor (1979) and the earlier Keynesian tradition, while others give preference to sticky prices, following Rotemberg (1982) and Calvo (1983), and as Kimball (1995) has notably insisted. In essence, the two approaches are not so different and – within NOEM – often imply each other, as Hau (2000) and Obstfeld and Rogoff (2000) have recently argued.

[13] Since our focus is not on inflation dynamics, the static stochastic framework we borrow from Bacchetta and van Wincoop (2000 a) and related NOEM research seems not too constraining.

determined output, on an individual-firm as well as on an aggregate level.[14] In such a (New-)Keynesian situation, technology shocks do not influence production possibilities and output quantities sold.[15]

Governments and Shocks In each country, there is a government whose only (passive) role is to proportionally transfer cash denominated in national currency to all domestic households in a random way.[16] Seigniorage is then repaid in a lump-sum fashion at the end of the period, to make agents willing to hold money, as is standard in the finite-horizon literature. We interpret such a money supply behavior, equivalent in our context to a flexible exchange-rate system, as exogenous "monetary policy" and model it in terms of stochastic money stock growth rates. Moreover, we restrict it to be *jointly symmetric*, in the sense we explain next.

For $\forall s \in S$, μ_s and μ_s^* are, respectively, H-money stock and F-money stock *net* rates of growth, having the same mean and variance. For the sake of symmetry, ex-ante (state 0) national money holdings of the representative households in Home and Foreign are assumed identical in terms of units of each country's currency:[17] $M_0 = M_0^*$. The ex-post (state s) cash balances, i.e. the domestic-currency budgets with which Home and Foreign households dispose for transactions purposes in any realized state of nature $s \in S$, are then respectively given by $M_s \equiv M_0 + \mu_s M_0 = (1 + \mu_s) M_0$ and $M_s^* \equiv M_0^* + \mu_s^* M_0^* = (1 + \mu_s^*) M_0^*$.

The only difference between float vs. peg in terms of the joint distribution (up to second moments, inclusive) of national money growth shocks (μ_s, μ_s^*) and, hence, of the resulting ex-post money stocks (M_s, M_s^*) thus arises from their *covariance* terms. It is imposed by the definition itself of a fixed vs. flexible exchange-rate regime: under (pure) *float*, the correlation of national money stocks is 0; under (credible) *peg*, this correlation is 1. In essence, our fixed exchange-rate version is thus isomorphic to a model where a monetary union or a single-currency area is hit by just one, common money shock.

Since this is a first comparative analysis within NOEM of the effects of the exchange-rate regime on trade prices and flows under alternative assumptions on price rigidity, we have preferred to focus on jointly symmetric shock distributions. In fact, such an approach adds to the underlying simplicity of the economic structure we postulated: symmetric uncertainty seems more appealing given the symmetric deterministic environment we retain from the usual open-economy benchmark. Moreover, before considering any extensions to more realistic settings, which would complicate matters

[14] For this to be realistic, we note that our subsequent analysis applies only to money growth disturbances of a sufficiently *small* magnitude.

[15] That is why we abstract here from also modelling productivity disturbances. Even if explicitly accounted for, they will not change much in the present single-period setting.

[16] One could argue that monetary authorities are ultimately unable to perfectly control the money *supply* or precisely estimate the *demand* for money in order to always equilibrate them.

[17] At an initial *equilibrium* exchange rate of 1, as will be discussed later.

and perhaps require simulations, our initial objective here has rather been to obtain analytical clarity in uncovering some key channels in the international transmission of monetary shocks.

Timing of Events In the single period we analyze, decisions are made in two stages, ex-ante and ex-post. Only *firms* optimize ex-ante, solving a stochastic optimization problem. Before observing the particular state of the world that will materialize but having common knowledge on the distribution of the jointly symmetric monetary shocks, they preannounce prices. Due to (prohibitive) menu costs, they cannot change ex-post these optimally prefixed prices. After observing the state of the world, firms employ labor at the equilibrium wage to produce goods. Output, hence, labor input and, ultimately, leisure hours are simply determined in any realized state of nature by the optimal consumption demand for the respective differentiated product each one of the firms faces. *Households*, contrary to firms, optimize only ex-post. After receiving their random cash, they allocate total money balances across the differentiated goods which make up the real consumption composite.

1.2.2 Households and Firms

Households In each country, H and F, there is a continuum of identical households. The population in each of these economies is assumed constant and is normalized to 1. The representative household (in H as well as in F) likes diversity and consumes *all* brands on the interval $[0, 2]$. It also supplies labor, earning the equilibrium wage, and owns an equal proportion of domestic firms, receiving their profits (in the form of dividends).

The representative household in Home[18] maximizes utility:

$$\underset{c_s, l_s}{Max} \quad u(c_s, l_s), \quad \forall s \in S. \tag{1.1}$$

Our utility function is assumed to be well-behaved (i.e. to exist, be continuous, twice differentiable and concave) and separable in its two arguments. l_s is (hours of) leisure and c_s is a constant elasticity of substitution (CES) real consumption index defined in the standard way by the following Dixit-Stiglitz (1977) aggregator:[19]

$$c_s \equiv \left[\left(\tfrac{1}{2}\right)^{\frac{1}{\varphi}} (c_{H,s})^{\frac{\varphi-1}{\varphi}} + \left(\tfrac{1}{2}\right)^{\frac{1}{\varphi}} (c_{F,s})^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}}, \quad \forall s \in S, \tag{1.2}$$

with

[18] The notation in which the model is further on set out generally refers to Home, but for Foreign symmetric relationships hold (unless otherwise stated).

[19] Accordingly, the representative household in Home (and, analogously, in Foreign) minimizes the cost of buying a unit of real consumption.

$$c_{H,s} \equiv \left(\int_0^1 c_{i,s}^{\frac{\varphi-1}{\varphi}} di \right)^{\frac{\varphi}{\varphi-1}} \quad \text{and} \quad c_{F,s} \equiv \left(\int_1^2 c_{i^*,s}^{\frac{\varphi-1}{\varphi}} di^* \right)^{\frac{\varphi}{\varphi-1}}.$$

Similarly to Bacchetta and van Wincoop (2000 a) and most NOEM set-ups, we begin by assuming throughout chapter 1 that international trade is costless[20] and that $\varphi > 1$.[21] As evident from the equations below, φ in the above formulas is the elasticity of substitution in demand between *any* two brands, no matter where they are produced. $c_{i,s}$ is the consumption by the Home representative household of brand i produced by a Home firm i and $c_{i^*,s}$ is its consumption of brand i^* produced by a Foreign firm i^*. $c_{H,s}$ is an index of the consumption by the Home household of all brands produced in Home and $c_{F,s}$ is an analogous index for all brands produced in Foreign. Textbook derivations in this well-known Dixit-Stiglitz (1977) setting[22] give the allocation of consumption across brands:

$$\begin{aligned}
c_{H,s} &= \frac{1}{2}\left(\frac{P_{H,s}}{P_s}\right)^{-\varphi} c_s, \quad c_{F,s} = \frac{1}{2}\left(\frac{P_{F,s}}{P_s}\right)^{-\varphi} c_s; \\
c_{i,s} &= \left(\frac{P_{i,s}}{P_{H,s}}\right)^{-\varphi} c_{H,s} = \frac{1}{2}\left(\frac{P_{i,s}}{P_s}\right)^{-\varphi} c_s, \\
c_{i^*,s} &= \left(\frac{P_{i,s}}{P_{F,s}}\right)^{-\varphi} c_{F,s} = \frac{1}{2}\left(\frac{P_{i^*,s}}{P_s}\right)^{-\varphi} c_s.
\end{aligned}$$

$P_{i,s}$ is the price (in Home currency) paid by the Home household for one unit of a brand i produced by a Home firm i and $P_{i^*,s}$ is the price (in Home currency) paid by the Home household for one unit of a brand i^* produced by a Foreign firm i^*. $P_{H,s}$ is the price index (in Home currency) paid by the Home household across all Home produced brands and $P_{F,s}$ is the price index (in Home currency) paid by the Home household across all Foreign produced brands. P_s, finally, is the price index (in Home currency) across all brands consumed by the Home household, i.e. the consumer price index (CPI) in H. These price indexes too are defined in the usual way:[23]

$$\begin{aligned}
P_s &= \left(\frac{1}{2}P_{H,s}^{1-\varphi} + \frac{1}{2}P_{F,s}^{1-\varphi}\right)^{\frac{1}{1-\varphi}} \quad \text{with} \\
P_{H,s} &= \left(\int_0^1 P_{i,s}^{1-\varphi} di\right)^{\frac{1}{1-\varphi}} \quad \text{and} \quad P_{F,s} = \left(\int_1^2 P_{i^*,s}^{1-\varphi} di^*\right)^{\frac{1}{1-\varphi}}.
\end{aligned}$$

Respective symmetric expressions hold, of course, for Foreign. Note that, up to this point, all of the indexes are written down as independent of the underlying price

[20] An extension to costly trade in a richer version of the model here is provided in chapter 2.

[21] The reason is that otherwise the marginal revenue of firms will be negative (see, for instance, Obstfeld and Rogoff (1996), p. 661, footnote 2). The implications of a cross-country output substitutability lower than 1 are studied in the extension of the present set-up considered in our second chapter.

[22] See, for instance, Obstfeld and Rogoff (1996).

[23] To represent the minimal expenditure required for the purchase of one unit of the corresponding basket.

setting. Their particular variants under CCP vs. PCP invoicing, modified by the appropriate notation, are discussed in the next section.

In this representative agent economy, the aggregate constraints on (per-)household behavior coincide with those of the identical households. They are standard in NOEM but, for completeness, we briefly present them below.

Time Endowment Constraint The endowment of hours to the representative household (in Home) is normalized to 1 in each state,

$$l_s + n_s \equiv 1, \quad \forall s \in S, \tag{1.3}$$

so that $n_s \equiv 1 - l_s$ is the (Home) household's labor (supply).

Cash-in-Advance (CiA) Constraint Households need to carry cash before going to the goods market.[24] Moreover, we restrict them to hold and receive from their monetary authority only *domestic* currency. Thus (for Home)

$$\underbrace{c_s P_s}_{H \text{ national } \textit{expenditure} \text{ (in } H \text{ currency)}} \leq \underbrace{M_s}_{\text{available } \textit{cash} \text{ in } H \text{ (in } H \text{ currency)}}, \quad \forall s \in S. \tag{1.4}$$

National Money Market Equilibrium Since CiA constraints are *binding*[25] and there is no investment and government spending in the model, the nominal value of national output sold (for consumption) is equal to the total stock of money in each of the countries. For Home:

$$Y_s = M_s, \quad \forall s \in S. \tag{1.5}$$

National Income Identity With a nominal wage rate of W_s and total hours of work amounting to $1 - l_s$, the nominal labor income of the (Home) representative household is given by $W_s(1 - l_s)$. Nominal dividends from firm profits earned by this household are denoted by Π_s. In equilibrium, all income from the activity of firms is distributed to domestic households who are their ultimate owners, as will be assumed (but this happens only at the end of the one-period framework we consider):[26]

[24] The alternative would be to introduce money and, hence, the nominal exchange rate whose determination and regimes we wish to analyze, via a *money-in-the-utility* (MiU) function, also common in monetary general-equilibrium models. Our modelling choice here is anyway not crucial, since Feenstra (1986) has demonstrated the equivalence of these two approaches.

[25] For at least two reasons in our present set-up: (i) this is implied by the *concavity* of utility we assumed; (ii) it is also the optimal strategy for the representative household when no future is allowed for, as in the *one-period* stochastic framework analyzed here. The binding CiA implies, in turn, a *unitary* velocity of (quantity theory) money demand (1.5), which is, certainly, another limitation but one that is common to similar CiA settings.

[26] Factor income is thus not used further on, to buy consumption goods and to lend or borrow, with no dynamics modelled.

$$\underbrace{\underbrace{W_s(1-l_s)}_{\text{labor income}} + \underbrace{\Pi_s}_{\text{ownership income}}}_{H \text{ national (factor) } income \text{ (in } H \text{ currency)}} \equiv \underbrace{Y_s}_{H \text{ national } output \text{ (in } H \text{ currency)}}, \quad \forall s \in S. \tag{1.6}$$

First-Order Conditions The following "compact" first-order condition can be derived in a familiar way from the above-described constrained optimization problem for the H representative household:

$$W_s = \frac{u_{l,s}}{u_{c,s}} P_s, \quad \forall s \in S. \tag{1.7}$$

$u_{l,s}$ and $u_{c,s}$ in (1.7) are the marginal utilities of leisure and consumption, respectively, in the realized state s. The real wage rate is thus equal, in equilibrium, to the ratio of these marginal utilities.

Firms Unlike the NOEM alternative of "yeoman-farmers", firms exist in themselves in our model and effect production. A usual restriction in similar settings we impose at this stage too is that firms are owned by *domestic* households only. In the present study we also abstract from an international stock market, as well as of risk-sharing issues in general. As noted, product differentiation makes firms monopolistically competitive. We focus in chapter 1 on international trade in *similar* output mixes, i.e. on the case where differentiated brands belong to the *same* type of a homogeneous good produced in both countries, with identical technology common to all firms.[27] Just one factor, labor, available in fixed quantities in both economies, is used as input. For Home:

$$y_s = n_s = 1 - l_s. \tag{1.8}$$

Such a production function does seem simplistic, but is actually sufficient for the purposes of our sticky-price single-period analysis here. The reason is that, given the (New-)Keynesian set-up we described, it is household demand and not productivity that ultimately determines output.

1.3 The Role of Price Setting

The basic set-up we have introduced thus far is developed further in the present section to enable us to draw an explicit parallel between the essential differences in the optimization problem specifications and the resulting consumption demand and monopolistic pricing functions across alternative price setting. On that basis, a formal definition of equilibrium is provided. Under *float* and *symmetry*, we then derive CCP vs. PCP equilibrium expressions for the exchange-rate level, international relative

[27] In Chapter 2 we allow for national good types that *differ* in the sense of being less substitutable than brands.

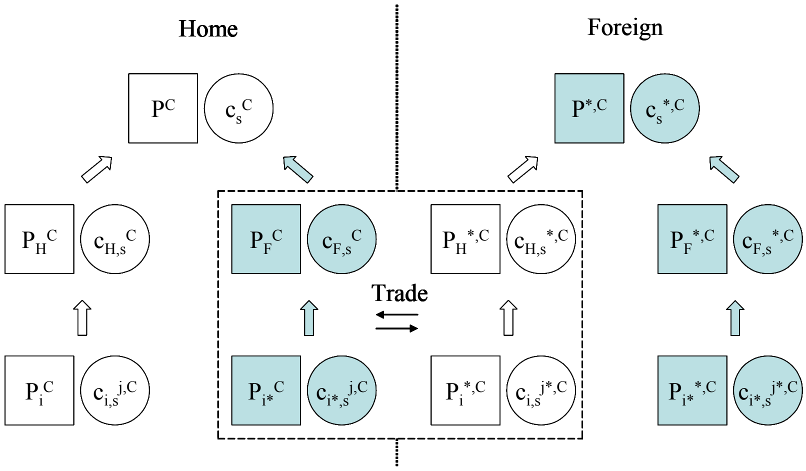

Figure 1.1: Notation on Price and Quantity Aggregation under CCP

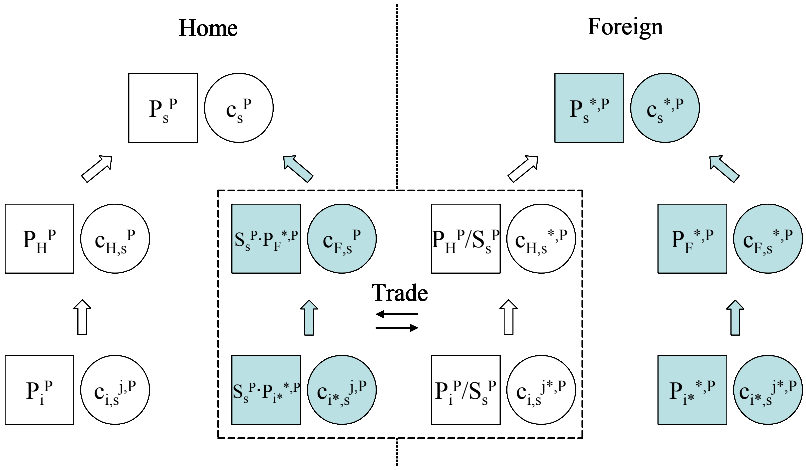

Figure 1.2: Notation on Price and Quantity Aggregation under PCP

prices, cross-country consumption and leisure allocations and the resulting trade-to-output ratios.

Invoicing-Specific Notation The two invoicing practices in the open economy whose implications we highlight here have imposed a specific notation, which we now summarize. For a schematic representation of prices, quantities and their (definitional) interrelations as well as of the general structure of our CCP vs. PCP model versions, compare the respective elements and blocks in figures 1.1 vs. 1.2. Details on their invoicing-specific definitions and interpretations follow below.

All our quantity variables are denoted by lowercase Latin letters. These quantities can be indexed by up to two subscripts and up to two superscripts. A first *sub*script H or F indicates the origin of the respective variable at the national-economy level, i.e.

the country where a particular good i or i^* (first *sub*scripts again but at the individual-firm level) has been produced. Following the tradition, we use an asterisk ($*$) as a first *super*script to denote that a particular quantity variable has been consumed in Foreign. The second *sub*script, 0 for ex-ante quantities and s for ex-post quantities, indexes the state of nature whereas the second *super*script, C (for CCP) or P (for PCP), indicates the assumed price setting. The same notational rules apply to the (money) prices or nominal variables that correspond to all respective quantities in our model, the only difference being that these are denoted by uppercase Latin letters. Greek letters, in turn, designate model parameters and shocks.

1.3.1 Optimization and Equilibrium

Consumption Demands and Price Levels The consumption aggregator (1.2) is only at first sight identical across our alternative price-setting conventions. The reason is that its components, $c_{H,s}$ and $c_{F,s}$, although seemingly the same, are in fact defined by different expressions under CCP vs. PCP. They originate in some initial, price and quantity invoicing-specific assumptions but, as the optimization proceeds and is nationally aggregated, these differences also feed on into the resulting analytical outcomes.

Standard derivations à la Dixit-Stiglitz (1977) under CCP vs. PCP result in optimal demands of the Home representative household for H- (equations (1.9) below) and F-produced (1.10) brands and the respective Home price indexes at the domestic absorption (1.11), import demand (1.12) and consumer (1.13) levels as follows:

$$c^C_{H,s} = \frac{1}{2}\left(\frac{P^C_H}{P^C}\right)^{-\varphi}\frac{M_s}{P^C} \quad \text{vs.} \quad c^P_{H,s} = \frac{1}{2}\left(\frac{P^P_H}{P^P_s}\right)^{-\varphi}\frac{M_s}{P^P_s}; \tag{1.9}$$

$$c^C_{F,s} = \frac{1}{2}\left(\frac{P^C_F}{P^C}\right)^{-\varphi}\frac{M_s}{P^C} \quad \text{vs.} \quad c^P_{F,s} = \frac{1}{2}\left(\frac{\overbrace{S^P_s P^{*,P}_F}^{\equiv P^P_{F,s}}}{P^P_s}\right)^{-\varphi}\frac{M_s}{P^P_s}; \tag{1.10}$$

with

$$P^C_H \equiv \left[\int_0^1 \left(P^C_i\right)^{1-\varphi} di\right]^{\frac{1}{1-\varphi}} \quad \text{vs.} \quad P^P_H \equiv \left[\int_0^1 \left(P^P_i\right)^{1-\varphi} di\right]^{\frac{1}{1-\varphi}}; \tag{1.11}$$

$$P^C_F \equiv \left[\int_1^2 \left(P^C_{i^*}\right)^{1-\varphi} di^*\right]^{\frac{1}{1-\varphi}} \quad \text{vs.} \quad \underbrace{S^P_s P^{*,P}_F}_{\equiv P^P_{F,s}} \equiv \left[\int_1^2 \underbrace{\left(S^P_s P^{*,P}_{i^*}\right)}_{\equiv P^P_{i^*,s}}^{1-\varphi} di^*\right]^{\frac{1}{1-\varphi}}; \tag{1.12}$$

$$P^C \equiv \left[\frac{1}{2}\left(P_H^C\right)^{1-\varphi} + \frac{1}{2}\left(P_F^C\right)^{1-\varphi}\right]^{\frac{1}{1-\varphi}} \quad \text{vs.} \tag{1.13}$$
$$P_s^P \equiv \left[\frac{1}{2}\left(P_H^P\right)^{1-\varphi} + \frac{1}{2}\underbrace{\left(S_s^P P_F^{*,P}\right)}_{\equiv P_{F,s}^P}^{1-\varphi}\right]^{\frac{1}{1-\varphi}}.$$

Clearly, the exchange-rate pass-through to import prices – i.e. the elasticity of the import price index, $P_{F,s}$, with respect to the nominal exchange rate, S_s – is *unitary* under PCP, while under CCP it is *zero* (cf. the CCP vs. PCP expression in (1.12)). For the same reason, the CPI is constant under CCP, P^C, but state-dependent under PCP, P_s^P (cf. equations (1.13)). This causes demands for even domestically-produced brands, at first sight identical, to be actually defined by different expressions across our alternative price-setting assumptions (cf. the CCP vs. PCP expression in (1.9)).

Output Prices Similarly to the consumption aggregator (1.2), the expected market value of real profits which a Home firm $i \in [0,1]$ maximizes is seemingly the same, but is nevertheless differently defined under CCP vs. PCP:

$$\underset{P_i^C, P_i^{*,C}}{Max} E_0 \left[\frac{u_{c,s}}{P^C} \underbrace{\left(P_i^C c_{i,s}^C + S_s^C P_i^{*,C} c_{i,s}^{*,C} - W_s^C c_{i,s}^C - W_s^C c_{i,s}^{*,C}\right)}_{\equiv \Pi_{i,s}^C}\right], s \in S \tag{1.14}$$

$$\text{vs.} \ \underset{P_i^P}{Max} E_0 \left[\frac{u_{c,s}}{P_s^P} \underbrace{\left(P_i^P c_{i,s}^P + P_i^P c_{i,s}^{*,P} - W_s^P c_{i,s}^P - W_s^P c_{i,s}^{*,P}\right)}_{\equiv \Pi_{i,s}^P}\right], s \in S. \tag{1.15}$$

Under CCP this firm i – which in our setting is also the Home *representative* firm – presets *two* prices, one in national currency and the other in foreign currency. Under PCP just *one* price, in national currency, is prefixed. Using the respective first order conditions, CCP vs. PCP optimal prices of the Home representative firm (relevant for consumer households in the domestic and foreign market) are thus:

$$P_i^C = P_H^C = \frac{\varphi}{\varphi - 1} \frac{E_0\left[u_{c,s} W_s^C M_s\right]}{E_0\left[u_{c,s} M_s\right]} \quad \text{vs.} \tag{1.16}$$

$$P_i^P = P_H^P = \frac{\varphi}{\varphi - 1} \frac{E_0\left[\frac{u_{c,s}}{P_s^P} W_s^P \left(P_s^P\right)^{\varphi-1}\left(M_s + S_s^P M_s^*\right)\right]}{E_0\left[\frac{u_{c,s}}{P_s^P}\left(P_s^P\right)^{\varphi-1}\left(M_s + S_s^P M_s^*\right)\right]}; \tag{1.17}$$

$$P_i^{*,C} = P_H^{*,C} = \frac{\varphi}{\varphi - 1} \frac{E_0 \left[u_{c,s} W_s^C M_s^*\right]}{E_0 \left[u_{c,s} S_s^C M_s^*\right]} \text{ vs.} \tag{1.18}$$

$$\underbrace{P_{H,s}^{*,P} \equiv \frac{P_H^P}{S_s^P}}_{\text{LOP}} \quad \Rightarrow \quad \underbrace{P_s^{*,P} = \frac{P_s^P}{S_s^P}}_{\text{PPP}}. \tag{1.19}$$

As evident from (1.19), the price at which Home representative firm's product sells in Foreign under PCP, $P_{H,s}^{*,P}$, depends on the exchange-rate level that has materialized ex-post, S_s^P. In fact, it is LOP applied to the homogeneous good type (differentiated across monopolistically produced brands) in the present context that underlies the above PCP Foreign import price index definition. Moreover as we noted earlier, the price which is preset in the currency of the seller (Home, in the case we comment here) under PCP, P_H^P, becomes state-dependent when converted – via the observed exchange rate, S_s^P – in the currency of the buyer, $P_{H,s}^{*,P}$.

To sum up, the difference between our invoicing conventions boils down to polar implications of exchange-rate pass-through to import prices and, hence, price level indexes. Under CCP, all prices and, thus, the CPIs (P^C and $P^{*,C}$) are fixed across states and pass-through is absent. By contrast, under PCP the price of imported goods moves with the exchange rate, hence so do the CPIs (P_s^P and $P_s^{*,P}$) and pass-through is operating. As we shall see, this is the major channel of monetary shocks transmission – via optimal expenditure switching under PCP but not CCP – along which we distinguish and interpret our model versions under alternative price setting.

Definition of Equilibrium We now formally define an equilibrium concept that corresponds to the described sequential optimization.

Definition 1.1 *In the context of the model versions we presented, an* equilibrium *is a set of quantities and prices, such that:*

1. ***[Ex-Ante Conditions]*** before *the resolution of monetary uncertainty but under common knowledge of the jointly symmetric distribution of money growth shocks* (μ_s, μ_s^*)*;*

   (a) *[Firms Stochastic Optimization] given the technology constraint and the* expected *quantities demanded in the* goods *market,* $\left\{E_0\left[c_{H,s}^C\right], E_0\left[c_{H,s}^{*,C}\right], E_0\left[c_{F,s}^{*,C}\right], E_0\left[c_{F,s}^C\right]\right\}$ *under CCP or* $\left\{E_0\left[c_{H,s}^P\right], E_0\left[c_{H,s}^{*,P}\right], E_0\left[c_{F,s}^{*,P}\right], E_0\left[c_{F,s}^P\right]\right\}$ *under PCP, the prices,* $\left\{P_H^C, P_H^{*,C}, P_F^{*,C}, P_F^C\right\}$ *under CCP or* $\left\{P_H^P, P_F^{*,P}\right\}$ *under PCP, that are optimally preset ex-ante (i.e. in state* 0*) and bindingly posted to consumer households for transactions ex-post (in state* s *for* $\forall s \in S$*) solve the profit maximization problem of the representative producer firm in* Home *as well as in* Foreign*;*

2. ***[Ex-Post Conditions]*** following *the resolution of monetary uncertainty and in any state of nature $s \in S$ that has materialized;*

   (a) *[Households Labor-Leisure Trade-Off] given its constraints and the posted prices,* $\{P_H^C, P_H^{*,C}, P_F^{*,C}, P_F^C\}$ *under CCP or* $\{P_H^P, P_F^{*,P}\}$ *under PCP, the representative consumer household in* Home *as well as in* Foreign *spends up all available cash on its* total *real consumption* $\{c_s, c_s^*\}$*; hours of work (employment)* $\{1 - l_s, 1 - l_s^*\}$ *are supplied by households until firms demand labor to equilibrate ex-post consumption demand for their differentiated products at the resulting equilibrium real wage rates* $\left\{\frac{W_s^C}{P^C}, \frac{W_s^{*,C}}{P^{*,C}}\right\}$ *under CCP and* $\left\{\frac{W_s^P}{P_s^P}, \frac{W_s^{*,P}}{P_s^{*,P}}\right\}$ *under PCP;*

   (b) *[Households Consumer Basket Allocation] given the posted prices,* $\{P_H^C, P_H^{*,C}, P_F^{*,C}, P_F^C\}$ *under CCP or* $\{P_H^P, P_F^{*,P}\}$ *under PCP, the consumption quantities* $\left\{c_{H,s}^C, c_{H,s}^{*,C}, c_{F,s}^{*,C}, c_{F,s}^C\right\}$ *under CCP or* $\left\{c_{H,s}^P, c_{H,s}^{*,P}, c_{F,s}^{*,P}, c_{F,s}^P\right\}$ *under PCP solve the cost minimization problem à la Dixit-Stiglitz (1977) of the representative consumer household in* Home *as well as in* Foreign*;*

   (c) *[Goods Market Clearing] all quantities under CCP or PCP satisfy the feasibility conditions for each* differentiated brand *so that all product-brand markets – and, hence, the* international *product-type market as a whole – clear;*

   (d) *[Forex Market Clearing] the* international *forex market clears as well.*

1.3.2 Equilibrium Nominal Exchange Rate

The simple structure of the model we analyze allows an explicit derivation of the equilibrium nominal exchange rate (NER), S_s.[28] It solves the international forex market clearing condition which states that excess supply of each of the two currencies (expressed in the same monetary unit[29]) is zero for any $s \in S$:[30]

$$\underbrace{P_F^C c_{F,s}^C}_{F \text{ export revenues} \Leftrightarrow HC \text{ supply}} - S_s^C \cdot \underbrace{P_H^{*,C} c_{H,s}^{*,C}}_{H \text{ export revenues} \Leftrightarrow HC \text{ demand}} = 0 \qquad (1.20)$$

$$\text{vs.} \quad S_s^P \cdot \underbrace{P_F^{*,P} c_{F,s}^P}_{H \text{ import demand} \Leftrightarrow HC \text{ supply}} - \underbrace{P_H^P c_{H,s}^{*,P}}_{F \text{ import demand} \Leftrightarrow HC \text{ demand}} = 0. \qquad (1.21)$$

[28] Defined in the usual way as the *Home*-currency price of *Foreign* money.

[29] Taking the currency of H as the common unit of account below.

[30] Note as well that because of symmetry this condition also imposes, in effect, *balanced trade* for both economies no matter the particular state that has materialized.

Substituting for optimal demands above as well as for H and F CPI definitions further on in the algebraic manipulation derives the following *general* expressions for the equilibrium NER under CCP vs. PCP:

$$S_s^C = \frac{1+\left(\frac{P_F^{*,C}}{P_H^{*,C}}\right)^{1-\varphi}}{1+\left(\frac{P_H^C}{P_F^C}\right)^{1-\varphi}}\frac{M_s}{M_s^*} \quad \text{vs.} \quad S_s^P = \frac{1+\left(\frac{S_s^P P_F^{*,P}}{P_H^P}\right)^{1-\varphi}}{1+\left(\frac{\frac{P_H^P}{S_s^P}}{P_F^{*,P}}\right)^{1-\varphi}}\frac{M_s}{M_s^*}. \tag{1.22}$$

Equilibrium NER under Symmetry Under *symmetry*, i.e. with $P_H^C = P_F^{*,C}$, $P_F^C = P_H^{*,C}$, $P^C = P^{*,C}$ under CCP vs. $P_H^P = P_F^{*,P}$, $P_{F,s}^P \equiv S_s^P P_F^{*,P}$, $P_{H,s}^{*,P} \equiv \frac{P_H^P}{S_s^P}$, $P_s^P = S_s^P P_s^{*,P}$ under PCP, the above expressions simplify to

$$S_s^C = \frac{M_s}{M_s^*} \text{ vs. } S_s^P = \left(\frac{M_s}{M_s^*}\right)^{\frac{1}{\varphi}}. \tag{1.23}$$

The equilibrium exchange rate (1.23) under CCP vs. PCP only differs in including or not the key model parameter, $\varphi > 1$. This result implies that, in equilibrium, the NER should be less volatile under PCP than under CCP.[31] In both cases, however, the equilibrium exchange rate is a function of "fundamentals", namely the money stocks in Home and Foreign.

The *more general* formula (1.22) does *not* impose symmetry in order to apply simplifying substitutions relying on *PPP*, $P_s^P = S_s^P P_s^{*,P}$ under PCP or even stronger equations such as, in our CCP case, $P^C = P^{*,C}$. The benefit from looking at (1.22) is that this formula makes evident another principal difference between the price-setting assumptions we study here. In general, the equilibrium exchange rate in a sticky-price model of trade will depend not only on relative money stocks but also on relative price levels resulting from aggregation of the optimally prefixed prices of domestic and foreign brands. This is true for both the cases of CCP and PCP, but the difference is, again, that under PCP import prices are state-dependent, and hence sensitive to (or affected by) the ex-post exchange rate, whereas this is not so under CCP.[32]

Optimal Firm Prices under Symmetry Using (1.7) and its equivalent for Foreign as well as (1.23) under CCP and PCP to substitute for the endogenous variables W_s, W_s^* and S_s in (1.16) through (1.19), the optimal firm prices derived earlier can now be

[31] A point first made by Betts and Devereux (1996). It is also evident that, for a given *symmetric* distribution of money growth shocks, NER volatility will thus be lower under PCP by a magnitude depending directly on the particular value of consumption demand substitutability, φ, or, which is essentially the same, the degree of monopolistic competition, $\frac{\varphi}{\varphi-1}$.

[32] Another parameter that will also, in principle, determine the equilibrium exchange rate in this type of NOEM set-ups could be a nationally-specific elasticity of substitution in consumption, $\varphi \neq \varphi^*$ (or, equivalently, a nationally-specific degree of product market monopolization, $\frac{\varphi}{\varphi-1} \neq \frac{\varphi^*}{\varphi^*-1}$).

fully determined. The final model solutions for prices in terms of exogenous variables and parameters only are thus:

$$P_i^C = P_H^C = \frac{\varphi}{\varphi - 1} P^C \frac{E_0 \left[u_{l,s} M_s \right]}{E_0 \left[u_{c,s} M_s \right]} \text{ vs.}$$

$$P_i^P = P_H^P = \frac{\varphi}{\varphi - 1} \frac{E_0 \left[u_{l,s} \left(P_s^P \right)^{\varphi - 1} \left(M_s + M_s^{\frac{1}{\varphi}} M_s^{*\frac{\varphi - 1}{\varphi}} \right) \right]}{E_0 \left[\frac{u_{c,s}}{P_s^P} \left(P_s^P \right)^{\varphi - 1} \left(M_s + M_s^{\frac{1}{\varphi}} M_s^{*\frac{\varphi - 1}{\varphi}} \right) \right]};$$

$$P_i^{*,C} = P_H^{*,C} = \frac{\varphi}{\varphi - 1} P^{*,C} \frac{E_0 \left[u_{l,s} M_s^* \right]}{E_0 \left[u_{c,s} M_s \right]} \text{ vs.}$$

$$\underbrace{P_{H,s}^{*,P} \equiv \frac{P_H^P}{\left(\frac{M_s}{M_s^*} \right)^{\frac{1}{\varphi}}}}_{\text{LOP}} \quad \Rightarrow \quad \underbrace{P_s^{*,P} = \frac{P_s^P}{\left(\frac{M_s}{M_s^*} \right)^{\frac{1}{\varphi}}}}_{\text{PPP}}.$$

It is easily seen that under *CCP*, as in Bacchetta and van Wincoop (2000 a), the prices set by the Home representative firm domestically, P_H^C, and abroad, $P_H^{*,C}$, will be the same only if $E_0 \left[u_{l,s} M_s \right] = E_0 \left[u_{l,s} M_s^* \right]$. This will always be true under peg, since then M_s^* can be substituted by M_s everywhere in the formulas up to here, but not generally under float. Bacchetta and van Wincoop (2000 a) formally prove, in their Lemma 1 and related Proposition 1, that $E_0 \left[u_{l,s} M_s \right] = E_0 \left[u_{l,s} M_s^* \right]$ and, hence, $P_H^C = P_H^{*,C}$ is true only when utility is *separable* in consumption and leisure. With no costs of trade and separable utility, as we assumed, the prices optimally preset domestically and abroad under CCP and float will therefore be the *same*, due to symmetry, so that $P_H^C = P_H^{*,C} = P_F^C = P_F^{*,C}$.

It is also clear from the respective formula above for Home and the corresponding one for Foreign that under *PCP* and *float*, when just one price is optimally prefixed in each country, in the domestic currency, the two preannounced prices will have the same level, $P_H^P = P_F^{*,P}$, given the symmetry and separability assumed. Yet the respective ex-post PCP prices in the foreign currency, $P_{H,s}^{*,P}$ and $P_{F,s}^P$, will in general not be equal to those preset domestically. The reason is, as we stressed earlier, the equilibrium NER, $\left(\frac{M_s}{M_s^*} \right)^{\frac{1}{\varphi}}$: it enters as a denominator in $P_{H,s}^{*,P}$ but as a numerator in $P_{F,s}^P$. Observe, however, that under PCP and *peg* the domestic-currency prices of home and foreign substitutes faced by consumers in a given country will be the same for any $s \in S$, so that $P_H^P = P_H^{*,P} = P_F^P = P_F^{*,P}$.

A final set of key equations in the model provides, under symmetry, straightforward expressions for some traditional characteristics of international trade. In addition to the trade share in output, considered under CCP in Bacchetta and van Wincoop (2000 a), in the present extension we also discuss an aspect missing in their study but central to understanding the CCP vs. PCP outcomes of our analysis. It concerns the role of international *relative* prices, particularly in affecting the share of trade in output under PCP for both countries and for the *world* as a whole.

1.3.3 Equilibrium Relative Prices

Relative Price of Foreign to Domestic Goods We saw that under CCP – with zero trade costs, jointly symmetric money shocks and separable preferences, as assumed throughout the present chapter – all prices are optimally prefixed in the currency of the buyer at the *same* level: $P_H^C = P_H^{*,C} = P_F^C = P_F^{*,C}$. As a consequence, the relative price of foreign-produced goods in terms of domestically-produced ones in both countries is predetermined at 1:

$$p_H^C \equiv \frac{P_F^C}{P_H^C} = 1 = \frac{P_H^{*,C}}{P_F^{*,C}} \equiv p_F^{*,C} \text{ for } \forall s \in S. \tag{1.24}$$

In such a way, any effects of the ex-post NER on them and, ultimately, on consumer behavior are precluded under CCP.

Under PCP, the prices which firms preannounce in their *domestic* currency have likewise the *same* level across countries, $P_H^P = P_F^{*,P}$. However, the corresponding *foreign*-currency prices obtained via LOP, $P_{H,s}^{*,P}$ and $P_{F,s}^P$, can remain equal to the domestic-currency ones only if some low-probability state of *relative* monetary equilibrium, $s_e \in S_e \subset S$, occurs. In general, the resulting relative prices of foreign-produced goods in terms of domestically-produced ones under PCP are *reciprocal* across countries and reflect directly the ex-post nominal exchange rate:

$$p_{H,s}^P \equiv \frac{\overbrace{S_s^P P_F^{*,P}}^{\equiv P_{F,s}^P}}{P_H^P} = S_s^P = \left(\frac{\overbrace{\frac{P_H^P}{S_s^P}}^{\equiv P_{H,s}^{*,P}}}{P_F^{*,P}} \right)^{-1} \equiv \left(p_{F,s}^{*,P}\right)^{-1} \neq 1 \text{ unless } s_e. \tag{1.25}$$

A depreciation under PCP is therefore passed on to the relative price of domestic and foreign brands. This pass-through induces, in turn, *expenditure switching*, an international spillover channel largely debated in the Mundell-Fleming-Dornbusch tradition and crucial in understanding the different implications of PCP vs. CCP on equilibrium consumption allocations across national outputs. We return to this key transmission mechanism of money shocks later on.

Terms of Trade In our symmetric set-up, the terms of trade (ToT) are *inversely* defined – across countries for the same invoicing convention as well as across price setting assumptions for each of the countries with respect to the nominal exchange rate. Our *CCP* model version thus implies a *negative* relationship between the NER and the ToT: a nominal depreciation *improves* the terms of trade. Just the opposite effect is, however, predicted by our *PCP* model version: the relationship between the NER and the ToT is *positive*, so that a nominal depreciation *weakens* the terms of trade. This is clear from the expressions below, with a definition of the terms of trade as the price of imports divided by the price of exports.

$$(ToT)_{H,s}^{C} \equiv \frac{P_F^C}{S_s^C P_H^{*,C}} = \frac{1}{S_s^C} = \left(\frac{P_H^{*,C}}{\frac{P_F^C}{S_s^C}}\right)^{-1} \equiv \left[(ToT)_{F,s}^{*,C}\right]^{-1} \neq 1 \text{ unless } s_e \text{ vs.} \tag{1.26}$$

$$(ToT)_{H,s}^{P} \equiv \frac{P_{F,s}^P}{P_H^P} = \frac{S_s^P P_F^{*,P}}{P_H^P} = S_s^P = \left(\frac{\frac{P_H^P}{S_s^P}}{P_F^*}\right)^{-1} \equiv \left[(ToT)_{F,s}^{*,P}\right]^{-1} \neq 1 \text{ unless } s_e. \tag{1.27}$$

This latter result is in line with Obstfeld-Rogoff's (2000) correlation approach of checking for pricing-to-market in macrodata.[33]

Real Exchange Rate In compliance with the PPP literature, our *PCP* model results in a real exchange rate (RER) that is *constant* (across states of nature), at 1:

$$(RER)_H^P \equiv \frac{S_s^P P_s^{*,P}}{P_s^P} = \frac{P_s^P}{P_s^P} = 1 = \frac{P_s^{*,P}}{P_s^{*,P}} = \frac{\frac{P_s^P}{S_s^P}}{P_s^{*,P}} \equiv (RER)_F^{*,P} \text{ for } \forall s \in S. \tag{1.28}$$

On the other hand, our *CCP* version leads to a RER that moves *one-to-one* with the NER (across states of nature), as consistent with the higher RER volatility implied by PTM-based models:

$$(RER)_{H,s}^C \equiv \frac{S_s^C P^{*,C}}{P^C} = S_s^C = \left(\frac{\frac{P^C}{S_s^C}}{P^{*,C}}\right)^{-1} \equiv \left[(RER)_{F,s}^{*,C}\right]^{-1} \neq 1 \text{ unless } s_e. \tag{1.29}$$

1.3.4 Equilibrium Consumption and Leisure across Countries

To better understand the implications of the microfounded two-country framework we study for CCP vs. PCP trade flows, we now have to first consider its equilibrium outcomes across price setting in terms of the ingredients of the utility function, namely consumption and leisure. Our essential points are summarized below in their logical order. Proofs are straightforward, based largely on earlier definitions and derivations, and are not included.

[33] Our theoretical point here is the subject of related empirical work in Chapter 3.

Relative Consumption Dividing the invoicing-specific equilibrium consumption expressions, c_s and c_s^*, one finds that *relative* real consumption is ultimately determined by the *relative* money stock, *no matter* the particular *price setting* assumed. To put it differently, it is national money shocks and, consequently, relative money stocks (or relative "wealth" in our simple NOEM framework) that really matter – via demand and trade – for ex-post real consumption differences across the ex-ante symmetric countries.

Consumption Switching Dividing now our invoicing-specific equilibrium expressions for $c_{H,s}$ and $c_{F,s}$, we arrive at a result with important consequences for our conclusions in the present first chapter. Under *CCP* the optimal allocation of real consumption between demand for domestic and foreign goods is always evenly split-up (50 : 50), whereas under *PCP* it is ultimately determined by the *relative* money stock. This principal difference between our model versions originates in the fact that CCP precludes consumption substitution across borders, while under PCP such substitution, i.e. expenditure switching, is optimal. The result is of major importance for understanding our equilibrium trade share outcomes across price-setting assumptions, to be discussed in more detail later on. It implies that in the *CCP* model version a monetary expansion – coordinated under peg or unilateral under float – does *not* induce any *bias* in goods consumption. In the *PCP* case with float, by contrast, a monetary expansion in one of the countries results – by depreciating (appreciating, for the other country) the equilibrium exchange rate, making imports more expensive (cheaper) and inducing substitution away from (into) them – in a *bias in both countries* favoring consumption of the goods produced in the *expansionary* country.

Relative Leisure Dividing finally the invoicing-specific equilibrium real output expressions, $y_s \equiv c_{H,s} + c^*_{H,s}$ and $y^*_s \equiv c^*_{F,s} + c_{F,s}$, and making use of our two results above, we derive that under *CCP* equilibrium output, employment and leisure (but not consumption) are always equal across countries, whereas under *PCP* output, employment and leisure (as well as consumption) are ultimately determined by the *relative* money stock. The basic intuition is that under CCP – when there is optimally no consumption switching away from the preferred even (50 : 50) split-up – the two countries always produce the *same* real quantities of *output*, no matter the particular state of nature that has occurred. Because of the identical technologies, the two countries employ the *same* amount of *labor*. Therefore, the hours of *leisure* the representative household in Home and in Foreign enjoys – residually, due to the demand-determined output and, hence, labor input – under CCP are always the *same* too. By contrast, under PCP – when consumers switch to the cheaper product due to the now operating pass-through and expenditure-switching channel – the two countries do *not* produce the *same* real quantities of *output*, unless some state of nature of relative monetary equilibrium has materialized. Due to the identical technologies again, the two countries do *not* employ the *same* amount of *labor*. Consequently, the hours of *leisure* in Home and in Foreign under PCP are generally *not* the *same* either.

1.3.5 Equilibrium Trade Flows

Trade Shares by Country Under CCP vs. PCP, the Home equilibrium (i.e. ex-post) *foreign trade* / GDP ratio in each state of nature $s \in S$ is defined by

$$(ft)^C_{H,s} \equiv \frac{(Ex)^C_{H,s} + (Im)^C_{H,s}}{(DA)^C_{H,s} + (Ex)^C_{H,s}} = \frac{S^C_s \cdot P^{*,C}_H \cdot c^{*,C}_{H,s} + P^C_F \cdot c^C_{F,s}}{P^C_H \cdot c^C_{H,s} + S^C_s \cdot P^{*,C}_H \cdot c^{*,C}_{H,s}} \text{ vs.} \tag{1.30}$$

$$(ft)^P_{H,s} \equiv \frac{(Ex)^P_{H,s} + (Im)^P_{H,s}}{(DA)^P_{H,s} + (Ex)^P_{H,s}} = \frac{P^P_H \cdot c^{*,P}_{H,s} + \overbrace{S^P_s \cdot P^{*,P}_F}^{\equiv P^P_{F,s}} \cdot c^P_{F,s}}{P^P_H \cdot c^P_{H,s} + P^P_H \cdot c^{*,P}_{H,s}}, \tag{1.31}$$

where $(Ex)^C_{H,s}$ denotes Home exports, $(Im)^C_{H,s}$ Home imports and $(DA)^C_{H,s}$ Home domestic absorption, all these three Home-currency *values* (prices multiplied by quantities) under CCP and in any state $s \in S$ that has materialized. $(Ex)^P_{H,s}$, $(Im)^P_{H,s}$ and $(DA)^P_{H,s}$ are, of course, the respective PCP values.

Substitutions for optimal demands and use of the Home CPI definition derive – under frictionless-trade *symmetry* and *separable* preferences – the CCP vs. PCP *trade share curve* for Home:

$$(ft)^C_H = \frac{2}{\left(\frac{P^C_H}{P^{*,C}_H}\right)^{1-\varphi} + 1} = \frac{2}{\left(\frac{E_0\left[u_{l,s} M_s\right]}{E_0\left[u_{l,s} M^*_s\right]}\right)^{1-\varphi} + 1} = const = 1 \text{ vs.} \tag{1.32}$$

$$(ft)^P_{H,s} = \frac{2}{\left(\frac{P^P_s}{P^{*,P}_s}\right)^{\varphi-1} + 1} = \frac{2}{(S^P_s)^{\varphi-1} + 1} = \frac{2}{\left(\frac{M_s}{M^*_s}\right)^{\frac{\varphi-1}{\varphi}} + 1} \neq 1 \text{ unless } s_e. \tag{1.33}$$

These two equations compare directly the impact of our alternative price-setting assumptions on trade, measured relative to output.[34] Under CCP, the *equilibrium* trade share is constant at 1 in each country and in any state of nature that has materialized. Under PCP, this is not generally the case: national trade-to-output ratios now both become state-dependent, i.e. volatile.

To see the intuition behind, assume some state of Home *relative* monetary expansion $s_H \in S_H \subset S$, with $M_{s_H} > M^*_{s_H}$, and compare the numerator and denominator in (1.30) under float. Under CCP, *no substitution* occurs between domestic and foreign brands of the same product type we model here, due to the preset *buyer*'s currency

[34] The first equality in the formulas expresses the trade/GDP ratio as a function of *price levels*. The last equality is, in turn, the reduced-form version which expresses trade relative to output as a function of the *exogenous variables*.

prices and the resulting foreign/domestic relative price *equality* across countries highlighted in (1.24). That is why the additional (or excessive, with respect to Foreign) Home cash in the observed state of nature splits up evenly (50 : 50) into a domestic demand increase and an import demand increase: $(DA)^C_{H,s_H} \uparrow = (Im)^C_{H,s_H} \uparrow$. Thus, the denominator in (1.30) changes by the same amount as the numerator, and the trade/output ratio remains constant (across states).

Under PCP, by contrast, prices are prefixed in the currency of the *seller*. Therefore, the observed nominal exchange rate affects import prices and, hence, consumer price levels, in effect partly "flexibilizing" our otherwise fix-price model. The ex-post NER feeds on into the foreign/domestic relative price *reciprocity* across countries highlighted in (1.25). This key ratio is now state-dependent and, in turn, influences optimal consumer decisions on cross-border *substitution*[35] in output demand. Home import demand falls as more expensive imports resulting from the depreciated exchange rate (relative to its ex-ante equilibrium of 1) are substituted away and into domestic analogues so that domestic demand rises, as well as Home exports, for the same (or rather symmetric) reason applied to Foreign importing households: $(Im)^P_{H,s_H} \downarrow = (Ex)^P_{H,s_H} \uparrow = (DA)^P_{H,s_H} \uparrow$. Thus, the denominator in (1.31) goes up whereas the numerator stays flat, as rising exports and falling imports compensate *exactly* each other in *value*, due to the symmetry and forex market clearing imposed.[36] The equilibrium trade share in Home is consequently less than its CCP magnitude of 1, and the trade share in Foreign is more than 1, following a Home *relative* monetary expansion.

To illustrate the interpretation suggested above, we present in Figure 1.3 the *PCP trade share curves* for Home, equation (1.33), and for Foreign, given by the corresponding analogous equation, according to a baseline computation we have performed setting $\varphi = 11$. This latter value of the elasticity of substitution in consumption demand is consistent with a markup $\frac{\varphi}{\varphi-1}$ of 10%, a largely consensual estimate in empirical studies. For completeness, we have also studied the cases of a very elastic demand, $\varphi = 101$, which corresponds to a tiny markup of only 1% as in Figure 1.4 and of almost inelastic demand, $\varphi = 2$, corresponding to a huge markup of 100% as in Figure 1.5. The graphs show the frictionless trade share in output $(ft)^P_s$ (on the vertical axis) under PCP, float and symmetry as a function of the equilibrium nominal exchange rate S^P_s or, ultimately, the underlying relative money stock $\left(\frac{M_s}{M^*_s}\right)^{\frac{1}{\varphi}}$ (on the horizontal axis).

A comparison among the reported three cases indicates that the *degree* of substitutability $\varphi > 1$ across the individualized brands that nations exchange within the

[35] Whose *degree* depends on the particular value of the key *elasticity* parameter $\varphi > 1$.

[36] So that the trade balance is always *zero* in both countries, no matter the state of nature that has occurred, as noted earlier.

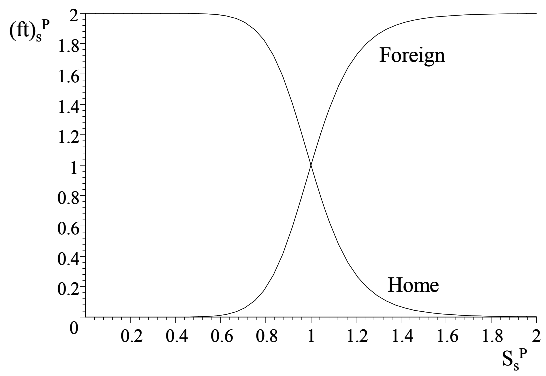

Figure 1.3: PCP Trade Share Curves under "Usual" Monopolistic Competition (for a markup of 10%, i.e. $\varphi = 11$)

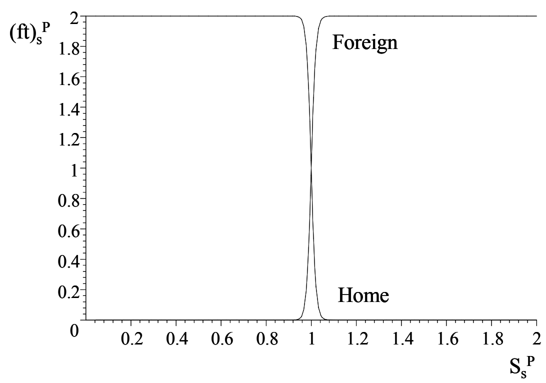

Figure 1.4: PCP Trade Share Curves under Near-Perfect Competition (for a markup of 1%, i.e. $\varphi = 101$)

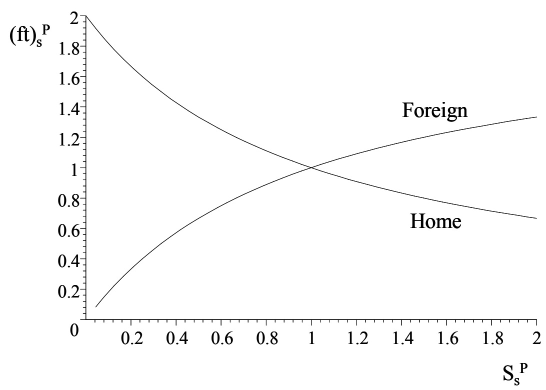

Figure 1.5: PCP Trade Share Curves under High Monopolistic Competition (for a markup of 100%, i.e. $\varphi = 2$)

same type of good under PCP trade – or, alternatively, the *degree* of imperfect competition identified by the monopolistic markup $\frac{\varphi}{\varphi-1} > 1$ charged over price – matters a lot in related research. In particular, PCP trade share curves are much flatter and more curved in the vicinity of 1 – of interest here, with small money shocks to comply with price stickiness – under *low* substitutability and *highly monopolized* world market structure relative to the "normal" situation ($\varphi = 11$). By contrast, these same curves are almost vertical and straight in the *near* vicinity of 1 with *high* substitutability and competition *close to perfect.*

World Trade Share We now state an important result from our analysis, as a first proposition. A proof for the less evident PCP case is given in Appendix A.

Proposition 1.1 *(Equilibrium World Trade-to-Output) No matter the particular price-setting model version, equilibrium trade-to-output is state-invariant for the world economy as a whole.*

Under CCP, from (1.32) and the symmetric equation for Foreign, $(ft)_F^{*,C} = 1 = (ft)_H^C$ so that (equally-weighted) world trade in terms of world output is obviously constant at 1.[37] Under PCP, by contrast, the Home and Foreign trade shares are state-dependent and not equal to each other and to 1, unless relative monetary equilibrium occurs (in some state $s_e \in S_e \subset S$). Nevertheless, the proof of Proposition 1.1 under PCP provided in Appendix A verifies that although relative monetary expansion under float increases equilibrium trade-to-GDP in one country, it decreases in the same proportion trade-to-GDP in the other country. Thus, in our model of frictionless trade under symmetry and separability, the world trade share always remains constant at 1, irrespective of the particular price-setting assumption.

1.4 Effects of the Exchange-Rate Regime

Making further use of the equilibrium solutions under float we characterized thus far, the present section turns to the implications of a peg, and therefore of the alternative exchange-rate regimes we study here, for international trade prices and flows. Our regime comparisons discussed below are made along two dimensions, namely with respect to *ex-post (equilibrium)* and *ex-ante (expected)* trade measures. The reason is that when evaluating float vs. peg under (monetary) uncertainty it is the expected levels of the relevant variables, i.e. integrated over the entire distribution of shocks, that can be meaningfully compared, the ex-post ones being stochastic, i.e. state-specific. We saw, however, that some equilibrium model outcomes – in particular, those concerning the share of nominal trade in nominal output *by country* – were not

[37] This latter equality does not, however, mean that real consumption is equal in the two countries, which will be true only under equal money growth rates in a given state of nature $s_e \in S_e \subset S$, as made clear earlier.

necessarily state-dependent, and whether they were or not depended on the currency of invoicing assumed. Moreover, the equilibrium solutions are a necessary first step in deriving the expected level ones. That is why we also retain in what follows the ex-post dimension of our analysis.

1.4.1 Comparative Synthesis of Equilibrium Results

Table 1.1 captures in a synthetic form the effects we evoked up to now. It compares the *equilibrium* model outcomes under a *flexible* exchange-rate regime across the alternative price-setting conventions studied.

	CCP	PCP
NER	$S^C_s = \frac{M_s}{M^*_s} \neq 1$ unless s_e	$S^P_s = \left(\frac{M_s}{M^*_s}\right)^{\frac{1}{\varphi}} \neq 1$ unless s_e
relative prices		
foreign/home	$p^C_H = p^{*,C}_F = 1$	$\overbrace{p^P_{H,s} = \left(p^{*,P}_{F,s}\right)^{-1} = S^P_s =}^{\neq 1 \text{ unless } s_e}$
ToT	$(ToT)^C_{H,s} = \frac{1}{(ToT)^{*,C}_{F,s}} = \frac{1}{S^C_s} =$	$\overbrace{= (ToT)^P_{H,s} = \frac{1}{(ToT)^{*,P}_{F,s}}}^{\neq 1 \text{ unless } s_e}$
RER	$= \frac{1}{(RER)^C_{H,s}} = (RER)^{*,C}_{F,s} \neq 1$ unless s_e	$(RER)^P_H = (RER)^{*,P}_F = 1$
consumption		
relative	$c^C_s \neq c^{*,C}_s$ unless s_e	$c^P_s \neq c^{*,P}_s$ unless s_e
split-up	$\frac{c^C_{H,s}}{c^C_{F,s}} = \frac{c^{*,C}_{F,s}}{c^{*,C}_{H,s}} = 1, \forall s$	$1 \neq \frac{c^P_{H,s}}{c^P_{F,s}} \neq \frac{c^{*,P}_{F,s}}{c^{*,P}_{H,s}} \neq 1$ unless s_e
aggregates	$c^C_{H,s} = c^C_{F,s} \neq c^{*,C}_{H,s} = c^{*,C}_{F,s}, \forall s$	$c^P_{H,s} \neq c^P_{F,s} \neq c^{*,P}_{H,s} \neq c^{*,P}_{F,s}$ unless s_e
labor/leisure		
employment	$n^C_s = n^{*,C}_s, \forall s$	$n^P_s \neq n^{*,P}_s$ unless s_e
leisure	$l^C_s = l^{*,C}_s, \forall s$	$l^P_s \neq l^{*,P}_s$ unless s_e
trade-to-output		
by country	$(ft)^C_H = (ft)^{*,C}_F = 1$	$\overbrace{(ft)^P_{H,s}}^{\neq 1} \neq \overbrace{(ft)^{*,P}_{F,s}}^{\neq 1}$ unless s_e
world	$\frac{1}{2}(ft)^C_H + \frac{1}{2}(ft)^{*,C}_F = 1$	$\frac{1}{2}(ft)^P_{H,s} + \frac{1}{2}(ft)^{*,P}_{F,s} = 1, \forall s$

Table 1.1: Equilibrium Results under Float

Similarly, Table 1.2 provides a compact account of our CCP vs. PCP *equilibrium* findings under a *fixed* exchange-rate regime, i.e. with $M_s \equiv M^*_s$ for $\forall s \in S$. It helps clarify in an explicit manner the parallels and divergencies with regard to the corresponding float results in Table 1.1.

	CCP	PCP
NER	$S_s^C = \frac{M_s}{M_s} = 1, \forall s$	$S_s^P = \left(\frac{M_s}{M_s}\right)^{\frac{1}{\varphi}} = 1, \forall s$
relative prices		
foreign/home ToT RER	*same* as under float $(ToT)_H^C = (ToT)_F^C = S^C =$ $= (RER)_H^C = (RER)_F^C = 1$	$p_H^P = p_F^{*,P} = S^P =$ $= (ToT)_H^P = (ToT)_F^P = 1$ *same* as under float
consumption		
relative split-up aggregates	$c_s^C = c_s^{*,C}, \forall s$ *same* as under float $c_{H,s}^C = c_{F,s}^C = c_{H,s}^{*,C} = c_{F,s}^{*,C}, \forall s$	$c_s^P = c_s^{*,P}, \forall s$ $\frac{c_{H,s}^P}{c_{F,s}^P} = \frac{c_{F,s}^{*,P}}{c_{H,s}^{*,P}} = 1, \forall s$ $c_{H,s}^P = c_{F,s}^P = c_{H,s}^{*,P} = c_{F,s}^{*,P}, \forall s$
labor/leisure		
employment leisure	*same* as under float *same* as under float	$n_s^P = n_s^{*,P}, \forall s$ $l_s^P = l_s^{*,P}, \forall s$
trade-to-output		
by country world	*same* as under float *same* as under float	$(ft)_H^P = (ft)_F^P = 1$ *same* as under float

Table 1.2: Equilibrium Results under Peg

On the basis of these two comparative tables, we finally discuss the impact of alternative exchange rate-regimes on trade prices and flows, given CCP or PCP.

1.4.2 Relative Prices under Peg

As far as the key international prices are concerned, a peg makes a difference with respect to a float in that it ensures all three relative prices we considered – the foreign/domestic output price, the ToT and the RER – to be equal to 1, i.e. to the *fixed* NER (cf. tables 1.1 and 1.2) not only ex-ante (in expectation) but also ex-post (in equilibrium) in any realized state. Consequently, Home as well as Foreign agents perceive these prices, in particular the first one, in the same *neutral* way which does not induce substitutions in consumption via pass-through and expenditure switching. Under float and *CCP* (see Table 1.1), this is not generally the case for the ToT and the RER, no matter that the relative price of foreign-produced goods in terms of domestic goods is always predetermined at 1 (so that the expenditure-switching channel is inoperative). Under float and *PCP* (see again Table 1.1), it is not generally the case for this latter relative price (so that now NER pass-through induces optimal expenditure switching) and for the ToT, no matter that the equilibrium RER is always 1, due to PPP.

1.4.3 Expected Trade Flows

As far as expected *world* trade-to-output is concerned, an immediate consequence of Proposition 1.1 is stated in the following corollary.

Corollary 1.1 *(Expected World Trade-to-Output) No matter the particular price-setting model version, the exchange-rate regime cannot affect expected* world *trade-to-output.*

The proof is straightforward: the *expected* world trade share, i.e. integrated over the whole distribution of money shocks, will be 1 under float as well as under peg because the *equilibrium* world trade-to-output is 1 in all states of nature.

We next verify, as a second proposition, the "decomposition" *by country* of the above world-economy result. A proof for the less obvious PCP case is given in Appendix A.

Proposition 1.2 *(Expected National Trade-to-Output) No matter the particular price-setting model version, the exchange-rate regime cannot affect expected trade-to-output in* any *of the countries.*

Under CCP, equation (1.32) showed that the value of trade is equal to the value of output in each of the national economies, irrespective of the state of nature that has materialized. To put it differently, both trade and output by country do vary in *value* across states, but under CCP when there is no consumption switching this variation is in the same direction and proportion so that their *ratio* always remains constant, at 1 under frictionless trade with symmetry and separable preferences. Therefore, equilibrium as well as expected national trade-to-output is state-invariant at 1 under CCP:

$$E_0\left[(ft)_H^C\right] = E_0\left[(ft)_F^C\right] = E_0\left[1\right] = 1. \tag{1.34}$$

Taking expectations from the equilibrium trade share formulas under PCP with float, (1.33) for Home and the corresponding equation for Foreign, is shown in Appendix A to derive the same conclusion:

$$E_0\left[(ft)_{H,s}^P\right] = 1 = E_0\left[(ft)_{F,s}^P\right], \quad s \in S. \tag{1.35}$$

Thus, in the context of our model, expected trade-to-output by country is 1 under PCP too.

To sum-up, our alternative assumptions on invoicing and monetary arrangements are neutral to *expected* trade-to-output (by country as well as for the world as a whole), the *relevant* measure to compare them under uncertainty.

However, there is one essential way, valid only under (some degree of) PCP, in which the exchange-rate regime does matter for trade in our set-up. It is that a peg then eliminates – by preventing any exchange-rate pass-through on relative prices and, hence, by shutting down the expenditure-switching channel – trade-to-output *variability* across states of nature. This interesting PCP effect of the exchange-rate regime on trade volatility is highlighted next, as a second corollary. Its proof is evident from just looking at the trade share formula (1.33) for Home (and, by analogy, for Foreign) under peg.

Corollary 1.2 *(Trade-Output Equalization under PCP with Peg) A fixed exchange-rate regime under PCP guarantees equilibrium trade to* equal *output in any of the countries.*

Note that, given our assumptions, trade-output equalization obtains always under CCP even with float, so a peg is in that case not needed to bring about such a result. Yet under both CCP and PCP a peg will also equalize relative consumption and, hence, relative utility across states of nature.

1.5 Concluding Comments

The objective of this first chapter of the dissertation was to analyze the implications of alternative price setting in evaluating the effects of the exchange-rate regime on international trade. The recent NOEM modelling approach underlying much related research has provided a modern toolkit to revisit this classic but still controversial issue. To study it within an appropriate framework, we essentially extended Bacchetta and van Wincoop's (2000 a) stochastic "benchmark monetary model" based on consumer's currency pricing (CCP) to a producer's currency pricing (PCP) version as well. We then provided an explicit parallel how these polar price-setting conventions affect equilibrium trade prices and flows and the role of the exchange-rate regime.

Our analysis confirmed in a broader context that a peg does not necessarily imply a higher trade share in output relative to a float, for any of the two identical countries, or currency blocs, modelled as well as for the world economy as a whole. With symmetry, only monetary shocks, frictionless trade and separable utility – as assumed throughout the chapter – the exchange-rate regime does not matter for the *expected level* of trade-to-output ratios across nations, irrespective of the price-setting convention. This important result was explicitly derived from microfoundations and formally proved. We also pointed out that once nominal rigidity is distinguished across open-economy invoicing practices, a comparison of exchange-rate regimes is nevertheless meaningful under (some degree of) *PCP*, although not (full) CCP, in terms of the *volatility* of the relative price faced by consumers and, hence, national trade shares. More precisely, the equilibrium trade share *by country* becomes state-dependent under PCP, although it is still constant at 1 for the *world* as a whole, just like in the CCP model version. There is, thus, an effect of a peg under (some) PCP, absent under (full) CCP, in *stabilizing* across states of nature equilibrium trade-to-output in each of the economies at its expected level of 1.

We identified the difference in the impact of exchange-rate regimes on national trade share variability as originating in the currency denomination of transactions and, hence, the *exchange-rate pass-through* implied by our alternative price-setting model versions. Consequently, the expenditure-switching channel functions well under (even partial) PCP but not at all under (complete) CCP. In analyzing this difference from the perspective of microfoundations, we also came up with a few results on consumption and leisure across countries that have not been highlighted in the NOEM or earlier literature. We stressed, in particular, that under *both* CCP and PCP relative real consumption is determined in equilibrium by the relative money stock, although in a different way. Another key finding is that the optimal allocation of real consumption between demand for domestic and foreign goods is evenly split-up (50 : 50) under *CCP* no matter the state of nature, so any kind of monetary expansion – coordinated under peg or unilateral under float – does not induce switching in the consumption of cross-country output. Under *PCP*, this optimal split-up depends instead on the relative money stock in the realized state. Thus, a monetary expansion under float in one of the economies results in a bias in both economies favoring consumption of the goods produced in the expansionary economy. Finally, we also established that equilibrium output, employment and, ultimately, leisure (but not consumption) are always the same across countries under *CCP*, whereas under *PCP* they are determined (as well as consumption) by the relative money stock and are therefore not equal between nations unless in the case of relative monetary equilibrium. A peg would thus equalize consumption and, hence, utility across countries in any state of nature.

We are, of course, aware of the many limitations of the NOEM set-up we employed as a baseline in this first chapter of the dissertation. We would not repeat them here, since we have kept an honest account of them in the relevant parts of the main text and in the numerous footnotes. These limitations, however, constitute avenues for future research and could be addressed with more realism in subsequent extensions. One possible such extension is developed in the next chapter.

Chapter 2

When and How Much Does a Peg Increase Trade? The Role of Trade Costs and Import Demand Elasticity

2.1 Introduction

The literature that has directly or indirectly addressed the question whether the exchange-rate regime matters for trade has not arrived yet at a satisfactory answer. A fixed exchange rate has often been claimed to substantially increase trade, mostly on empirical grounds and notably in Rose (1999), as far as recent research is concerned. But in theoretical work focusing on monetary uncertainty under high substitutability of cross-country output and no trade costs, Bacchetta and van Wincoop (2000 a) have warned that this is not necessarily the case. In related analysis in the preceding chapter, still under frictionless trade, we have furthermore shown that alternative modelling of the currency of price setting in open economies with nominal rigidity implies certain distinction among the trade effects of the exchange-rate regime. Our main point was that under (complete) consumer's currency pricing (CCP), as assumed in the quoted paper by Bacchetta and van Wincoop, a peg versus float does not matter for trade prices and, hence, flows because the pass-through and expenditure-switching channel of the international transmission of money shocks is closed. However under (some degree of) producer's currency pricing (PCP), when pass-through and expenditure switching are operating, a peg can stabilize trade-to-output *variability.* Nevertheless it cannot, neither can a float, increase the *expected* trade share in GDP, irrespective of the assumed currency of price stickiness.

The objective of the present second chapter of this dissertation is thus to examine further the effects of the exchange-rate regime on trade prices and flows in a more careful manner, by also looking into some of their key *non-monetary* determinants. Wishing to achieve analytical clarity in uncovering the mechanisms of such effects as well as direct comparability with earlier results, we build on the "baseline" stochastic new open-economy macroeconomics (NOEM) set-up in chapter 1. But a major import of chapter 2 is that it embeds trade in similar vs. different output mixes within a *common* theoretical framework, at the same time taking an explicit account of the implications of impediments to cross-border transactions under alternative invoicing, namely CCP vs. PCP; whereas the previous literature, classic as well as NOEM, has usually modelled in separation either trade of differentiated brands belonging to the same homogeneous product[1] or trade arising from complete specialization in the production of just one national good-type.[2] Our unified approach becomes feasible, it is true, at the cost of a highly stylized environment, by essentially attributing the primary cause of the international exchange of goods to identical tastes for diversity and not to Ricardian comparative advantage in productivity. Nevertheless, our microfounded general-equilibrium parallel of consumer's to producer's currency pricing under monetary uncertainty and costs of cross-border transactions has provided valuable insights into trade determination, in particular about the role of nominal and real factors in it. In essence, it has permitted us to derive and interpret conditions when a peg would dominate a float in generating more expected trade-to-output and when a float would do that instead.

It turns out from the present second chapter that the effects of the exchange-rate regime on both expected trade shares and their variability ultimately depend on whether import demand is elastic or inelastic, once an international trade friction and distinct cross-country substitutability have been explicitly incorporated, like we do here, into the baseline NOEM set-up of chapter 1. In a preview of our principal findings, we could say that, first, with production of *similar* brands national trade shares in GDP drastically fall relative to the case of costless exchange. The reason is that obstacles to trade such as distance or tariffs induce a home bias in consumption, much stronger under CCP than under PCP, in the optimal behavior of agents with identical tastes. A major contribution is to show that this home bias is, however, considerably mitigated to more empirically relevant levels by each of two additional features of our model: (i) allowing for production of *different* output mixes, i.e. for inelastic import demand, under (even full) CCP; (ii) allowing for (even partial) PCP, which introduces expenditure switching to the cheaper nationally-specific good, determined by the particular realization of the nominal exchange rate under float and to the extent this is feasible given cross-country output substitutability. But the most important result chapter 2 derives is that, unlike in the frictionless-trade NOEM research, the exchange-rate regime affects under (some) PCP *expected* trade-to-output, in a way

[1] As in Obstfeld-Rogoff (1995, 1998, 2000, 2001) models, to quote just the earliest NOEM examples.

[2] As in Corsetti-Pesenti (1997, 2001 a, b, 2002) extensions, under unit substitutability across national good-types, of the original Obstfeld-Rogoff framework.

depending on the *interaction* of trade costs with the degree of substitutability between the nationally-produced composites: under *elastic* demand of similar products a peg reduces expected trade-to-output relative to a float, in both economies we study and, hence, for the world as a whole; under demand which is *inelastic* because of complete specialization in two different but equally-valued good-types, a peg slightly increases expected trade-to-output relative to a float. Another new point from our analysis in the present chapter is that non-monetary factors such as transport or tariff frictions and the substitutability of output mixes also determine, via the optimally arising consumption bias, *both* the expected level and the variability of trade-to-GDP. As to the trade stabilization a peg can achieve under (some degree of) PCP, a contribution of chapter 2 is to clarify that its extent would be greater for countries, or currency blocs, which produce less substitutable good-types for meaningful costs of exchanging them and are located closer to one another or apply weaker restrictions in their bilateral trade.

The chapter is further down organized as follows. Section 2.2 outlines our extended stochastic NOEM model of exchange rate and trade determination and highlights the differences in its initial assumptions under CCP vs. PCP. The third section studies under symmetry and float how *trade costs* and distinct *type* and *brand* consumption substitutabilities affect international relative prices and, consequently, agents' optimization and the resulting equilibrium relationships across our alternative invoicing. Section 2.4 then focuses on the effects of the *nominal* exchange-rate regime on both the expected level and the variability of trade-to-output ratios, whereas the fifth section clarifies the role played by their *real* determinants. Section 2.6 concludes and appendices B.1 and B.2 contain, respectively, a detailed derivation of our key equilibrium expressions and the proofs of propositions.

2.2 The Extended Model

In this section, we explain how our two extensions in chapter 2, the "transport" cost friction and the distinct cross-country substitutability, have been analytically integrated within the baseline set-up of chapter 1.

As in chapter 1, the representative household in Home[3] maximizes utility:

$$\underset{c_s, l_s}{Max} \quad u(c_s, l_s), \quad \forall s \in S. \tag{2.1}$$

But c_s is now defined in a more general way, as we shall discuss soon.

In this representative agent economy, the aggregate constraints on (per-)household behavior coincide with those of the identical households. They remain the same as in chapter 1, so we do not repeat them here.

[3] The notation in which the model is further on set out generally refers to Home, but for Foreign symmetric relationships hold (unless otherwise stated).

As in the first chapter, production is effected by firms which are owned by *domestic* households only. We likewise continue to abstract here from an international stock market and of risk-sharing issues in general. To simplify this initial NOEM analysis of trade in similar vs. different output mixes within a *unified* framework, we focus in this second chapter on identical technologies in terms of labor input for producing a unit of output – although national endowments may differ – common to all firms in Home and Foreign. In H it is:

$$y_s = n_s = 1 - l_s, \quad \forall s \in S. \tag{2.2}$$

As the production function is identical across countries, international trade does not arise in the model from comparative advantage but from the equal preference to consume each of the national good-types. Although Ricardian trade theory is, certainly, important for an analysis like ours, it will complicate matters here and is left for future work. For the same reason, productivity shocks are abstracted away in the present chapter as well.[4]

2.2.1 Incorporating Iceberg Costs

Although heavily exploited in many NOEM models, the key *pricing-to-market* (PTM) assumption – which changes crucially their equilibrium outcomes – has not yet received an explicit and solid grounding within this line of literature. To rationalize *market segmentation* and the ensuing *possibility* for PTM behavior by monopolistically competitive firms, we now introduce *symmetric* costs of international trade in goods, $\tau\,(\equiv \tau^*)$, in the set-up under CCP vs. PCP analyzed in chapter 1. Following Obstfeld and Rogoff's (2001) NOEM application of ideas in the traditional literature,[5] we model them as being of the "iceberg" type, i.e. real losses in transit expressed in per cent of the quantity shipped: $0 \leq \tau < 1$. Although we model our τ parameter in a quite literal, "melting iceberg" fashion, we would nevertheless wish to interpret it in a much more general context, essentially capturing all kinds of frictions or impediments to international trade (or transaction costs, in a still broader sense). These may normally range from obstacles of a subjective (policy) nature such as tariff and non-tariff barriers to considerations of an objective (physical) character such as transport costs that are themselves a function of distance and transportation technology.

[4] Within the (New-)Keynesian modelling perspective of which we make use here this is not so unusual since output is anyway demand-determined.

[5] Exogenous real *"iceberg" costs* of international trade originate in the modelling approach common to the Ricardian comparative advantage trade and payments theory: to mention just the most prominent classic studies, in Samuelson (1952) and Samuelson (1954). Transport costs of that type are assumed too in the seminal paper by Dornbusch, Fisher and Samuelson (1977) and its NOEM interpretations in Obstfeld and Rogoff (1996: Chapter 4, Section 5, pp. 235-257) and Kraay and Ventura (2002). Trading frictions, not necessarily modelled as iceberg costs, have also recently been employed outside NOEM, by Martin and Rey (2000), Sercu and Uppal (2000), Parsley and Wei (2000) and Betts and T. Kehoe (2001), among others.

In both our CCP and PCP versions, the iceberg cost parameter $\tau \in [0, 1)$ enters the model via firms' production cost structure. Under this assumption a fixed fraction τ of each good shipped abroad "melts" in transit. Therefore firms have to also produce the *additional output* that is eventually lost when crossing the "ocean", given that there is demand corresponding to the remaining (i.e. "surviving") part of the output produced for export. A wedge of τ is consequently driven between output *produced* and output *consumed* in *real* terms. For a *real* (*Foreign*) import demand of $c^*_{i,s}$, a *Home* firm $i \in [0, 1]$ must ensure (and hence, produce) a *real* (*Home*) export supply of $\frac{c^*_{i,s}}{1-\tau}$.[6] A simple calculation shows why: a real quantity of $\frac{c^*_{i,s}}{1-\tau}$ is produced and shipped abroad from which only $c^*_{i,s}$ arrives and is consumed. The difference,

$$\frac{c^*_{i,s}}{1-\tau} - c^*_{i,s} = \tau \frac{c^*_{i,s}}{1-\tau}, \tag{2.3}$$

"melts" in transit, so *real* losses due to such a trade friction are a constant fraction τ of the amount shipped by the exporting producer.

2.2.2 Distinguishing Brand from Type Substitutability

The original NOEM set-up, e.g. Obstfeld-Rogoff (1995, 2000) or Bacchetta-van Wincoop (1998, 2000 a, b), was one of frictionless trade and a unique consumption substitutability. Subsequent contributions, such as Corsetti-Pesenti (1997, 2001 a, b, 2002), Obstfeld-Rogoff (1998), Galí-Monacelli (2002) and, notably, Tille (1998 a, b, 2000 a, 2002), have extended it to include a second parameter, determining cross-country output substitutability, but have assigned to it a *unitary* value. To allow for a richer setting, in the present paper we relax the latter restriction, although under symmetry. Our model thus involves two distinct substitutability parameters – see (2.4) below: $\varphi\,(\equiv \varphi^*) > 1$, the elasticity of substitution between any two nationally-produced *differentiated brands*, and ν, with $0 \leq \nu \leq \varphi > 1$, the elasticity of substitution between the *composite good-types* across countries. The good-type is, in effect, the nationally-specific output mix, itself an aggregation of all domestically produced brands.

Such a substitutability decomposition proves to be a useful analytical device. It allows us to distinguish trade between countries producing the same, but *diversified* across brands, output type (under $\nu \equiv \varphi > 1$ as in chapter 1) from trade between countries *specializing* in only one of two different output types, each diversified across *national* brands (under $\nu < \varphi > 1$ as in the present chapter). In a more general sense or as a metaphor, we could refer to these alternative extremes as complete *diversification* of (world) production and complete *specialization* of (national) production, respectively. Our model thus conveniently nests two conceptually different types of international trade, namely the exchange of *similar* vs. *different* "output mixes". To our knowledge, they have not been explicitly compared within a coherent framework in

[6] The logic for a *Foreign* firm $i^* \in (1, 2]$ is, certainly, symmetric.

the existing literature, with Tille (2002) providing a very recent exception. Although retaining the usual NOEM restriction of unit substitutability, Tille's (2002) analysis allows for even greater generality than our second chapter by introducing two sectors in each of the two countries and by varying sectors' relative size. Yet he does not explore how transport costs and non-unitary substitutability of national output composites influence trade prices and flows, which we do here.

In both our CCP and PCP versions, the substitutability parameters ν and φ enter the model via the symmetric *preference* structure embodied in the real consumption aggregator, (2.4) for Home:

$$c_s \equiv \left\{ \left(\frac{1}{2}\right)^{\frac{1}{\nu}} \left[\left(\int_0^1 c_{i,s}^{\frac{\varphi-1}{\varphi}} di \right)^{\frac{\varphi}{\varphi-1}} \right]^{\frac{\nu-1}{\nu}} + \left(\frac{1}{2}\right)^{\frac{1}{\nu}} \left[\left(\int_1^2 c_{i^*,s}^{\frac{\varphi-1}{\varphi}} di^* \right)^{\frac{\varphi}{\varphi-1}} \right]^{\frac{\nu-1}{\nu}} \right\}^{\frac{\nu}{\nu-1}} . \quad (2.4)$$

Following NOEM modelling tradition, φ is assumed to be *larger* than 1, as was explained in chapter 1. In general, we further down assume that $0 < \nu < \varphi > 1$. Such an assumption seems the appropriate one in our stylized context. The reason is that $\nu < \varphi$ implies that there is less substitutability across the aggregate national outputs of the two countries than between any two differentiated brands produced in each of these countries, because of naturally (geographically) predetermined complete national *specialization* in production. Consumption substitutability is thus *lower across types than across brands* in the unified international trade framework we study.[7] Moreover unlike φ, ν is not restricted to the elastic region of its domain only, a feature that is related to some lasting debates in the empirical trade and development literature[8] and that has important theoretical implications in our further analysis.

2.3 Costly Trade under CCP vs. PCP

In this section, we compare across our *invoicing-specific* model versions and under *float* and *symmetry* the optimization problems agents solve and the resulting equilibrium. In particular, the outcomes for the exchange-rate level, international relative prices, cross-country consumption and leisure allocations and, ultimately, some key measures of trade flows are derived and interpreted.

[7] In the special case of $\nu \equiv \varphi > 1$, our two elasticity parameters coincide so that the set-up reduces to world production of the same homogeneous good type *diversified* across brands, as in chapter 1.

[8] A number of studies have argued that world demand for many products, in particular primary commodities, is income- and price-inelastic. This has also been advanced as a major explanation behind the secular decline in the terms of trade of the exporting nations of such goods. Todaro and Smith (2002), p. 522, for instance, refer to World Bank (1994), Table 2.5, to claim that the elasticity of demand for foodstuffs with respect to income changes in developed countries is 0.6% and of agricultural raw materials such as rubber and vegetable oils 0.5%.

2.3.1 Optimization and Equilibrium

Consumption Demands and Price Levels Standard cost minimization à la Dixit-Stiglitz (1977) of (2.4) defines the optimal demands of the Home representative household for H- (equations (2.5) below) and F-produced ((2.6) below) goods and the respective Home price indexes at the domestic absorption (equations (2.7)), import demand (2.8) and consumer (2.9) levels for the CCP vs. PCP model versions[9] as follows:

$$c_{H,s}^{C} = \frac{1}{2}\left(\frac{P_H^C}{P^C}\right)^{-\nu}\frac{M_s}{P^C} \quad \text{vs.} \quad c_{H,s}^{P} = \frac{1}{2}\left(\frac{P_H^P}{P_s^P}\right)^{-\nu}\frac{M_s}{P_s^P}; \tag{2.5}$$

$$c_{F,s}^{C} = \frac{1}{2}\left(\frac{P_F^C}{P^C}\right)^{-\nu}\frac{M_s}{P^C} \quad \text{vs.} \quad c_{F,s}^{P} = \frac{1}{2}\left(\frac{\overbrace{\frac{S_s^P P_F^{*,P}}{1-\tau}}^{\equiv P_{F,s}^P}}{P_s^P}\right)^{-\nu}\frac{M_s}{P_s^P}; \tag{2.6}$$

with

$$P_H^C \equiv \left[\int_0^1 \left(P_i^C\right)^{1-\varphi} di\right]^{\frac{1}{1-\varphi}} \quad \text{vs.} \quad P_H^P \equiv \left[\int_0^1 \left(P_i^P\right)^{1-\varphi} di\right]^{\frac{1}{1-\varphi}}; \tag{2.7}$$

$$P_F^C \equiv \left[\int_1^2 \left(P_{i^*}^C\right)^{1-\varphi} di^*\right]^{\frac{1}{1-\varphi}} \quad \text{vs.} \quad \underbrace{\frac{S_s^P P_F^{*,P}}{1-\tau}}_{\equiv P_{F,s}^P} \equiv \left[\int_1^2 \underbrace{\left(\frac{S_s^P P_{i^*}^{*,P}}{1-\tau}\right)^{1-\varphi}}_{\equiv P_{i^*,s}^P} di^*\right]^{\frac{1}{1-\varphi}}; \tag{2.8}$$

$$P^C \equiv \left[\frac{1}{2}\left(P_H^C\right)^{1-\nu} + \frac{1}{2}\left(P_F^C\right)^{1-\nu}\right]^{\frac{1}{1-\nu}} \quad \text{vs.} \tag{2.9}$$

$$P_s^P \equiv \left[\frac{1}{2}\left(P_H^P\right)^{1-\nu} + \frac{1}{2}\underbrace{\left(\frac{S_s^P P_F^{*,P}}{1-\tau}\right)}_{\equiv P_{F,s}^P}^{1-\nu}\right]^{\frac{1}{1-\nu}}.$$

Output Prices The expected market value of real profits which a H firm $i \in [0,1]$ maximizes under CCP vs. PCP is defined by:

[9] Indicated by a superscript of C or P, respectively. For more deatils on our invoicing-specific notation see the relevant section of chapter 1.

$$\underset{P_i^C, P_i^{*,C}}{Max} E_0 \left[\frac{u_{c,s}}{P^C} \underbrace{\left(P_i^C c_{i,s}^C + S_s^C P_i^{*,C} c_{i,s}^{*,C} - W_s^C c_{i,s}^C - \frac{W_s^C c_{i,s}^{*,C}}{1-\tau} \right)}_{\equiv \Pi_{i,s}^C} \right], s \in S \tag{2.10}$$

$$\text{vs. } \underset{P_i^P}{Max} E_0 \left[\frac{u_{c,s}}{P_s^P} \underbrace{\left(P_i^P c_{i,s}^P + \frac{P_i^P c_{i,s}^{*,P}}{1-\tau} - W_s^P c_{i,s}^P - \frac{W_s^P c_{i,s}^{*,P}}{1-\tau} \right)}_{\equiv \Pi_{i,s}^P} \right], s \in S. \tag{2.11}$$

Using the first order conditions of the two problems, the CCP vs. PCP optimal prices preset by the Home firm i, which is also the representative Home firm, for consumer households in the domestic and foreign market are thus, respectively:

$$P_i^C = P_H^C = \frac{\varphi}{\varphi - 1} \frac{E_0 \left[u_{c,s} W_s^C M_s \right]}{E_0 \left[u_{c,s} M_s \right]} \text{ vs.} \tag{2.12}$$

$$P_i^P = P_H^P = \frac{\varphi}{\varphi - 1} \frac{E_0 \left[\frac{u_{c,s}}{P_s} W_s \frac{M_s}{P_s^{1-\nu}} \right] + (1-\tau)^{\nu-1} E_0 \left[\frac{u_{c,s}}{P_s} W_s \frac{S_s M_s^*}{(S_s P_s^*)^{1-\nu}} \right]}{E_0 \left[\frac{u_{c,s}}{P_s} \frac{M_s}{P_s^{1-\nu}} \right] + (1-\tau)^{\nu-1} E_0 \left[\frac{u_{c,s}}{P_s} \frac{S_s M_s^*}{(S_s P_s^*)^{1-\nu}} \right]}; \tag{2.13}$$

$$P_i^{*,C} = P_H^{*,C} = \frac{1}{1-\tau} \frac{\varphi}{\varphi - 1} \frac{E_0 \left[u_{c,s} W_s^C M_s^* \right]}{E_0 \left[u_{c,s} S_s^C M_s^* \right]} \text{ vs.} \tag{2.14}$$

$$P_{H,s}^{*,P} = \frac{P_H^P}{S_s^P (1-\tau)} \quad \Rightarrow \quad \underbrace{P_s^{*,P} = \left[\frac{1 + \left(\frac{1}{1-\tau} \frac{1}{S_s^P} \right)^{1-\nu}}{1 + \left(\frac{1}{1-\tau} S_s^P \right)^{1-\nu}} \right]^{\frac{1}{1-\nu}} P_s^P}_{\text{PPP-}\textit{reminiscent}\text{ equation}}. \tag{2.15}$$

As in chapter 1, under PCP the exchange-rate pass-through to import prices is *operating*, while under CCP it is *zero*.[10] For the same reason, the (Home) CPI is constant under CCP, P^C, but state-dependent under PCP, P_s^P. With transport cost and distinct cross-country substitutability incorporated in the extended model of the present chapter, one should observe the following modifications in the corresponding formulas. First, because of τ, pass-through on import prices under PCP is not *unitary* anymore (like it was in chapter 1) but higher – see the PCP expression in (2.8). Second, equations (2.6) show that, irrespective of the invoicing assumption, import demand now optimally depends on τ as well, via the prices P_F^C and $P_{F,s}^P$.[11] Note

[10] Compare the invoicing-specific equations in (2.8).

[11] The CCP export market price for Foreign, P_F^C, is optimally preannounced at a level symmetric to expression (2.14) for the analogous price for Home, $P_H^{*,C}$.

that under both CCP and PCP τ enters the *consumer* price (cif) but this latter price is preset under CCP in the currency of the destination market, while under PCP it is the price *excluding* transportation costs (fob) which is preset in the national currency of the producer. Consequently, the corresponding PCP *consumer* price becomes sensitive to the exchange rate and is, in such a way, "flexibilized". Third, optimal consumer demands (2.5) and (2.6) reveal that it is now ν that matters for cross-country substitution, although φ is still important in the determination of CPIs.[12]

The cost of international exchange, τ, is thus ultimately passed on to consumers, via the effective consumer-relevant price, but in a different way under the alternative invoicing conventions we study. Under *CCP* it is passed on to importing foreign consumer-households via the price charged directly in *foreign* currency. The exchange-rate risk is nevertheless borne by domestic producing firms, because of their preset export-market prices. Under *PCP* the trade cost is passed on to importing foreign consumer-households too, but now the mechanism is not the same. It consists in buying, at the price charged in the *seller's* currency, the equivalent – including the output to be lost in transit – of the quantity of imports optimally demanded. Then the buyer loses τ% of the shipped quantity, so that he effectively consumes less in *real* terms than the amount paid for.[13]

As evident from (2.15), the price at which Home representative firm's product sells in Foreign under PCP, $P^{*,P}_{H,s}$, depends on the exchange-rate level, S^P_s. But unlike the frictionless, unique substitutability case analyzed in chapter 1, PPP does not hold anymore in the present PCP model version with costly trade. Nevertheless, there is still an equation reminiscent of PPP, with a much more complicated function replacing the exchange rate. Observe in (2.15) that, once trade frictions are accounted for, CPIs can be equalized only under peg, implying $S^P_s = \frac{1}{S^P_s} = 1$ for $\forall s \in S$ as will be shown later.

Equilibrium The constrained optimization problems agents solve and the market clearing conditions for the world economy, given the invoicing and timing assumptions of our stochastic NOEM framework, lead to an equilibrium concept consistent with the described environment. Since it is not essentially different from the one in our first chapter, we do not repeat its definition. The equilibrium solutions for the macrovariables we are interested in are discussed in the following subsections.

2.3.2 Equilibrium Nominal Exchange Rate

As in chapter 1, the equilibrium nominal exchange rate (NER) solves the international *forex market clearing* condition in any state of nature $s \in S$. Given the *full symmetry* we assumed, i.e. with $P^C_H = P^{*,C}_F$, $P^C_F = P^{*,C}_H$, $P^C = P^{*,C}$ under CCP vs. $P^P_H = P^{*,P}_F$,

[12] Which becomes clear from the price level formulas (2.7) through (2.9) above.

[13] An alternative interpretation could be that importing households pay a *higher* "true" price for the consumed quantity, because they also buy the quantity lost in transit and thus not consumed.

$P_{F,s}^{P} \equiv \frac{S_s^P P_F^{*,P}}{1-\tau}$, $P_{H,s}^{*,P} \equiv \frac{P_H^P}{(1-\tau)S_s^P}$, $P_s^P = \left[\frac{1+\left(\frac{1}{1-\tau}S_s^P\right)^{1-\nu}}{1+\left(\frac{1}{1-\tau}\frac{1}{S_s^P}\right)^{1-\nu}} \right]^{\frac{1}{1-\nu}} P_s^{*,P}$ under PCP[14] it can be derived to be[15]

$$S_s^C = \frac{M_s}{M_s^*} \text{ vs. } S_s^P = \left[\frac{1+(1-\tau)^{1-\nu}\left(S_s^P\right)^{1-\nu}}{(1-\tau)^{1-\nu}+\left(S_s^P\right)^{1-\nu}} \right]^{\frac{1}{\nu}} \left(\frac{M_s}{M_s^*}\right)^{\frac{1}{\nu}}. \tag{2.16}$$

The exchange rate expression (2.16) under CCP, S_s^C, is exactly the same as the one in our first chapter, so under full symmetry neither transport cost nor distinct substitutability considerations affect CCP NER determination in equilibrium. The reason is that import prices, relevant to consumers, are preset independently from the ex-post NER at the same level relative to domestic prices in Home and in Foreign. However, the equilibrium PCP exchange rate, S_s^P, is now given by a more complicated (although again implicit) function reflecting the role of τ and ν in household decisions on how to split-up their state s budget across the national good-types. Our brief explanation here will soon become clearer.

With a fixed exchange-rate regime, i.e. when $M_s \equiv M_s^*$ for $\forall s \in S$, the CCP NER obviously becomes 1. The PCP NER expression in (2.16) also reduces to a unique solution of 1 once S_s^P is restricted to be a positive real number (as it should be for an exchange rate), yet this is not directly evident from the formula above.[16] So in the present context with an iceberg friction and two distinct substitutabilities a *peg* implies again that – under CCP as well as under PCP and ex-post as well ex-ante – the exchange rate can be substituted by 1 in all expressions which contain it. We shall exploit this finding further on, in discussing the effects of a fixed exchange-rate regime on trade prices and flows.

Optimal Firm Prices under Full Symmetry Using (1.7) and its equivalent for Foreign as well as (2.16) to substitute for the endogenous variables W_s, W_s^* and S_s in (2.12) through (2.15), the optimal firm prices derived earlier can now be fully determined under CCP and (via the implicit function giving the equilibrium NER) PCP. The final model solutions for prices in terms of exogenous variables and parameters are thus, respectively:

$$P_i^C = P_H^C = \frac{\varphi}{\varphi-1} P^C \frac{E_0\left[u_{l,s}M_s\right]}{E_0\left[u_{c,s}M_s\right]} \text{ vs.}$$

$$P_i^P = P_H^P = \frac{\varphi}{\varphi-1} \frac{E_0\left[u_{l,s}\frac{M_s}{P_s^{1-\nu}}\right] + (1-\tau)^{\nu-1}E_0\left[u_{l,s}\frac{S_s M_s^*}{(S_s P_s^*)^{1-\nu}}\right]}{E_0\left[\frac{u_{c,s}}{P_s}\frac{M_s}{P_s^{1-\nu}}\right] + (1-\tau)^{\nu-1}E_0\left[\frac{u_{c,s}}{P_s}\frac{S_s M_s^*}{(S_s P_s^*)^{1-\nu}}\right]};$$

[14] With also $\nu < \varphi \equiv \varphi^* > 1$ and $0 < \tau \equiv \tau^* < 1$ in both model versions.
[15] See Appendix B.1.1.
[16] See Appendix B.1.1.

$$P_i^{*,C} = P_H^{*,C} = \frac{1}{1-\tau}\frac{\varphi}{\varphi-1}P^{*,C}\frac{E_0\left[u_{l,s}M_s^*\right]}{E_0\left[u_{c,s}M_s\right]} \text{ vs.}$$

$$P_{H,s}^{*,P} = \frac{P_H^P}{S_s^P\left(1-\tau\right)} \quad \Rightarrow \quad \underbrace{P_s^{*,P} = \left[\frac{1+\left(\frac{1}{1-\tau}\frac{1}{S_s^P}\right)^{1-\nu}}{1+\left(\frac{1}{1-\tau}S_s^P\right)^{1-\nu}}\right]^{\frac{1}{1-\nu}} P_s^P}_{\text{PPP-}\textit{reminiscent}\text{ equation}}.$$

It is easily seen that under *CCP* the prices set by the Home representative firm domestically, P_H^C, and abroad, $P_H^{*,C}$, will generally not be the same with now nonzero iceberg costs $0 < \tau < 1$ even if $E_0\left[u_{l,s}M_s\right] = E_0\left[u_{l,s}M_s^*\right]$ is true, as it is under *separable* utility in consumption and leisure. It is also clear that under *PCP* and float when just one price, in the domestic currency, is optimally prefixed in each country, the two preannounced prices in the model will have the same level, $P_H^P = P_F^{*,P}$ (given symmetry and separability, again). Yet the respective ex-post PCP prices in the foreign currency, $P_{H,s}^{*,P}$ and $P_{F,s}^P$, will in general not be equal to those preset domestically, as obvious from the last equation above. Observe as well that in the presence of iceberg costs ($0 < \tau < 1$), a *peg* will *never* guarantee that the relevant (ex-post) prices of home and foreign goods agents in both countries face under CCP as well as under PCP are the same, i.e. that $P_H^C = P_H^{*,C} = P_F^C = P_F^{*,C}$ and $P_H^P = P_H^{*,P} = P_F^P = P_F^{*,P}$. This is a result very different from – in a sense, opposite to – what one would obtain in the frictionless model version considered in the first chapter.

We are now ready to derive – under full symmetry and separable utility – expressions for some traditional characteristics of international trade, which we interpret below.

2.3.3 Equilibrium Relative Prices

Let us begin by comparing across our invoicing conventions the three most important pairs of international relative prices. This analysis will help us later in understanding the channel along which optimal consumption – and, hence, trade – flows are determined in the extended NOEM set-up of chapter 2.

Relative Price of Foreign to Domestic Goods With costly trade under (full) CCP, the relative price of foreign-produced goods in terms of domestically-produced ones in both countries is still *preannounced* at the *same* level, as it was in chapter 1. Instead of being 1, this level is now $\frac{1}{1-\tau}$, once a symmetric iceberg friction has also been introduced. In such a way, no matter whether trade is costless or costly, any effects of the ex-post values of this key international relative price on consumer behavior are *precluded* under CCP:

$$p_H^C \equiv \frac{P_F^C}{P_H^C} = \frac{1}{1-\tau} = \frac{P_H^{*,C}}{P_F^{*,C}} \equiv p_F^{*,C} \text{ for } \forall s \in S. \tag{2.17}$$

Under PCP, the relative price of foreign-produced goods in terms of domestically-produced ones is generally *not reciprocal* across countries anymore, as it was in our frictionless baseline, just because of the *nonzero* iceberg costs ($\tau \neq 0$):

$$p_{H,s}^{P} \equiv \frac{\overbrace{\frac{S_s^P P_F^{*,P}}{1-\tau}}^{\equiv P_{F,s}^P}}{P_H^P} = \frac{S_s^P}{1-\tau} \neq \frac{1}{S_s^P(1-\tau)} = \frac{\overbrace{\frac{P_H^P}{S_s^P(1-\tau)}}^{\equiv P_{H,s}^{*,P}}}{P_F^{*,P}} \equiv p_{F,s}^{*,P} \text{ unless } S_s^P = 1. \tag{2.18}$$

This latter result is new in NOEM. The transmission mechanism of money shocks abroad uncovered in (2.18) plays an important role in the interpretation of the principal contribution of this second chapter, as we shall explain later.

Terms of Trade With $0 < \tau < 1$, the terms of trade (ToT) are still *inversely* defined with respect to our symmetric *countries* under CCP, like it was in the baseline model without trade frictions in chapter 1, but not anymore under PCP. However, the *inverse* relationship in the ToT definitions across *price setting* in terms of the exchange rate remains valid in the present extended set-up too. This is clear from the expressions below.

$$(ToT)_{H,s}^{C} \equiv \frac{P_F^C}{S_s^C P_H^{*,C}} = \frac{1}{S_s^C} = \left(\frac{P_H^{*,C}}{\frac{P_F^C}{S_s^C}}\right)^{-1} \equiv \left[(ToT)_{F,s}^{*,C}\right]^{-1} \neq 1 \text{ unless } S_s^P = 1 \tag{2.19}$$

$$\text{vs. } (ToT)_{H,s}^{P} \equiv \frac{P_{F,s}^P}{P_H^P} = \frac{\frac{S_s^P P_F^{*,P}}{1-\tau}}{P_H^P} = \frac{S_s^P}{1-\tau} \neq \frac{1}{S_s^P(1-\tau)} =$$

$$= \frac{\frac{P_H^P}{S_s^P(1-\tau)}}{P_F^*} \equiv (ToT)_{F,s}^{*,P} \text{ unless } S_s^P = 1. \tag{2.20}$$

The result in (2.20) is new as well. It implies that once transport costs are considered in a model assuming PCP, state-dependent NER deviations from the initial symmetric equilibrium of $S_0 = 1$ are *magnified* in the terms of trade a country faces. In other words, the equilibrium PCP ToT should be *more volatile* (across states of nature) than the underlying PCP NER once a symmetric trade friction is considered in a stochastic NOEM context like the one we analyze. By contrast, with $\tau = 0$ under PCP or even with $\tau \neq 0$ under CCP, the volatility of the ToT is exactly the same as that of the NER, which is evident from (2.19) and (2.20).

Real Exchange Rate With $0 < \tau < 1$, PPP now fails, as we noted earlier. Yet both our PCP and CCP versions imply a *real* exchange rate (RER) that is *inversely* defined across *countries*, as it was in the CCP frictionless baseline:

$$(RER)^P_{H,s} \equiv \frac{S^P_s P^{*,P}_s}{P^P_s} = \frac{(1-\tau)S^P_s+1}{(1-\tau)+S^P_s} =$$

$$= \left(\frac{\frac{P^P_s}{S^P_s}}{P^{*,P}_s}\right)^{-1} \equiv \left[(RER)^{*,P}_{F,s}\right]^{-1} \neq 1 \text{ unless } S^P_s = 1 \text{ vs.} \tag{2.21}$$

$$(RER)^C_{H,s} \equiv \frac{S^C_s P^{*,C}}{P^C} = S^C_s = \left(\frac{\frac{P^C}{S^C_s}}{P^{*,C}}\right)^{-1} \equiv \left[(RER)^{*,C}_{F,s}\right]^{-1} \neq 1 \text{ unless } S^P_s = 1. \tag{2.22}$$

2.3.4 Equilibrium Consumption and Leisure across Countries

Having looked at CCP vs. PCP international relative prices in equilibrium, we now turn to the corresponding cross-country real allocations. Our main results are summarized below in logical order. Their proofs are straightforward, based largely on earlier definitions and derivations, and are not included.

Relative Consumption Dividing – as we did in chapter 1 – the invoice-specific equilibrium consumption expressions, c_s and c^*_s, one finds that under costly trade in the present chapter 2 *relative* real consumption is ultimately determined again by the *relative* money stock. But under *PCP* and not CCP, *trade costs* and *import demand elasticity* influence as well the equilibrium allocation across countries of the quantities consumed. An important modification in the conclusions with respect to our initial set-up in chapter 1 is that it is now a *richer* parameter set, (τ, ν) compared to only φ earlier, which pins down relative consumption under PCP in any state of nature $s \in S$. In particular, the elasticity of consumption demand relevant to imports is the *cross-country* one, ν with $0 \leq \nu < \varphi > 1$, and not the substitutability across the homogeneous product brands, $\varphi > 1$, as in our initial study. What is novel here, as also mentioned earlier, is that ν is defined over a larger domain, including in addition the region of import demand *in*elasticity as well as the case of *unit* elasticity, $0 \leq \nu \leq 1 < \varphi$. This finding has insightful consequences for our analysis to which we shall return in more detail later.

Home Bias and Consumption Switching Dividing now our invoice-specific equilibrium expressions for $c_{H,s}$ and $c_{F,s}$, we arrive at a result with prime importance for our study. With *positive* (symmetric) trade costs and *non-zero* cross-country output substitutability, the optimal split-up of real consumption between demand for domestic ($c_{H,s}$, for Home) and foreign ($c_{F,s}$, for Home) goods always results under CCP in a (symmetric) *home bias* in both countries, $(1-\tau)^{-\nu} > 1$, *invariant* across states of nature. Under PCP, by contrast, this split-up is ultimately determined by the *equilibrium nominal exchange rate*, through the induced optimal consumption switching in any state of nature that has materialized, $\left(S_s^P\right)^{\nu}(1-\tau)^{-\nu}$ for Home and $\left(S_s^P\right)^{-\nu}(1-\tau)^{-\nu}$ for Foreign.

Now with iceberg costs, *import substitution* is generally *optimal* not only under PCP when there is exchange rate pass-through but also – and much more – under CCP when there isn't. Consequently, under CCP with costly trade in *similar* output mixes and even full symmetry, there will always be a *home* bias (identical for the two countries), unless (i) $\tau = 0$ or (ii) $\nu = 0$. This home bias under *elastic* import demand and *unique* consumption substitutability, across brands of a *homogeneous* good-type, $(1-\tau)^{-\varphi}$, is a positive function of τ and $\varphi(\equiv \nu) > 1$. Due to the trading friction, $\tau \neq 0$, foreign-produced goods become more expensive, hence less demanded, than their nationally-produced (close) substitutes. These conclusions are also valid under costly trade in *different* composite outputs (when $\nu < \varphi > 1$) with CCP but not with PCP. In that latter case, the consumption bias is not necessarily also a home bias for both countries in all states of nature.

Evidence for a home bias in goods consumption has often been found in applied work, and is thus empirically relevant. The theoretical reasons proposed to explain it have usually been associated with either transaction costs or structural or informational asymmetries. The NOEM literature has only recently started to integrate such a feature into its mainstream set-up. Warnock (2003), for example, imposes it via *heterogeneous preferences* of households. In our analytical framework here the home bias originates in the optimal behavior of economic agents when facing a trade friction, as Obstfeld and Rogoff (2001) first did within NOEM (under unit cross-country substitutability). The realistic home bias *rationalized* by incorporating iceberg costs into a fully symmetric two-country economy *and nuanced* across trade/output compositions and price-setting conventions is another novel feature within NOEM modelling, to which we have contributed with this chapter.

Relative Leisure It follows from our two results highlighted above that under costly trade equilibrium output, employment and leisure are not generally equal across nations, no matter the price-setting convention. The intuition is that, since output is demand-determined up to *exhausting* the CiA constraint in any state of nature and technologies are assumed *identical*, the two countries do not generally produce the same quantities and do not employ the same labor in equilibrium. Hence, the hours of leisure the representative households residually enjoy in Home and in Foreign are in general not the same either.

2.3.5 Equilibrium Trade Flows

In this subsection we interpret *equilibrium trade-to-output*, derived under our alternative invoicing assumptions with shipment losses in Appendix B.1.2.

Trade Shares by Country It is shown in the mentioned appendix that the *iceberg-cost augmented* trade share curve for Home under CCP vs. PCP is given by

$$(ft)_H^C = \frac{2}{(1-\tau)^{1-\nu}+1} = const \lesseqgtr 1 \text{ for } \nu \gtreqless 1 \text{ vs.} \tag{2.23}$$

$$(ft)_{H,s}^P = \frac{2}{(1-\tau)^{1-\nu}\underbrace{\left[\left(\frac{M_s^*}{M_s}\right)^{\frac{1}{1-2\nu}}\left(\frac{P_s^P}{P_s^{*,P}}\right)^{\frac{1-\nu}{1-2\nu}}\right]}_{=S_s^P}^{\nu-1}+1} \neq const \text{ unless } S_s^P = 1. \tag{2.24}$$

The corresponding curves for Foreign are, of course, symmetric:

$$(ft)_F^C = \frac{2}{(1-\tau)^{1-\nu}+1} = const \lesseqgtr 1 \text{ for } \nu \gtreqless 1 \text{ vs.} \tag{2.25}$$

$$(ft)_{F,s}^P = \frac{2}{(1-\tau)^{1-\nu}\underbrace{\left[\left(\frac{M_s^*}{M_s}\right)^{\frac{1}{1-2\nu}}\left(\frac{P_s^P}{P_s^{*,P}}\right)^{\frac{1-\nu}{1-2\nu}}\right]}_{=S_s^P}^{1-\nu}+1} \neq const \text{ unless } S_s^P = 1. \tag{2.26}$$

The above equations compare directly the impact of our alternative price-setting assumptions on the ratio of nominal trade to nominal output.

Under CCP, (2.23) and (2.25) show that the equilibrium trade share is a state-*invariant* function (implicitly) of the relative price of domestic goods in terms of foreign ones, $1-\tau$ (cf. (2.17)) and the home bias, $(1-\tau)^{-\nu}$, and (explicitly) of their deeper "fundamentals", τ and ν. Moreover, CCP trade-to-output is the *same* for the two countries in any state of nature that has materialized. However, with positive iceberg costs it is not 1 anymore, as in the frictionless baseline of chapter 1, unless cross-country output substitutability is *unitary.* For *elastic* import demand, $\nu > 1$, CCP trade-to-output ratios are smaller than 1 in both economies, due to costly trade and high substitutability. If import demand is instead *inelastic*, $\nu < 1$, CCP trade shares are larger than 1, because of the identical taste for both goods which are now, under national specialization of production, practically not substitutable no matter the costs of their exchange.

Under PCP, by contrast, equilibrium trade-to-output ratios by country are *not* state-invariant, as clear from (2.24) and (2.26). Trade-to-output can be 1 in both economies only with *unitary* import substitutability, similarly to the CCP case. Otherwise, PCP trade shares are *decreasing* in the *own* NER under elastic import demand but *increasing* in the *own* NER under demand inelasticity.

This analysis helps highlighting the role played by each of our three key ingredients of the NOEM model developed in the present second chapter, namely the NER, trade costs and cross-country substitutability. In addition to the home bias originating in costly trade under CCP, $(1-\tau)^{-\nu}$, it is the equilibrium exchange rate, S_s^P, that induces under PCP and float – by means of its *pass-through* on import and, ultimately, consumer-relevant relative prices, $\frac{S_s^P}{1-\tau}$ for Home and $\frac{1}{S_s^P(1-\tau)}$ for Foreign – the optimally arising *expenditure switching* , $\left(S_s^P\right)^{\nu}(1-\tau)^{-\nu}$ for Home and $\left(S_s^P\right)^{-\nu}(1-\tau)^{-\nu}$ for Foreign, away from the home bias allocation under CCP: toward domestic products in the country having experienced currency depreciation (or relative monetary expansion) and toward foreign products in the country with appreciating currency (or relative monetary contraction). But just because of τ (for any given ν), demand for domestic goods in the country of depreciation is now *stronger* than that for foreign goods in the country of appreciation, which would not be the case in a frictionless model. Finally, ν (for any given τ) determines *how strong* (or rather how feasible) this cross-country output substitution is, in any state of nature that has materialized.

World Trade Share We now state an important result from our analysis as a first proposition. A proof is provided in Appendix B.2.

Proposition 2.1 *(Equilibrium World Trade-to-Output) With iceberg costs and flexible exchange rates, equilibrium trade-to-output for the world economy as a whole is constant under CCP; but state-dependent under* PCP*, and* always lower *than its peg level when import demand is* inelastic*:*

$$(ft)_{W,s}^P = \frac{1}{1+(1-\tau)^{1-\nu}\left(S_s^P\right)^{1-\nu}} + \frac{\left(S_s^P\right)^{1-\nu}}{(1-\tau)^{1-\nu}+\left(S_s^P\right)^{1-\nu}}, \forall s \in S \neq M_s = M_s^*.$$

The formula in Proposition 2.1 makes it obvious that under PCP and float the world trade/GDP ratio, $(ft)_{W,s}^P$, is a function of the NER, S_s^P, in any state of nature, whereas it was state-invariant at 1 in the frictionless case of chapter 1. Note also that a constant PCP world trade share, $\frac{2}{(1-\tau)^{1-\nu}+1}$ as under costly trade with CCP or peg, obtains only under a *fixed* exchange-rate regime, i.e. $S_s^P = 1, \forall s$. In two other, analytically important cases, much exploited in the NOEM literature, the above constant further reduces to 1: (i) *frictionless* trade, i.e. $\tau = 0$, and (ii) *unit* cross-country output substitutability, i.e. $\nu = 1$.

From the formula above it becomes clear too that under *inelastic* import demand, i.e. for $0 < \nu < 1$, with PCP and float the world trade share in output integrated over the symmetric distribution of monetary shocks is always lower than 1 and will therefore be *less* than the same expected trade measure under peg, itself always higher than 1. In other words, a peg would increase expected trade relative to float whenever demand is inelastic. An analogous conclusion for the elastic case is, however, not evident from the formula in Proposition 2.1. We return to the issue of whether and how the exchange-rate regime matters for *expected* trade in Proposition 2.2.

2.4 Does the Exchange-Rate Regime Matter for Trade?

Making further use of the CCP vs. PCP equilibrium solutions under a symmetric iceberg friction and two distinct substitutabilities affecting consumption demand we characterized thus far, the present section focuses on the implications of the alternative *monetary* arrangements we study for international trade prices and flows. We analyze both the *expected* level of trade-to-output ratios (by country and for the world economy as a whole), the relevant measure of trade under *uncertainty*, and their *variability* across states of nature.

2.4.1 When Does a Peg Increase Trade-to-Output?

Trade-to-Output under CCP (with Float or Peg) Under (full) *CCP* with *float*, we derived national trade shares to be independent of the nominal exchange rate and, ultimately, of relative money stocks. CCP equilibrium trade-to-output ratios are thus invariant across states of nature and coincide with their expected level. A *peg* under (full) *CCP* will therefore not change anything directly related to trade shares or their volatility.

Mind however that, under float, CCP by itself does not generally imply equal equilibrium consumption, hence leisure and utility across countries. This will be the case only in the much less probable states of monetary shocks having the same magnitude. A peg under (full) CCP, by equalizing equilibrium cross-country utility, will bring about this additional effect in all states of the world.

Trade-to-Output under PCP with Float By contrast, a *peg* under (some degree of) *PCP* will equalize the *ex-post* Home and Foreign trade shares, thus leading to a result that is essentially the same – concerning trade only, not consumption and leisure – as the one implied by (full) CCP under float. The peg trade share function in Figure 2.1 summarizes across trade costs and cross-country output substitutabilities the *identical* under CCP (with either float or peg) or peg (with either CCP or PCP) Home and Foreign *equilibrium* trade/GDP ratios. It will be interpreted in more detail along the dimensions of its two arguments in section 2.5.

Our principal result in this paper is stated in the following proposition.

Proposition 2.2 *(Expected Trade-to-Output under PCP) Under (some degree of)* PCP*, a peg reduces expected trade-to-output if import demand is* elastic *but increases it if import demand is* inelastic*.*

A proof is given in Appendix B.2. In interpreting Proposition 2.2 we first note that our trade measure is a *ratio*, not the value or volume of trade in general, as in many studies usually claiming that a peg would increase trade. Second, we stress that

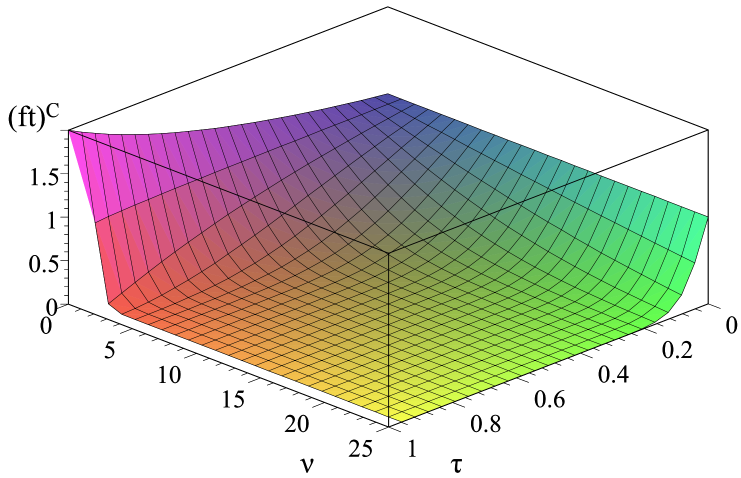

Figure 2.1: Peg Trade Share Surface across Iceberg Costs and Substitutabilities

in a *frictionless*, *unique-substitutability* setting with trade of highly similar brands of a homogeneous good-type imposing *elastic* demands for imports, the expected trade share would be the same no matter the price setting and the exchange-rate regime, as shown in chapter 1 of this dissertation. The introduction in the present second chapter of more realistic features – such as costs of trade and a distinct substitutability between good-types lower than that among brands (within each type) which is, furthermore, not restricted outside the inelastic zone – has thus helped improve our understanding on the effects of the exchange-rate regime on trade, measured in terms of output. Finally, the presence of any one of our two real trade "fundamentals" *alone* in the extended NOEM model we developed is not sufficient to produce the reversal effect of interest here: it is precisely the *interaction* of ν and τ that drives our main result.[17] The combination of the wedge driven between the cost of the domestic vs. the foreign good-type, intervening in decisions on import substitution, and the particular magnitude of the substitutability between these good-types, embodying the wish to trade and inducing, in consequence, a certain level of the equilibrium PCP NER in each state, thus ultimately matters in explaining when a peg would increase trade and when a float would do it instead. Without the richer setting of the present set-up, this channel of interaction could not have been uncovered, and in that consists our principal import to the related NOEM literature.

The intuition for the result in Proposition 2.2 we would provide is the following.

Consider first a *fixed* exchange-rate regime, $S_s = 1, \forall s$. CCP vs. PCP is then irrelevant for trade: the nominal exchange rate is constant so the pass-through and expenditure-switching channel is inoperative. Trade-to-output in each of the countries and, hence, for the world as a whole would be state-invariant, at $\frac{2}{(1-\tau)^{1-\nu}+1}$. Take as

[17] As clear from the changing sign of the second term of $F''(1)$ in the proof of Proposition 2.2 in Appendix B.2, the first one being always positive.

a first benchmark the case of *zero* cross-country output substitutability, $\nu = 0$: the home bias, otherwise identical for both trading nations at $(1-\tau)^{-\nu}$, now vanishes, so equilibrium as well as expected trade-to-GDP equals $\frac{2}{2-\tau} > 1$: the higher the trade cost, the higher the trade share, because countries are "doomed" to expensive trade by their identical preferences but differing endowments. As a second benchmark, consider *unitary* import demand elasticity, $\nu = 1$: there is now a bias in favour of the domestic product consumption, $\frac{1}{1-\tau} > 1$, but the price of the foreign good consumer-households are facing is $1-\tau$ times higher than that of the home good so the *values* of imports and domestic absorption in each country match exactly and, hence, expected trade-to-output becomes 1, i.e. lower than when ν is zero. Now let us turn to the two more general cases of interest in this second chapter. In the *elastic* zone, when $\nu > 1$, there is a home bias, $\frac{1}{(1-\tau)^{\nu}} > 1$, weaker than with unit elasticity but increasing in ν (and τ), which is intuitive; expected trade is thus lower than 1, the more so the higher ν (and τ); at the extreme of $\nu \to \infty$, the home bias becomes so huge that trade vanishes completely. Conversely, in the *inelastic* zone, when $0 < \nu < 1$, there is again a home bias, $\frac{1}{(1-\tau)^{\nu}} > 1$, increasing in ν (and τ) again but much weaker than with elastic import demand, which is intuitive too; yet now import substitution by consuming domestic products is much less possible and the (cif) value of expected trade-to-GDP is ultimately higher than 1, due to expensive imports; at the extreme of $\nu \to 0$ the home bias is forced to a negligible magnitude so that the expected trade share is further "inflated" and approaches $\frac{2}{2-\tau} > 1$.

In the preceding paragraph, we analyzed four interesting cases. But all of them assumed a fixed exchange-rate regime. Our argumentation has not, as yet, taken into account the effect of *exchange-rate variability*.[18] We now incorporate in the interpretation of our principal result, Proposition 2.2, the role played by a float. In what a float differs from a peg regime, as far as trade-to-GDP is concerned, is the volatility of the latter ratio across countries (in any state of nature of differing money shocks, $\mu_s \neq \mu_s^* \Rightarrow M_s \neq M_s^* \Rightarrow S_s^P \neq 1$).

Now, with $\tau \neq 0$, the symmetry – or rather reciprocity – on which the NER regime irrelevance for expected trade rested in the frictionless baseline of $\tau = 0$ in chapter 1 is gone. Given float and PCP, this is obvious from comparing the equilibrium world trade expressions under costless (with $\nu \equiv \varphi > 1$) vs. costly trade, respectively:

$$\frac{1}{2}\left[\frac{2}{(S_s^P)^{\varphi-1}+1} + \frac{2}{\left(\frac{1}{S_s^P}\right)^{\varphi-1}+1}\right] = 1, \forall S_s^P,$$

but

[18] Recall that a peg is consistent with *monetary uncertainty*, i.e. it is equivalent to (or, rather, a special case of) a common monetary shock hitting the world economy across states of nature, as noted in the beginning.

$$\frac{1}{2}\left[\frac{2}{\left(\frac{1-\tau}{S_s^P}\right)^{1-\nu}+1}+\frac{2}{\left[(1-\tau)\,S_s^P\right]^{1-\nu}+1}\right]\neq\frac{2}{(1-\tau)^{1-\nu}+1}\neq 1,\forall S_s^P\neq 1.$$

More precisely, the intuition behind Proposition 2.2 is related to the definition of elastic and inelastic demand and to key results we derived earlier. Under *elastic* import demand and float with PCP, any change in the relative price of domestic to foreign goods, $\frac{1-\tau}{S_s^P}$ for Home (see (2.18)), following the realization of the equilibrium NER, induces an even *larger* change in the relative quantity of cross-country output demanded, i.e. in consumption switching, $\left(S_s^P\right)^{\nu}(1-\tau)^{-\nu}=\left(\frac{1-\tau}{S_s^P}\right)^{-\nu}$ for Home. The product then of the relative price and quantity under float, $\left(\frac{1-\tau}{S_s^P}\right)^{1-\nu}$, is higher, on average, than that under peg, $(1-\tau)^{1-\nu}>1$, when $S_s^P=1$ and there is no consumption switching. That is why trade-to-output is ultimately lower under peg than under float with elastic cross-country substitutability and (some degree of) PCP. The case of *inelastic* demand reverses our interpretation above, in that now $\left(\frac{1-\tau}{S_s^P}\right)^{1-\nu}<(1-\tau)^{1-\nu}<1$, on average, so a peg would increase expected trade-to-GDP relative to a float. What drives the result is the intensity of consumption switching, determined by $\left(S_s^P\right)^{\nu}$ for Home and $\left(S_s^P\right)^{-\nu}$ for Foreign. Taking Home, the function $\left(S_s^P\right)^{\nu}$ is increasing convex for $\nu>1$ but increasing concave for $0<\nu<1$.[19] Therefore, trade is lost under peg relative to float when consumption switching, $\left(S_s^P\right)^{\nu}(1-\tau)^{-\nu}$, is strong under $\nu>1$. In other words, a flexible exchange-rate regime increases trade-to-output for elastic import demand. Conversely, trade is gained under peg relative to float when consumption switching, $\left(S_s^P\right)^{\nu}(1-\tau)^{-\nu}$, is weak under $0<\nu<1$, due to low substitutability. To put it differently, a fixed exchange-rate regime increases trade-to-output for inelastic import demand. It is also easy to see why unit substitutability leads to nominal trade equal to nominal output in any state of nature: simply the relative price change and the corresponding change in the relative quantity demanded cancel out when $\nu=1$, resulting in $\frac{1-\tau}{S_s^P}\left(\frac{1-\tau}{S_s^P}\right)^{-1}=1$.

Overall then, under costly trade with elastic import demand of similar output mixes, a float mitigates, on average, the home bias inherent to a fixed exchange-rate regime and plays a trade-promoting role, once some degree of PCP is allowed for; by contrast, under inelastic demand because of differing but equally-valued national good-types, a float makes the exchange of goods too costly, on average, relative to a peg and thus plays a trade-reducing role, unless there is full CCP.

2.4.2 How Much Does a Peg Increase Trade-to-Output?

To further judge about the likely magnitude of the effect of the exchange-rate regime on expected trade-to-output we established in Proposition 2.2 and at the same time

[19] As was formally shown in Appendix B.1.1.

to explore how exchange rate volatility translates into variability of the resulting trade shares, we next simulated our model. We assumed a uniform distribution of the nominal exchange rate with 20 equally-likely states centered symmetrically around 1, $S_s \in \mathcal{U}_l\,(0.95, 1.05)$. Having in mind our framework of *price stickiness*, in line with the NOEM approach we follow here, we were interested in, and imposed in the simulation, *low* uncertainty, i.e. corresponding to a NER standard deviation of 3.04% (as implied by the above distribution). The outcomes across a few sets of parameter constellations are reported in Table 2.1.[20]

$S_s \in$ $\mathcal{U}_l\,(0.95, 1.05)$	Cif *Trade Shares* in Output, %			*Peg Gain* for *World* Trade over Float, %
	PCP-Float Sample		*CCP⇔Peg* constant	
	Mean	SD		
	$H=F$	$H=F$	$H=F$	
Panel I: (very) *low* trade costs: $\tau = 0.01$				
$\nu = 11$	95.09	1.74	94.98	−0.1188
$\nu = 2$	99.50	1.00	99.50	−0.0001
$\nu = 0.5$	100.25	2.00	100.25	0.0000
$\nu = 0.2$	100.40	7.84	100.40	0.0001
Panel II: *moderate* trade costs: $\tau = 0.2$				
$\nu = 11$	20.05	0.37	19.39	−3.2582
$\nu = 2$	88.89	0.94	88.89	−0.0029
$\nu = 0.5$	105.57	1.89	105.57	0.0003
$\nu = 0.2$	108.90	5.85	108.90	0.0012
Panel III: (very) *high* trade costs: $\tau = 0.6$				
$\nu = 11$	0.02	0.00	0.02	−4.4797
$\nu = 2$	57.15	0.67	57.14	−0.0142
$\nu = 0.5$	122.51	1.55	122.51	0.0010
$\nu = 0.2$	135.09	2.92	135.09	0.0034

Table 2.1: Gains from Peg/Float for World Trade: Simulation Summary

The second column of Table 2.1 indicates the sample mean and the third one the standard deviation of the trade share in GDP under PCP with float. The fourth column gives the *state-invariant* trade share in output attained under CCP with float (as well as with peg) or, alternatively, under peg with PCP (but also with CCP). We interpret the reported results on trade share volatility in the next section.

Now looking at the last column of Table 2.1, the first regularity one notices is related to the sign of what we have defined as the gain for expected world trade as a share in world output from a peg regime relative to a float. This measure is simply the percentage difference between the constant world trade share under peg (or CCP) and the "expected" world trade-to-GDP under float with PCP, the latter approximated by the (equally-weighted) *sample* means for Home and Foreign and taken as a base (i.e. normalized to 100). A positive difference is thus a trade gain from a

[20] More details on the computations underlying the numbers in Table 2.1 are available upon request.

fixed exchange-rate regime, whereas a negative sign means the opposite, namely that a flexible exchange-rate regime would, on average, bring about more international trade relative to world output than a peg. The simulation has thus, first of all, cross-checked and confirmed our analytically derived conclusions in Proposition 2.2: under *elastic* demand for imports (i.e. for $\nu = 11$ and $\nu = 2$ in Table 2.1, no matter what the particular value of τ is) a peg does reduce the expected world trade share in GDP, but *only slightly* for sufficiently *low* elasticity – and this is the new point here, coming out from the simulation; and under *inelastic* demand, it does increase expected trade-to-output for the world economy as a whole, but – again – *only slightly* for *low* elasticity of cross-country output demand. "Only slightly" means, more precisely, by less than 1%, i.e. up to about 1.42 basis points,[21] as clear from the table.

However, for the case of *high* elasticity of import demand ($\nu = 11$), which corresponds to a situation of two countries producing very similar output mixes, the magnitude of the above-defined loss for world trade following a shift from float to peg is really *large*, of the order of $3 - 4\%$ for moderate ($\tau = 0.2$) to high ($\tau = 0.6$) trade frictions. This is another important result arising from our simulation, the more so at the background of the miniscule impact we found for lower cross-country substitutabilities ($\nu = 2$, $\nu = 0.5$, $\nu = 0.2$) and of similar conclusions in related NOEM papers. Our quantification of the *first*-moment effect, on *expected* trade-to-output, of a *second*-moment model feature, namely exchange rate *uncertainty*, does not overall go astray from the available literature on the impact of uncertainty: on trade shares, in our case, but also on the conduct of monetary policy or on the welfare implications of peg vs. float. Once uncertainty is driven by *small* shocks – like in our present work as well as in NOEM research by others, for instance, Devereux and Engel (1998, 1999, 2000) – to comply with the assumption of sticky prices, there is no way that it generally results in a large impact on the expected levels of any endogenous variable. The key import of our extended NOEM analysis in the second dissertation chapter is thus in the conclusion that under PCP with trade costs interacting with somewhat more structured preferences (and, ultimately, import demand), monetary and, hence exchange rate, uncertainty does have an effect on expected trade-to-GDP, the more so when countries produce similar output under meaningful costs of trade, whereas in a frictionless, single-substitutability model – e.g. our chapter 1 under PCP (and CCP) or Bacchetta and van Wincoop (2000 a) under CCP – such a channel of the international transmission of shocks cannot be captured and explained.

[21] A basis point is $\frac{1}{100}$ of 1%.

2.5 The Role of Trade Costs and Import Demand Elasticity

We finally turn to the role of the *real* determinants of trade/GDP ratios which were explicitly modelled here. This role is reflected in Figure 2.1 and Table 2.1 and relates to both expected trade-to-output and its variability, as will be discussed below.

Indeed, we have seen that the importance of our real trade fundamentals is crucial for the findings we reported. Recall that the magnitude of the trade friction τ in combination with that of import demand (in)elasticity ν defines the home bias, $(1-\tau)^{-\nu} > 1$, and ultimately the state-invariant and equal trade shares in Home and Foreign, under CCP or *peg*. Moreover, our Proposition 2.2 and the subsequent model simulation have shown that under PCP and *float* expected trade-to-output is (slightly) higher or lower than under peg (or CCP), depending on whether import demand is elastic ($\nu > 1$) or inelastic ($0 < \nu < 1$), respectively.

2.5.1 Trade Frictions

We first examine the impact of trade costs. Figure 2.2, in fact a two-dimensional variation of Figure 2.1, plots the peg (or CCP) trade share in any of the countries as a function of τ for different levels of ν. One can see that for given *elastic* import demand, *higher* transport costs *decrease* – *decreasingly* (for $\nu = 11$ or $\nu = 6$) or *increasingly* (for $\nu = 2$ or $\nu = 1.25$) – the *expected* level of trade-to-output.[22] But *inelastic* imports ($\nu = 0.75$ or $\nu = 0.5$ or $\nu = 0$) reverse this conclusion: higher trade frictions always lead to an increasing – but "inflated" – trade share (see also the last but one column in all three panels of Table 2.1).

The above reversal result needs a word of comment. As we noted earlier, in the inelastic ν region national output mixes are so *poor substitutes* that both countries are doomed – by their taste (or need) for diversity under complete specialization – to trade even when the international exchange of goods is extremely expensive, i.e. when shipping losses are very high (or exogenously rise). For a given level of transport costs under float, the trade share in output would thus be almost insensitive to (potential) ex-ante price discrimination under CCP or ex-post expenditure switching under PCP, since households practically cannot substitute away from imports into the (now completely different) home-produced good-type. Our finding that under peg with inelastic import demand national trade shares would both be higher than 1 is, in essence, explained by the fact that we used to derive them the *value* of *nominal* trade taking account of transport costs (*cif*) divided by *nominal* output. This latter ratio is thus

[22] It follows from our analysis that *space* (or geography) matters, as in *gravity* models of trade, in particular if transport costs are modelled to be some positive function of distance (as we have implicitly assumed here).

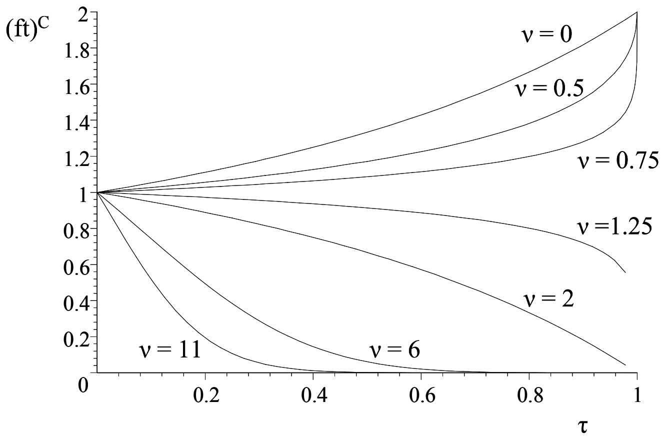

Figure 2.2: Peg Trade Share Curves across Iceberg Costs for Given Substitutability

highly inflated by the "true" price to the consumer of the huge percentage of output lost in transit.[23]

For moderate ($\tau = 0.2$) to high ($\tau = 0.6$) iceberg costs, simulations have furthermore indicated that lower shipment losses tend to increase trade share *volatility* (which becomes clear from comparing the standard deviation columns of panels II and III in Table 1). When tiny transport frictions ($\tau = 0.01$) are allowed for as well (see Panel I of Table 1), there is, however, no monotone function describing the relation discussed here, so trade variability generally depends on the particular parameter constellation.

2.5.2 Cross-Country Substitutability

We now summarize how the degree of import substitutability affects trade. Figure 2.3 – which is another two-dimensional perspective on Figure 2.1 – shows that, for any given iceberg cost, *lower* substitutability *increases* the *expected* value of the trade-to-output ratio common to both countries (see also the last but one column of panels I, II and III in Table 1). The intuition is that in this case consumers cannot substitute as much as they like to and would, *ceteris paribus*, so the resulting costly trade inflates trade shares in output. Another finding which stands out clearly in this graph is that as τ increases from 0 to 1 *(near-)linearity* of the peg trade share as a function of ν gradually transforms itself into a *steeper* and *more convex* curve.

For moderate to high shipment losses, lower substitutability also increases the PCP *volatility* of trade shares across states of nature (cf. the standard deviation columns in each of panels II and III of Table 1). Note, however, that for tiny costs of transport

[23] Yet there is no way to measure instead trade-to-GDP in terms of the exchanged quantities ultimately consumed relative to the produced ones in each country, $\frac{c^*_{H,s}+c_{F,s}}{c_{H,s}+\frac{c^*_{H,s}}{1-\tau}}$ for Home and $\frac{c_{F,s}+c^*_{H,s}}{c^*_{F,s}+\frac{c^*_{F,s}}{1-\tau}}$ for Foreign, because one cannot add up "apples to oranges"...

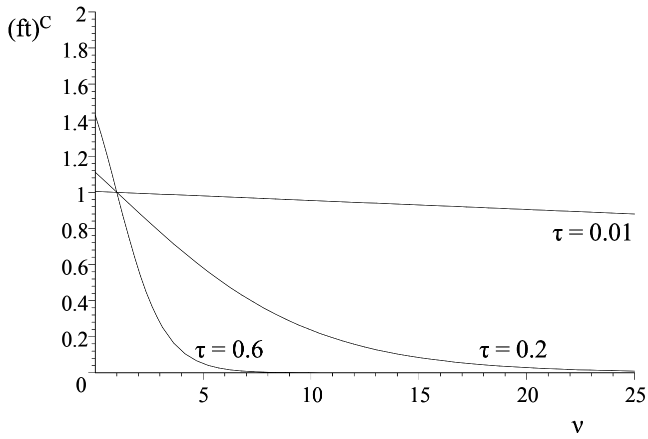

Figure 2.3: Peg Trade Share Curves across Substitutabilities for Given Iceberg Costs

($\tau = 0.01$) as in Panel I of Table 1 the relation in question appears not to be monotone. Instead, we have a divergence of simulated trade volatility under PCP away from 0 – which corresponds to the widely-exploited in NOEM unit substitutability special case ($\nu = 1$) – into higher magnitudes in both directions: as $\nu \to \infty$ and as $\nu \to 0$.

To sum-up, the simulations we performed have also indicated *how much* trade stabilization would be achieved by a shift from a flexible to a fixed exchange-rate regime. This depends on monetary as well as real trade determinants. As a lesson for policy, the *degree* of trade share variability thus eliminated would be greater for (symmetric) nations, or currency unions, which (i) have a larger proportion of PCP in their (bilateral) trade, (ii) are exposed to higher monetary uncertainty and – for moderate to high costs of international exchange – (iii) produce less substitutable outputs and (iv) are located closer to one another or apply weaker (reciprocal) tariff and non-tariff restrictions. Therefore, the lesser the extent to which the above-enumerated four conditions are met, the less efficient would a peg be as an instrument to stabilize trade.

2.6 Concluding Comments

The model we developed in chapter 2 is useful to study the role of monetary uncertainty under trade frictions, distinct brand and type demand elasticity and alternative currency of price rigidity in determining the effects of the exchange-rate regime on trade, measured in terms of output. Given symmetry of structures and shock distributions, we distinguished *two types* of effects, namely an *expected level* (or *first*-moment) effect and a *volatility* (or *second*-moment) effect.

Expected Level Effects Our unified NOEM framework designed to nest trade in both similar and different output mixes has clearly indicated when a peg would increase *expected* trade, the relevant measure in a stochastic setting as ours here, relative to a float and when not. A peg increases expected trade-to-output under *inelastic* import demand for a different foreign good-type valued equally as the domestic one and decreases it under elastic demand for similar composites produced in various brands across two symmetric economies. We have also concluded that this effect, although qualitatively novel and important, is quantitatively very *weak*, as already established in other models within the NOEM literature examining welfare issues. By contrast, a *strong* effect on the magnitude of the expected trade share in GDP has been found for some deeper trade "fundamentals" such as transport or tariff frictions and cross-country output substitutability, which is another contribution of the present chapter. More precisely, such real determinants affect – via the optimally arising home bias – both the expected level of trade-to-output and its volatility across states, in a different way under elastic vs. inelastic import demand. Some of these trade fundamentals, e.g. tariffs, can relatively quickly be affected by policy. Changing the structural underpinnings of other, e.g. transportation technologies or preferences, would require much more time.

Variability Effects What fixing the exchange rate also attains under (some degree of) *PCP* although not (full) CCP – by shutting down the pass-through and expenditure-switching channel – is to stabilize (across states of nature) and equalize (across countries) trade shares in GDP at their expected level. Our simulations have indicated that *how much* trade stabilization would be achieved by a policy change from a flexible to a fixed exchange-rate regime ultimately depends on both monetary and non-monetary trade determinants. Within the perspective of real-world economies, it seems worth concluding that the *degree* of trade share variability eliminated by a shift to peg would be greater for (symmetric) nations, or currency unions, which (i) have a larger proportion of PCP in their trade, (ii) are exposed to higher monetary uncertainty and – for moderate to high costs of international exchange – (iii) produce less substitutable outputs and (iv) are located closer to one another or apply weaker tariff and non-tariff restrictions.

Limitations of Our Analysis No matter the useful theoretical insights it provided, we do not have illusions about the limited direct applicability of the extended NOEM framework employed throughout the second chapter of this dissertation to data or policy issues in the global economy. However, certain implications of our "pure" analysis up to here could be traced further, as we have done in related empirical work in the last chapter. This is how a coherent and enlightening but thus far oversimplified analytical approach like NOEM will gradually be enriched to become more helpful in econometric or policy-oriented applications.

Chapter 3

The Empirical Range of Pass-Through in US, German and Japanese Macrodata

3.1 Motivation, Objective and Approach

In the preceding two chapters, we have analytically shown in a microfounded general-equilibrium model of trade driven by money shocks why from an economy-wide viewpoint the assumption of consumer's currency pricing (CCP) vs. producer's currency pricing (PCP) is of an essential nature under price rigidity. As also duly pointed out in the recent new open-economy macroeconomics (NOEM) literature, the reason is that *full* CCP – by preventing any pass-through – completely reverses a central result in the Keynesian international macroeconomics tradition known as the *expenditure-switching effect* (of a nominal exchange rate change). A monetary expansion that depreciates the national currency – and hence, within the short run of price stickiness, the real exchange rate – leads under full CCP to an improvement (not deterioration, as under full PCP) in the inflating country's terms of trade (ToT) and ultimately depresses (and does not stimulate) real economic activity.

Our stochastic framework in chapters 1 and 2, by making a purposeful parallel of a CCP to a PCP model version, has analyzed this alternative invoicing possible in an open economy under the extreme assumptions that either CCP is full for both interacting economies or PCP is, in turn, complete. It is clear, however, that in reality CCP and PCP will coexist in the prices of exported as well as imported products, and the *extent* of CCP (or, inversely, PCP) would thus largely determine the empirical range of pass-through from nominal exchange rate changes to import, producer, consumer and export prices of a given country. As we have shown in our theoretical analysis, pass-through will thus be a key factor in accounting for trade determination given some nominal rigidity and – together with the additional influence of transport, tariff and related frictions and of the elasticity of substitution between the good-types produced by the two economies – for any trade growth and stabilization role of the exchange-rate regime. We have concluded that, under monetary uncertainty, more CCP in bilateral trade invoicing would mean less pass-through from the exchange rate to import and consumer prices, so a peg would not achieve much in stabilizing national trade shares in output, neither – under inelastic demand for cross-country output – in increasing expected trade. On the contrary, if PCP is the dominant trade pricing convention between two (symmetric) economies so that the degree of pass-through is huge and induces considerable expenditure switching, fixing the exchange rate would always lead to trade stabilization, and also to some trade growth under inelastic import demand.

The objective of the present third chapter is to further examine empirically the unresolved issue of what is the likely *range* of aggregate exchange rate pass-through. One approach to do this would be to rely on survey data and study the *direct* evidence on currency denomination in actual international trade transactions. Many papers did pursue such an approach in the late 1970s and early 1980s, to generally find that trade in manufacturing goods between developed countries was mainly invoiced in accordance with PCP. This regularity has been referred to as "Grassman's law", after the important empirical contributions by Grassman (1973 a, b) based on 1968 Swedish trade data. Similar applied work, but using more recent (post Bretton-Woods) data, such as Friberg and Vredin (1997), for example, has however supported an increasing role of pricing-to-market (that is, CCP) practices.

An alternative strategy to study the range of pass-through is the *indirect* one, which exploits pertinent data and theoretically postulated relationships underlying their structure and/or dynamics to estimate and interpret key correlation and regression coefficients (elasticities).[1] Following this latter approach, we are interested here in extracting from macroeconomic time series robust interval estimates of pass-through in the three countries whose currencies have been the major international medium of exchange and store of value over the last half of a century, namely the US, Germany and Japan.[2] Similarly to some of the previous literature, we measure exchange rate pass-through at three stages, i.e. on import, export and consumer prices. Yet a particular feature of our analysis which distinguishes it from preceding ones is that we purposefully focus on *monthly* data, this frequency being more relevant to price rigidity and nominal exchange rate (NER) fluctuations predominating in the real world. Another novelty in pass-through research we introduce with this chapter is that apart from comparing our results (i) across the three largest national economies nowadays and (ii)

[1] An extensive and widely cited (but now somewhat old) survey of the empirical pass-through literature is P.Goldberg and Knetter (1997).

[2] For instance, in April 1998 the average daily foreign exchange market turnover has been estimated by the Bank for International Settlements (1999) – Statistical Annex, Table E-1 – to be 1260 billions of US dollars in the United States, 430 billions of US dollars in Germany and 300 billions of US dollars in Japan. United Kingdom comes next, with 157 billions of US dollars, followed by Switzerland with 101 billions of US dollars and France with 73 billions of US dollars.

across stages along the pricing chain, we essentially perform an exhaustive sensitivity analysis across four additional dimensions: (iii) frequency, (iv) time, (v) econometric methods and (vi) aggregate import/export price proxies and business cycle controls.

The frequency dimension of the empirical analysis relates our findings based on monthly data to their analogues obtained from the same estimation but with *quarterly* data. The time dimension – in effect, an indirect test of Grassman's law with recent data – consists in splitting up the whole sample in two symmetric *subperiods*, the 1980s and the 1990s, to look into the dynamic characteristics of the phenomenon. The methodology dimension of our approach progressively interprets (a) *correlations* as in Obstfeld and Rogoff (2000), (b) *OLS regressions* as in Campa and L.Goldberg (2002) and (c) *VARs*, applying *orthogonalized* impulse responses as in McCarthy (2000) and Choudhri, Faruquee and Hakura (2002) as well as – innovatively in the present study – *generalized* impulse responses, first proposed by Pesaran and Shin (1998), where ordering does not matter. Moreover, we perform a *battery* of seasonality and stationarity tests and report in explicit detail the conclusions from them, something rarely done in the literature unless in a footnote or two. We also carefully test for Granger causality and *cointegrating relations* suggested by theory to check for possible use of cointegrated VAR models, as recently done by Coricelli, Jazbec and Masten (2003). A final comparison is effected along the proxy dimension, with alternative proxies employed for both trade prices and business cycle indicators: we parallel estimates obtained using the more relevant aggregate import and export *price indexes* with corresponding ones based on the more readily available approximations of the mentioned indexes which are the *unit values* of imports and exports;[3] furthermore, we check how *industrial production* and *employment volume* indexes affect the magnitudes of pass-through when replacing *real GDP* as a standard business cycle control variable.[4] In fact, our different measurement strategies to appropriately quantify pass-through build upon one another in a complementary way, correcting for weaknesses in each one of them if applied in isolation.

All papers we quoted – except Coricelli, Jazbec and Masten (2003) whose data are anyway limited to 1993-2002 and four EU candidate economies – have relied on quarterly time series, mainly due to lack of monthly import and export price indexes on a wide and comparable international basis. Most of these authors, including McCarthy (2000) and Choudhri, Faruquee and Hakura (2002), have however admitted that monthly data would be more desirable in studying this particular issue, as pro-

[3] It should be noted that the importance of such a dimension of the study originates in the difference in the method of calculating these two trade price proxies. Whereas indices are computed via direct (but not systematic) surveys of exporters and importers concerning the actual prices of international trade transactions, unit values are indirectly obtained from customs declarations registering both volumes and values by transaction. Unit values are, therefore, less reliable although more easily available on a broad basis.

[4] It might also be interesting to try some *output gap* measure in addition to the three aggregate demand proxies enumerated. Yet calculation of output gaps on an internationally comparable basis is rather problematic methodologically and may thus introduce more noise into the estimates.

viding a better approximation to documented rigidity characterizing real-world prices. We therefore exploit essentially this line of empirical inquiry, hoping to improve on earlier pass-through estimates due to the use of data at a higher, and more relevant, frequency as well as to complement them by a thorough sensitivity analysis. Our approach of focusing on monthly time series becomes possible, it is true, within a rather narrow cross-section to ensure highest comparability.[5] Yet the initial country sample here can subsequently be extended to other economies, in particular when both price indexes and unit values of imports and exports are available for long (and coinciding) time spans, an extremely rare feature in the currently available national macroeconomic accounts.

Our results have confirmed that the use of monthly data is quite central when it comes to measuring pass-through more precisely. This is not surprising, since pass-through has to do with reactions of monopolistically competitive price-setters to (i) exchange rate movements (ii) under sticky prices. On both counts, quarterly observations would miss much of the "action". The New Keynesian literature has now converged to a broad agreement that the dynamics of real-world price rigidity, itself often narrowly related to exchange rate volatility, and, hence, the resulting pass-through, is usually better observed at a frequency lower than one quarter. Accordingly, we establish that quarterly data tend to *underestimate* pass-through and to somewhat *distort* its time profile when compared to corresponding monthly based ones, due to certain averaging out of shorter-run price adjustments to changes in exchange rates. Moreover, insofar most previous pass-through estimates have depended on quarterly data, we would claim that our present contribution has improved on earlier quantification in terms of both precision and robustness. Precision, because the monthly frequency matters indeed when measuring pass-through, as we have just stressed. Robustness, firstly, because of the three times higher number of observations provided by a monthly sampling relative to a quarterly one within the same period; and, secondly, because we have come up with sort of "interval" estimates for the empirical range of pass-through from pooling together magnitudes obtained by a variety of complementary econometric techniques and variable proxies.

To summarize our conclusions in a preview, we find that the empirical range of exchange rate pass-through varies across (i) countries, (ii) data frequencies, (iii) time periods, (iv) econometric methods, (v) aggregate price and volume proxies, (vi) stages along the pricing chain (import, export and consumer prices) and (vii) time horizons (one month, one quarter, one year). Any generalization should, in consequence, be done carefully and to the extent particular cases lend themselves to it. Leaving aside the specificity concerning some aspects of our pass-through quantification, which we shall discuss in detail further down, we could emphasize here at least three important and quite robust results. First, in the economies we focus on, pass-through on import

[5] And at the cost of interpolating GDP series and related deflators in those econometric specifications which include real GDP.

prices has considerably declined in the 1990s relative to the 1980s but pass-through on export prices has not changed much; as to consumer prices, pass-through has always been practically negligible over all horizons of up to one year. Grassman's law seems thus weaker nowadays as compared to the Bretton-Woods era. Second, the econometric methods and the measurement proxies we used do matter (more so for our price proxies, less so for our volume proxies) for the *precise* magnitudes and time patterns, yet they agree on the *general* tendencies. Third, the US is an economy with import price levels that are astonishingly irresponsive to nominal exchange rate changes, as has also been found in other pass-through studies.

The chapter is further down organized as follows. Section 3.2 describes the data, reports the results from our seasonality and stationarity tests and presents correlations between the terms of trade and the nominal exchange rate, the latter being indicative of predominance or not of CCP vs. PCP in foreign trade invoicing. The third section then discusses the most common approaches to estimating pass-through in related research and motivates our own empirical strategy. Section 3.4 interprets our estimates across the several dimensions of the present analysis at each stage of the underlying pricing chain, and the fifth section concludes. Definitions of the data, graphical illustrations and descriptive statistics are provided in Appendix C.1, while Appendix C.2 documents in detail the results from our econometric work.

Throughout the paper, we present and comment our pass-through estimates based on *monthly* data. The corresponding quarterly based estimates are thus only mentioned for comparison purposes and to reveal the differences – at times considerable in magnitude but less so in time pattern – we detect from the same underlying series across the frequency dimension.

3.2 Data and Preliminary Tests

Our sample is largely based on International Monetary Fund (IMF) data downloaded from the online version of *International Financial Statistics (IFS)* accessible via Datastream. As nominal GDP and GDP deflators are released in quarterly frequency, they were first *interpolated* by the spline method and the corresponding real GDP was then included as a control variable in some of our monthly specifications. An additional data source, in particular for the employment volume index, is *Main Economic Indicators (MEI)* published by the Organization for Economic Cooperation and Development (OECD) and downloadable via Datastream again. Since a monthly series was not available for Germany, estimations for this particular country based on the employment volume index as an alternative business cycle indicator were effected only at the quarterly frequency. The definitions of all data we use here and their respective unique IFS or MEI codes are provided in Appendix C.1.

3.2.1 Descriptive Statistics

To obtain higher comparability, we worked on purpose with a sample period divided in two *equal* halves that is completely identical for all our three economies. To circumvent a discontinuity in the IFS money supply series for Germany, which changed in January 1999 the unit of measure from deutsche marks (DEM) to euros (EUR), the German M1 aggregate was expressed in marks for the *entire* sample period.[6] Thus, our whole sample contains 276 monthly observations (1979:07 – 2002:06), with each of the two subsamples, "the 1980s" (1979:07 – 1990:12) and "the 1990s" (1991:01 – 2002:06) covering 138 observations. Graphs (in natural-logarithm levels) and descriptive statistics (in percentage changes) of the monthly series entering our principal specifications for estimating pass-through are provided in Appendix C.1.

3.2.2 Testing for Seasonality

The national sources of the data reflected in the original Datastream series are quite heterogeneous, and not all of these variables had been systematically treated for seasonality. To deal with this problem, we relied on explicit seasonality tests by performing the Census X12 procedure. To conclude whether a series displays a seasonal pattern or not, we looked at four formal tests within Census X12. If at least three of the tests indicated presence of some form of seasonality, we considered the time series in question seasonal and further used in our estimation the corresponding deseasonalized variable (again produced via Census X12). In the rare cases where two of the Census X12 tests have indicated seasonality whereas the other two not, we attributed the decisive weight to the *combined* test for identifiable seasonality. Our seasonality test results are summarized in Table C.1 in Appendix C.2.[7]

3.2.3 Testing for Stationarity

We applied a similar test-diversified procedure when deciding on stationarity issues related to the time series involved in our pass-through estimation. More precisely, we employed three tests that methodologically complement one another, with each of them having been effected in four alternative specifications. Augmented Dickey-Fuller (ADF) unit root tests based on autoregressive models were thus performed in parallel with kernel-based Phillips-Perron (PP) unit root tests, with the null for both tests being that of a unit root (i.e. nonstationarity) present. These two tests were further supplemented by a test constructed on the opposite null, of stationarity, namely the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and both autoregressive and kernel-based specifications of it were used. The results from our four specifications of each

[6] We converted the post-EMU EUR-denominated data into DEM-denominated equivalent applying the exchange rate of 1.95583, which was the same on 31 December 1998 and on 1 January 1999.

[7] Further details, including the EViews programs, are available upon request.

of the (non)stationarity tests are summarized in Table C.2 in Appendix C.2.[8] Our conclusion whether a time series is stationary (i.e. integrated of order 0, I(0)) or not and whether, if nonstationary, it is integrated of order 1 or 2 (I(1) or I(2)) was based on this latter table. In many cases our three tests have agreed quite unanimously on the order of integration to be 1. What is worth pointing out here – in particular with respect to Coricelli, Jazbec and Masten (2003) who have argued that most prices in transition economies seem to be integrated of order 2 and have consequently used a cointegrated I(2) VAR in deriving impulse responses to measure pass-through – is that we do not find (overwhelming) evidence of I(2) series in our data. Their claim is thus perhaps either a characteristic of transition economies which cannot be generalized or an artefact of the somewhat short sample they use (monthly data over 1993-2002).

3.2.4 ToT-NEER Correlation Analysis

In a preliminary look into the determinants of pass-through, we now refer to our theoretical results in chapters 1 and 2 concerning the microfounded definition of the terms of trade (ToT) under CCP vs. PCP. We use this definition in a way suggested by Obstfeld and Rogoff (2000) to motivate and replicate their ToT-NEER quarterly correlation tests for the empirical prevalence of one of these types of price-setting, within our sample and at the more relevant monthly frequency. As explained in the beginning, a (high) positive ToT-NEER correlation evidenced in the data may partly be due to a (strong) prevalence of traditional PCP in the foreign trade of a given country. Conversely, a negative correlation or an approximate absence of correlation would signal, among other things, a much greater importance (if not dominance) of CCP behavior consistent with pricing-to-market arguments. Our correlation findings are presented in Table C.3 in Appendix C.2, by country and by subperiod.

The monthly and quarterly ToT-NEER correlations we have computed[9] are practically the same, and are both very sensitive to the time period over which they are measured. For our whole sample, which is the period that compares most directly (although not exactly) with that of Obstfeld and Rogoff (2000), our correlations are much lower than the respective quarterly ones documented by the latter two authors for the US but much higher for Germany and Japan. Furthermore, these correlations fall in the 1990s relative to the 1980s, weakly for Germany and drastically for Japan, but slightly increase in the US. This would suggest a falling degree of pass-through, partly due to an increasing portion of CCP in trade transactions, in Germany and Japan but a reverse tendency, although weak, in US trade prices. We return to these observations in a more careful pass-through analysis and with some possible explanations in sections 3.3 and 3.4.

[8] Further details, including the EViews programs, are available upon request.

[9] For log-levels of the respective variables, following Obstfeld and Rogoff (2000).

3.3 Pass-Through Estimates

We next discuss alternative econometric methods of extracting estimates of pass-through from macroeconomic data that have recently been used in influential, or at least widely referred to, papers. In doing so, we also relate our approach to those in the quoted literature. In our empirical analysis further down, we are particularly interested to compare *single-equation* with *system* estimates of pass-through, i.e. the two model specification strategies usually suggested thus far. That is why we highlight the mentioned strategies in the two respective subsections below and then report our findings when employing each one of them in section 3.4.

3.3.1 Single-Equation Pass-Through Estimates

When it comes to single-equation pass-through estimates, the most recent study – also summarizing the preceding literature and trying to improve on it – is Campa and L.Goldberg (2002). For this reason, we first apply their OLS methodology to our sample and two subsamples by country and compare our *monthly*-based estimates on pass-through on *import* prices with the respective *quarterly* ones we also calculate, as well as with the *quarterly* estimates in the cited paper. Several specifications, starting from the original one in Campa-L.Goldberg (2002), were used to infer our pass-through measures. For comparability purposes, we report results only from the model which corresponds exactly to that in Campa and L.Goldberg (2002), but adjusted to account for the change from quarterly to monthly data in the lag structure and for the autocorrelation found and corrected for in the residuals.[10]

Tables C.4 and C.5 in Appendix C.2 document our results for the three countries, two subperiods and two aggregate price proxies from our principal OLS regression, which is the following:

$$d\ln\left(PMI_{i,t}\right) = c_0 + \sum_{k=0}^{12} c_{1,k} d\ln\left(NEERInv_{i,t-k}\right) + \sum_{k=0}^{12} c_{2,k} d\ln\left(CGCost_{i,t-k}\right) +$$

$$+ c_3 d\ln\left(GDPR_{i,t}\right) + \sum_{k=1}^{3} c_{4,k}\left(AR_{i,t-k}\right) + u_{i,t}, \tag{3.1}$$

where $PMI_{i,t}$ is the import price index for country i at time t; $NEERInv_{i,t}$ is the nominal effective exchange rate (NEER) index defined inversely to the IFS-Datastream original series to correspond to the usual interpretation of depreciation being the increase (not decrease) in the exchange rate, with k in (3.1) indexing the time lag; $CGCost_{i,t} \equiv \frac{NEER_{i,t}CPI_{i,t}}{REER_{i,t}}$ is a measure of overall competitiveness Campa and L.Goldberg (2002) suggest as a key control variable, with $CPI_{i,t}$ being the consumer

[10] More details about all other single-equation specifications we employed in estimating pass-through on import prices à la Campa-L.Goldberg (2002), including regression output and EViews programs, are available upon request.

price index (CPI) and $NEER_{i,t}$ and $REER_{i,t}$ being respectively the nominal (NEER) and real (REER) effective exchange rate indexes as defined in IFS-Datastream;[11] $GDPR_{i,t}$ is real GDP;[12] $AR_{i,t}$ are autoregressive error terms added to correct for identified serial correlation in the disturbance process, most likely of order 1, 2 or 3 (according to Durbin-Watson tests and Breusch-Godfrey Lagrange multiplier tests we performed); $u_{i,t}$ is the error term.

In order to judge about the effect of employing alternative aggregate import price proxies, in the cases of Germany and Japan (but not for the US, due to lack of data) equation (3.1) was also estimated with $PMU_{i,t}$, the unit value of imports, replacing $PMI_{i,t}$ above. Furthermore, we applied other business cycle proxies as controls reflecting aggregate demand conditions, and available at a monthly frequency: firstly, we replaced $GDPR_{i,t}$ by $IPI_{i,t}$, the industrial production index; secondly, in the cases of the US and Japan (but not for Germany, due to lack of data) equation (3.1) was in addition estimated with $Emp_{i,t}$, an employment volume index available from OECD-Datastream, replacing $GDPR_{i,t}$ above.[13]

We also estimated all corresponding *quarterly*-based specifications (including an additional one with $Emp_{i,t}$ for Germany, since the OECD German employment volume index was available at this particular frequency as well), which differ from (3.1) in that the respective sums are $\sum_{k=0}^{4}$ for the two lagged explanatory variables and in that there is just one, but quarterly, AR term to correct for first-order serial correlation in the residuals.

Following the literature, in particular Campa and L.Goldberg (2002) and Choudhri, Faruquee and Hakura (2002), we focus in this paper on the *time profile* of pass-through. Pass-through is, consequently, defined by the *cumulative sum* of the coefficients to the $NEERInv_{i,t-k}$ variable up to a given lag k. In tables C.4 and C.5 in Appendix C.2 we report, and in section 3.4.1 interpret, such pass-through on import prices – in effect, measuring *elasticities* given the log-difference functional form specified – within the horizon of 1 year.

To check for parameter stability, we next performed tests for structural changes. Looking, first of all, at the respective exchange rate graphs in Appendix C.1, we iden-

[11] It is true that the Campa-L.Goldberg (2002) competitiveness proxy does not render itself to a self-evident interpretation. Without much details in their paper (p. 8, paragraph 2), these authors state that the variable they construct should capture the shifting relative price of a country's trading partners and use it as a consolidated export partners cost proxy. The benefit from this particular measure is that it is readily constructible from standard macrodata (such as IFS NEERs, REERs and CPIs). That is why, for comparability to their estimates of pass-through and given the lack of an easy substitute for it, we also use the Campa-L.Goldberg competitiveness proxy in our computations.

[12] We also used lags of real GDP in specification (3.1). However, this has not significantly affected the pass-through coefficients of interest in the present study, as they are reported in tables C.4 and C.5 in Appendix C.2 and discussed in section 3.4.1. More detailed results are available upon request.

[13] Thus eliminating the problem of real GDP interpolation; yet introducing other problems, of course. First, related to how much the IPI is representative for aggregate economic activity. This point is particularly valid for the three countries in question, given the large services sector in them. Second, related to how much employment is responsive to short-run changes in the business cycle.

tified the most likely break points for each of the three countries. Thus, in the case of the inverse US NEER in Figure C.1, two potential breakpoint candidates suggested from the data stood out. Until March 1985 the US dollar index trended down (appreciation), then – which should partly be related to the Plaza and Louvre accords – until June 1995 it trended up (depreciation), and finally – perhaps in anticipation of implementing the European Monetary Union (EMU) – the downward trend (appreciation) was restored. We therefore tested our US regression for break points in 1985:03 and 1995:06. The Chow *breakpoint* test could not reject the null of no structural break for any of these dates as well as for both of them taken together, no matter whether we used the F-statistic or the log likelihood ratio as test criteria. The Chow *forecast* test, in turn, produced somewhat less convincing results: it could not reject the null in 1995:06, no matter which of the two alternative test statistics we used; as to the null in 1985:03, it was definitely rejected by the log likelihood ratio (with an associated probability of 0.0000) but decisively not rejected by the F-statistic (with an associated probability of 0.9865). For Germany and Japan, the graphs of the inverse NEER in figures C.2 and C.3, respectively, show a coinciding (local) minimum (strongest currency) in April 1995; but both of the above-mentioned Chow tests could not reject the null of no structural break at that particular point in time. Given the rejection of structural changes at the most critical NEER-related – and, hence, pass-through relevant – points in our data set for Germany and Japan and the only partial and conflicting test results for the US case about a potential break in March 1985, we concluded that the Chow tests did not find any strong evidence for structural breaks in all three economies analyzed. We then tested for a breakpoint in each of the countries exactly at the split of our sample, i.e. in January 1991. As already said, the reason for a sample split at that particular point in time was to obtain equal (that is, with the *same* number of observations) and, hence, more comparable subsample periods, denoted "the 1980s" and "the 1990s". For the US and Germany, both the Chow *breakpoint* test and the Chow *forecast* test could not reject the null of no structural change in 1991:01 at all usual levels of significance (i.e. at 1%, 5% and 10%). For Japan, however, we obtained somewhat ambiguous results: more precisely, the log likelihood ratio statistic of the Chow breakpoint test rejected the null at 5% and 10% but not at 1%, whereas the alternative F-statistic test criterion could not reject the null at these conventional significance levels, yet rejected it at just above 11%; at the same time, the Chow forecast test rejected the null at all usual levels according to the log likelihood ratio but the F-statistic decisively could not reject the null (with an associated probability as high as 0.9681). Therefore, our sample split in January 1991, from which we report our pass-through measures further down, should not lead to any detrimental consequences with respect to parameter stability, in particular in the cases of the US and Germany. In the Japanese case, such a sample split appears, moreover, to coincide with a likely break in structure at the time point in question.

Single-equation OLS regressions like the one we began our analysis with are common in empirical research, as they provide at least a first, benchmark estimation. Moreover, OLS is often the estimator with the minimum variance. That is why, in addition to its simplicity, it has been applied in the earlier pass-through literature too. And for the same reason, as well as for comparability, we started by extracting measures of pass-through from a particular OLS specification, defended by its proponents as attempting to synthesize and build upon most previous studies. However, OLS is known to yield estimates which are biased, the more so in small samples, when a regressor is correlated with the error term. This situation seems quite likely for some of the right-hand side variables in (3.1). To deal with a *potential bias*, we next estimated the same equation by the usual alternative to OLS, namely two-stage least squares (TSLS), itself a special case of the instrumental variables (IV) method. We employed as "instruments" the same variables as in the Campa-L.Goldberg (2002) specification but all lagged once. Now our results changed more, and in no systematic pattern across countries or subsample periods. *En gros*, the tendencies we summarize as robust conclusions from our present work remained valid again for Germany and Japan, yet not for the US.[14] To address this issue and perform an extensive sensitivity analysis of our initial pass-through measures, we moved on to compare our OLS estimates with ones obtained from VARs, as described below.

3.3.2 Pass-Through Estimates from VAR Systems

Application of vector autoregressions (VARs) is another widely used method to estimate the dynamic effects of shocks. In measuring pass-through from VAR systems, we principally pursued two objectives. First, to base our work on the recent advances in the related literature, essentially building upon them. Second, to stick at the same time to a parsimonious representation, bearing in mind the intended and most efficient use of VAR modelling. We now "borrowed" our specification from another recent study which claims to avoid weaknesses of previous similar research, namely Choudhri, Faruquee and Hakura (2002), but modified their system to a "minimal" one for our purposes here and complemented their estimation method as we explain below.

Testing for Cointegrating Relations Before specifying our VARs, we first duly checked for possible cointegrating relations among the variables to enter our system pass-through estimation. There has been a lot of disagreement in the literature as to whether cointegrated VAR models should be specified or not, in general as well as particularly when measuring pass-through. Two problems Choudhri, Faruquee and Hakura (2002) relegate to respective footnotes concern unit root and cointegration tests. These authors assume all their series except the interest rate to be I(1) based on Augmented Dickey-Fuller (ADF) tests and Kwiatkowski-Phillips-Schmidt-Shin (KPSS)

[14] Further details, including the EViews programs, are available upon request.

tests. They also note to have tested for potential cointegration related to 5 theory-suggested interdependencies among their 7 endogenous variables (including purchasing power parity), which has not been found. Coricelli, Jazbec and Masten (2003) go to the other extreme in basing their pass-through estimates on the only recently studied I(2) cointegrated VAR model, claiming that most nominal price data tend to be integrated of order 2 (and identifying 3 cointegrating vectors in the 5-variable system common to all 4 countries in their sample). As we already noted, in the special case of transition economies such a statement is perhaps statistically well-grounded, yet generally it need not be true.

Taking all these considerations seriously into account, we tried to be explicit and consistent in performing and interpreting our unit root and cointegration tests. We first checked for stationarity of potential cointegrating relations suggested by theory,[15] such as the (logs of the) terms of trade (ToT), purchasing power parity (PPP), the quantity theory of money (QTM)[16] and the ratio of the import price index to the CPI. We were not able to reject unit roots in these relations using four different specifications of each of the ADF and Phillips-Perron (PP) tests, as documented in Table C.6 in Appendix C.2.

Moreover, we supplemented this initial check by formal cointegration tests using Johansen's procedure. In particular, the *summary* test taking account of five possible specifications was applied. We generally found quite diverging results on the number of cointegrating vectors potentially linking the variables in our 4 theory-induced interdependencies referred to above as well as among the 5 time series we employ in our (nominal) VARs later, also duly selected given our objective to estimate pass-through at different price levels and the "constraint" for a parsimonious specification: import, export and consumer prices, the nominal exchange rate and narrow money (M1). The results from these tests are summarized in Table C.7 in Appendix C.2.

Having no clear guidance on the number of possible cointegrating relations, we thus did not engage in attempting to set up reasonable cointegrated VAR models for our data. This has, moreover, ensured greater comparability between the respective estimates of pass-through via OLS and impulse responses from VARs we report in the present paper.

Orthogonalized VAR Impulse Responses The most straightforward way to run a VAR is if the researcher leaves it *unrestricted*. In fact, the only restriction in this case is the Cholesky ordering which predetermines impulse responses and variance decompositions. This is the approach in estimating pass-through preferred, for instance, by McCarthy (2000) and, in essence, Choudhri, Faruquee and Hakura (2002). In applying it to our choice of sample and variables, we first used pairwise Granger-causality

[15] As done in Choudhri, Faruquee and Hakura (2002).

[16] To be more precise, we tested a simplified version of it implying unitary velocity.

tests[17] and prior intuition from economic theory to reduce the possible causal chains to a few most likely subsets of orderings. In a next step, we compared our orthogonalized impulse responses across the four specifications supported by the data, thus providing some sensitivity analysis of our VAR pass-through estimates. These turned out to be rather robust to the four orderings we identified from the Granger tests, which may be partly due to the generally low contemporaneous correlations between the variables in the system.[18] In addition, a generalized VAR estimation (to be commented later) finally confirmed that substantial errors related to our data-and-theory-informed selection of orderings would be unlikely.

The major benefit from using *unrestricted* VARs is that they remain (perhaps the only tool) *usable* when theoretical prescriptions for structural identification of the model are insufficient, if not contradictory or missing at all, as we believe is the case here. That is why we abstain in this paper from experimenting with *structural* VARs too.

The vector autoregressive (VAR) representation of the simultaneous equations model we apply can be compressed in the following general notation:

$$\underset{(n\times n)}{A(L)}\,\underset{(n\times 1)}{y_t} = \underset{(n\times 1)}{\varepsilon_t}\,, \tag{3.2}$$

where

$$A(L) \equiv A_0 - \sum_{k=1}^{\infty} A_k L^k$$

is a *one-sided* matrix polynomial. In (3.2), the exogenous shocks $\underset{(n\times 1)}{\varepsilon_t}$ are written as a distributed lag of current and lagged values of the endogenous variables $\underset{(n\times 1)}{y_t}$.

In our particular version of (3.2) $n = 5$, with the five variables making up the endogenous vector $\underset{(n\times 1)}{y_t}$ specified in four orderings (presented below), and the lag structure is approximated by a truncation at 12 ($k = 1, 2, ..., 12$) motivated by the monthly frequency of the data.

The corresponding vector moving average (VMA) representation of the system (3.2) from which our impulse response measures of pass-through are inferred after imposing Cholesky orthogonalization of $\underset{(n\times n)}{\Sigma} \equiv E(\varepsilon_t \varepsilon_t')$, the variance-covariance matrix of ε_t, is:

$$\underset{(n\times 1)}{y_t} = \underset{(n\times n)}{C(L)}\,\underset{(n\times 1)}{\varepsilon_t}\,, \tag{3.3}$$

[17] Granger causality does not, however, provide information on *within*-month causality (I am grateful for this point to Hans Genberg). Nevertheless, it is the principal technique used in the VAR-related literature when it comes to determining the order of variables. Fortunately, our results proved not to be much sensitive to ordering.

[18] For the precise numbers, see Table C.8 in Appendix C.2. A look into the table would also indicate a few exceptions in the pairwise correlations which are relatively high.

with

$$C(L) \equiv \sum_{k=0}^{\infty} C_k L^k.$$

Hamilton (1994: chapters 11 and 12) and Watson (1994) provide perhaps the standard references on the above correspondence between VAR and VMA representations and the related impulse response and variance decomposition analysis.

As mentioned, like most VAR researchers we relied on pairwise Granger-causality tests to judge about the most likely ordering of the five variables involved in our unrestricted VAR specifications. The tests were performed for the raw data[19] as well as for the seasonally adjusted ones, when these latter enter instead the system regressions due to identified seasonality. The outcomes from the Granger tests are summarized in figures C.7 (for the raw data) and C.8 (with seasonal adjustment) in Appendix C.2. Looking into these figures, sort of country-specific yet to some extent generalizable, motivated us to concentrate on a (12-lag) VAR alternating the following four orderings of the five variables (in first log-differences with a constant included) for each of the three countries examined.

1. Money → exchange rate → import prices → export prices → inflation: this is the ordering most frequently suggested by the Granger-causality tests (see again figures C.7 and C.8 in Appendix C.2). In our notation:

$$M1_{i,t} \rightarrow NEERInv_{i,t} \rightarrow PMI_{i,t} \rightarrow PXI_{i,t} \rightarrow CPI_{i,t}.$$

2. Ordering is the same as in the specification above but with the exchange rate first and money second, as indicated by part of the Granger tests and in accordance with a popular central bank policy which pays some more attention (at least implicitly) to the exchange rate:

$$NEERInv_{i,t} \rightarrow M1_{i,t} \rightarrow PMI_{i,t} \rightarrow PXI_{i,t} \rightarrow CPI_{i,t}.$$

3. Essentially, we now impose theoretical priors on the ordering which was most supported by our data, i.e. the one reflected in the first specification. This is done by moving the CPI from last to first in the causal chain, under the logic that inflation is the primary, if not the only, objective of most contemporary central banks, notably including the three countries of our present pass-through study:

$$CPI_{i,t} \rightarrow M1_{i,t} \rightarrow NEERInv_{i,t} \rightarrow PMI_{i,t} \rightarrow PXI_{i,t}.$$

[19] Because seasonal adjusment may have distorted the original relationship between the variables in the system and as a comparability check with regard to the same tests effected with the respective deseasonalized time series.

4. Ordering is the same as in the preceding specification but with the exchange rate coming before money, in conformity with certain circularity between the Granger-causality found for those variables (in particular, for Germany):

$$CPI_{i,t} \rightarrow NEERInv_{i,t} \rightarrow M1_{i,t} \rightarrow PMI_{i,t} \rightarrow PXI_{i,t}.$$

As noted earlier, our orthogonalized impulse response estimates of pass-through from the above four specifications have been relatively robust to ordering. This is reflected in the time profile up to the horizon of one year extracted from these impulse responses and summarized by the "interval" estimates (as defined by the lowest and the highest point estimates across our VAR orderings) in tables C.9 through C.14 in Appendix C.2, which we shall interpret in section 3.4. But before doing so, we would now emphasize another novel feature of our empirical strategy aimed at robustifying comparative pass-through measurement. It consists in also employing generalized VARs, the underlying theory for which is introduced next.

Generalized VAR Impulse Responses Building on Koop, Pesaran and Potter (1996), Pesaran and Shin (1998) proposed *generalized* impulse response analysis as an alternative to the traditional, *orthogonalized* one outlined above. The main virtue of generalized VAR modelling is that, unlike the traditional one, it does not require orthogonalization of shocks and is invariant to the ordering of variables. We finally benefited from this recent theoretical contribution to VAR analysis by applying it to our system pass-through estimates, as another check of robustness across methodology. As far as we know, pass-through has not yet been estimated using this particular approach.

For the sake of clarity, we here briefly summarize generalized VAR theory. For further details and formal proofs the interested reader may wish to look up in the original Pesaran and Shin (1998) paper.

Koop, Pesaran and Potter (1996) define the *generalized* impulse response function at horizon l of a vector like y_t we referred to above as:

$$GI_y\left(l, \delta, \Omega_{t-1}\right) = E\left(y_{t+l} \mid \varepsilon_t = \delta, \Omega_{t-1}\right) - E\left(y_{t+l} \mid \Omega_{t-1}\right), \tag{3.4}$$

where Ω_{t-1}, a non-decreasing information set, denotes the known history of the economy up to time $t-1$ and $\delta = (\delta_1, ..., \delta_m)'$ is some hypothetical $m \times 1$ vector of shocks hitting the economy at time t. Using (3.4) in (3.3) gives:

$$GI_y\left(l, \delta, \Omega_{t-1}\right) = C_l \delta,$$

which is independent of Ω_{t-1} but depends on the composition of shocks defined by δ.[20] Therefore the choice of hypothesized vector of shocks, δ, is central to the

[20] Pesaran and Shin (1998) note that this history invariance property of the impulse response is specific to linear systems and does not carry over to nonlinear ones.

properties of the impulse response function. The traditional approach, suggested by Sims (1980), is to resolve this problem by surrounding the choice of δ via the Cholesky decomposition of $\Sigma = E\left(\varepsilon_t \varepsilon_t'\right)$, the variance-covariance matrix of ε_t:

$$PP' = \Sigma, \tag{3.5}$$

where P is an $m \times m$ lower triangular matrix. Then (3.3) can be rewritten as:

$$y_t = \sum_{k=0}^{\infty} \left(C_k P\right)\left(P^{-1}\varepsilon_{t-k}\right) = \sum_{k=0}^{\infty} \left(C_k P\right)\xi_{t-k}, \qquad t = 1, 2, ..., T,$$

such that $\xi_t = P^{-1}\varepsilon_t$ are orthogonalized, namely $E\left(\xi_t \xi_t'\right) = I_m$. Hence the $m \times 1$ vector of the orthogonalized impulse response function of a unit shock to the jth equation on y_{t+l} is given by:

$$\psi_j^o\left(l\right) = C_l P e_j, \qquad l = 0, 1, 2, ..., \tag{3.6}$$

where e_j is an $m \times 1$ selection vector with unity as its jth element and zeros elsewhere.

The alternative approach to that of Sims (1980) proposed by Pesaran and Shin (1998) consists in using (3.4) directly but, instead of shocking all the elements of the vector ε_t, to shock just one, say the jth, of its elements and integrate out the effects of other shocks using an assumed or the historical distribution of the errors. In this case one would have:

$$GI_y\left(l, \delta_j, \Omega_{t-1}\right) = E\left(y_{t+l} \mid \varepsilon_{jt} = \delta_j, \Omega_{t-1}\right) - E\left(y_{t+l} \mid \Omega_{t-1}\right).$$

Assuming further that ε_t has a multivariate normal distribution, Koop, Pesaran and Potter (1996) show that:

$$E\left(\varepsilon_t \mid \varepsilon_{jt} = \delta_j\right) = \left(\sigma_{1j}, \sigma_{2j}, ..., \sigma_{mj}\right)' \sigma_{jj}^{-1}\delta_j = \Sigma e_j \sigma_{jj}^{-1}\delta_j.$$

Therefore, the $m \times 1$ vector of the (unscaled) generalized impulse response of the effect of a shock in the jth equation at time t on y_{t+l} is:

$$\left(\frac{C_l \Sigma e_j}{\sqrt{\sigma_{jj}}}\right)\left(\frac{\delta_j}{\sqrt{\sigma_{jj}}}\right), \qquad l = 0, 1, 2... \,.$$

Finally, by setting $\delta_j = \sqrt{\sigma_{jj}}$, Pesaran and Shin (1998) derive the scaled generalized impulse response function:

$$\psi_j^g\left(l\right) = \sigma_{jj}^{-\frac{1}{2}} C_l \Sigma e_j, \qquad l = 0, 1, 2, ... \,. \tag{3.7}$$

This latter function measures the effect of one standard error shock to the jth equation at time t on expected values of the vector y at time $t + l$.

The generalized impulse response estimates of pass-through have coincided with our second orthogonalized VAR specification enumerated above, and are thus included in the range estimates reported in tables C.9 through C.14 in Appendix C.2. As shown by Pesaran and Shin (1998), such a coincidence can happen only when impulse responses are estimated for innovations in the first equation in the system, which is exactly the case of our second VAR specification. In all other cases, generalized and orthogonalized time profiles accounting for the system dynamics following a shock are theoretically different, with the generalized impulse response function robust to ordering but the orthogonalized one not.

3.4 Interpretation of Findings

We now discuss our estimates of NEER pass-through along three different stages in the pricing chain, i.e. on import prices, on export prices and on consumer prices, and in relation to their specificity across methodology, frequency, proxy, time and country.

3.4.1 Pass-Through on Import Prices

Single-Equation Methodology Comparing first our OLS findings about the empirical range of pass-through from the exchange rate to *import* prices in tables C.4 and C.5 in Appendix C.2, we are able to reveal the following main conclusions, along the several dimensions of our study highlighted below.

Across Frequency The OLS regression à la Campa-L.Goldberg (2002) we ran at different frequencies with the same underlying data[21] produced rather different pass-through estimates, mostly in terms of magnitudes at identical time horizons but also in terms of overall dynamic patterns. A general finding valid for Germany and Japan is that quarterly based estimates tend to somewhat *understate* pass-through relative to monthly based ones, especially over the very short run and for the whole sample and the 1980s subsample. This understatement, however, seems not very high, being of the order $10-20\%$ of the respective magnitudes, and is almost completely absorbed by the fourth quarter, thus resulting in converging estimates over one year. For the 1990s, Japanese quarterly and monthly estimates are really very close. As for the US, quarterly and monthly estimates differ, not too much for the whole sample and in the 1980s, but substantially in the 1990s (the quarterly magnitudes being 2 to 3 times *higher* than the corresponding monthly based ones).

Across Proxy There is also some difference in the time profile extracted, using OLS estimation, from the two *aggregate import price* proxies, *indexes* and *unit values*

[21] In order not to overburden the chapter with factual material, we have preferred to include in appendix only descriptive statistics and estimation results concerning our *monthly* series. The analogous information for the corresponding *quarterly* data as well as our EViews programs are, certainly, available upon request. Nevertheless, when discussing the sensitivity of our results across *frequency*, we also summarize the respective findings based on our quartely data, essentially comparing them to our corresponding monthly based conclusions.

– mostly at the horizon of 2-3 months, hence 1 quarter; yet this difference likewise tends to diminish over longer horizons, 1 year in particular. Thus, for the cumulative pass-through on import prices, both our proxies result in quite close estimates, notably over the whole sample (109.0% using import price indexes and 110.3% using unit values of imports for Germany; and 100.0% and 104.3%, respectively, for Japan) and during the 1990s subperiod (57.0% and 57.3% for Germany; 52.8% and 53.2% for Japan). However, the slight *overstatement* of pass-through on import prices by OLS with unit values, almost imperceptible in the percentages we quoted, becomes more pronounced for the 1980s. To sum-up, the use of import unit values in place of price indexes seems to matter in terms of the *precise* magnitudes of NEER pass-through, especially in the short run of 1, 2 and 3 months (hence, 1 quarter), but not that much in capturing the *general* time profile.

As for *business cycle* controls in the Campa-L.Goldberg (2002) regression, using *industrial production* indexes or *employment* volume indexes instead of *real GDP* does not considerably affect our results either.[22] The interpolation of GDP-related data we used in our monthly pass-through measurement does not thus seem to matter much.

Across Time Irrespective of the frequencies and proxies we employ, a common conclusion is that NEER pass-through on import prices has diminished sharply in the 1990s relative to the 1980s at almost all horizons up to one year, as documented in tables 4 and 5 in Appendix C.2. A notable exception to this general finding is just the pass-through on impact (i.e. in the first month – but not in the first quarter – following an exchange rate innovation) in the US, higher (but still quite low) in the 1990s (4.9%) than in the 1980s (2.5%). One of the principal reasons behind such a secular phenomenon could be a shift to a higher extent of CCP, or – which is similar – to an increased pricing-to-market behavior by monopolistic firms competing strategically in today's globalizing economy. As mentioned in the introduction, other papers of the late 1990s such as, for instance, Friberg and Vredin (1997) had already challenged Grassman's law derived from data in the 1960s and early 1970s by finding empirically a growing role for PTM.

Across Country The interesting but more or less known result from the cross-country comparison of our single-equation estimates of exchange rate pass-through on import prices is the *very low* pass-through – along all studied horizons – in the US relative to Germany and Japan. Only $\frac{1}{4}$ of a NEER change is estimated to be passed on to import prices over one year in the US and only about 4% in the first month, during the whole sample period as well as (a little bit more) in the 1990s subsample. By contrast, our estimates for Germany and Japan present evidence for a virtually *full* pass-through on import prices over the same horizon of one year within the total

[22] More details are available upon request.

sample, with more than half of the cumulative change happening in the first month after the shock.

How Do Our Results Compare to Those in Campa-L.Goldberg (2002)? Our NEER pass-through elasticities on import prices obtained along the Campa-L.Goldberg (2002) OLS methodology but with *monthly* data and a corresponding specification, equation (3.1), are almost identical for the US, not much different for Japan and kind of exaggerated for Germany when compared to the *quarterly* based measures at the relevant horizons the mentioned authors report.[23] At one quarter Campa and L.Goldberg (2002) obtain[24] 18.4% for the US, 49.7% for Germany and 84.1% for Japan, within their whole sample of 1975-1999; at a horizon of one year the respective pass-through on import prices they find is 29.2%, 73.4% and 117.7%. Our own estimates are 18.3% and 24.4% for the US, 86.8% and 109.0% for Germany and 67.8% and 100.0% for Japan, using price indexes (as noted, employing unit values in this case would not change much).

VAR System Methodology To be able to directly compare our impulse response estimates of pass-through from the NEER to import prices obtained using VARs and documented in tables C.9 and C.10 with those obtained via OLS in tables C.4 and C.5 (all found in Appendix C.2), we applied a simple but informative transformation to the response values at all time horizons. This transformation consists in normalizing all impulse responses to an exchange rate innovation of one standard deviation by the magnitude of that same standard deviation. It results in a pass-through elasticity measured in percentage changes, just as in the case when we used first differences of natural logs to specify our OLS regressions. In effect, our VAR pass-through estimates quoted below continue to express what part (in %) is passed on to various price proxies following a unit change in the NEER, as it was until now. Moreover, with the help of this transformation we can judge to what extent the econometric method applied (single-equation OLS vs. simultaneous VAR system, in particular) may affect our principal findings along the several dimensions of the present empirical analysis.

Across Frequency Turning back to the frequency dimension, we could sum up the following main conclusions from the VARs we ran. Estimates of (cumulative) pass-through at the same time horizon – e.g. one, two, three and four quarters – obtained from quarterly data are generally *lower* than the corresponding estimates based on monthly series. This is particularly true for the whole sample period and the 1980s subsample and for Germany and Japan. The US monthly vs. quarterly based estimates do not diverge a lot, for all subperiods and for all stages in the pricing chain.

[23] Due to a lesser similarity/consistency of our OLS specification and sample with the one summarized in P.Goldberg and Knetter (1997), we would not engage here in comparing our quantitative findings with theirs.

[24] Cf. their Appendix Table 1, p. 29.

An interesting observation which comes out from our monthly pass-through estimates – but impossible to be captured at a quarterly frequency – is related to a kind of short-run dynamics of price adjustment to exchange rate changes, rather common across stages in the pricing chain, variable proxies, time periods and country cases. There is a "dive" in our pass-through estimates, more frequently in the third month and less frequently in the second month. It usually comes after a "spike", generally in the first or second month. Such a pattern in the initial dynamics of pass-through obviously exhibits some "overshooting", which appears typical for the economies we focused on.

Across Proxy Except for Germany in the 1990s, the use of one or the other of our two proxies of aggregate prices of imports in the VARs did not appear to change much, as it was with our OLS estimates. More precisely, unit value inferred impulse response measures tend to slightly *understate* pass-through on import prices in the shorter run (up to one quarter). Sometimes this underestimation is complemented by a weak exaggeration in the longer run (one year).

Across Time For all countries and no matter the frequency or proxy, VAR-estimated pass-through on import prices has decreased in the 1990s relative to the 1980s – weakly for the US, dramatically for Germany and, to a lesser extent, Japan – and at all horizons (except in the very short run in the US). This conclusion generally accords with our OLS estimates. However, the magnitude of the empirical range of pass-through measured via OLS vs. VARs as well as, consequently, the extent of decrease in pass-through in the recent decade differ across methodologies. As a result, US estimates from OLS and VARs largely coincide across all sample periods and horizons. The same is true for Japan and Germany in the 1990s, but not in the 1980s and, therefore, over the whole sample.

Across Country In the US, the single-equation *point* estimate à la Campa-L.Gold-berg (2002) is most of the time *inside* the system *range* estimate summarizing the four alternative orderings of our VARs. As to the generalized impulse response measures, they coincide with our orthogonalized impulse response findings when ordering with the exchange rate coming first (as in our second VAR specification) is effected, in compliance with the theoretical result by Pesaran and Shin (1998) mentioned earlier. The generalized impulse response magnitudes are thus also included within the intervals reported in tables C.9 and C.10 in Appendix C.2. If there are some differences to distinguish between OLS and VAR pass-through estimates on import prices in the case of the US, these would concern the cumulative response at the longer horizons (3 quarters and 1 year) and mostly the 1990s subperiod (when VAR-obtained values are somewhat higher). Otherwise, our OLS and VAR measures of pass-through on import prices are practically unanimous in the US case. As we said, this is not so for Japan and Germany right after the first month following an exchange rate depreciation has elapsed. In cumulative terms over the horizon of one year, Japanese VARs tend to *overestimate* pass-through on import prices relative to OLS by about $\frac{1}{3}$ during the whole sample period as well as over the 1980s; German VARs exaggerate pass-through on import prices with respect to our OLS estimates roughly twice over the same horizon. However, in the 1990s subperiod both Japanese and German VARs extract from the data ranges of pass-through on import prices largely similar to those obtained via OLS.

3.4.2 Pass-Through on Export Prices

Looking now at the pass-through from exchange rate changes to *export* prices in tables C.11 and C.12 in Appendix C.2, we could summarize our findings in the following manner.

Across Frequency With respect to pass-through on export price levels, the frequency dimension of our study does not easily lend itself to a simple generalization. On the one hand, Germany and Japan seem again more similar between themselves, with the US standing out as a special case. But the fact that quarterly estimates tend to *understate* pass-through relative to monthly ones remains valid for Japan in the whole sample and its two subperiods (with less divergence compared to what we observed concerning import prices) as well as for Germany in the whole sample and during the 1980s. For the US a similar conclusion is true for the 1980s only, not for the whole sample and the 1990s.

Across Proxy Although again preserving some very general trends, the estimates resulting from *unit values* now produce time profiles that are quite dissimilar to (in fact, much steeper than) the corresponding estimates obtained from *price indexes*. Moreover, in the Japanese case, unit value estimates are indicative of falling pass-through on the prices of exports in the 1990s relative to the 1980s, while price index-based measures reverse this conclusion. In the case of Germany, estimates based on indexes present evidence for a pass-through that diminishes considerably in the 1990s relative to the 1980s, especially over the one-year horizon, whereas estimates from unit values indicate only a modest reduction. Our proxy check, therefore, flashes a red light: measurement problems involved in unit values and price indexes may impair, as here, the robustness of similar pass-through estimates.

Across Time As to the general trend of *declining* pass-through across time, both discussed proxies confirm this conclusion only for Germany; the exact magnitude of this decline, however, differs, as we noted above. With respect to the US, pass-through on export prices has somewhat *increased* in the 1990s relative to the 1980s:

from $11.7 - 15.9\%$ to $16.5 - 17.6\%$ over a horizon of one year. The same tendency, but at a much higher pass-through magnitude, is true for Japan if price indexes are used in the VARs but not unit values, as already commented.

Our empirical findings thus indicate a considerably declining pass-through on import prices accompanied with more or less stable pass-through on export prices in the US, Germany and Japan. Observe that a simple two-country model of the types used in traditional and new open-economy macroeconomics would not capture such a *pass-through asymmetry*. The reason is that two-country models impose symmetric imports and exports: what is exports for the first economy is, by necessity, imports for the second one. A trading system in the real world remains closed too, but is not restricted to two countries only, so asymmetries on a bilateral basis are not excluded (and are often a feature of the data). Nevertheless, an interpretation of this asymmetric pass-through on import and export prices we would propose is, at least in part, consistent with our theoretical work in chapters 1 and 2. It boils down to the following trends in the price-setting behavior of monopolistically competitive producers and/or exporters: foreign exporters to the US, Germany and Japan have tried to maintain their shares in the huge markets of these economies throughout the 1990s by (i) more recourse to pricing-to-market, i.e. to exports priced according to CCP, and (ii) less pass-through from exchange-rate changes to the prices of that fraction of their exports which is denominated in the respective own national currency, i.e. priced according to PCP; at the same time, exporters from these three major economies to relatively smaller markets (of many other countries) have been more reluctant, when pricing exports, to shift from their domestic but world-wide accepted currency to foreign currencies (in particular, such that are of marginal significance in global forex markets).

Across Country The empirical range of pass-through across countries is, again, quite varied when pass-through on export prices is analyzed. The lowest pass-through is in the US (like it was with pass-through on import prices), of the order of $13.7 - 15.4\%$ at the one year horizon for the whole sample period. Japan exhibits the highest pass-through on export prices for that same horizon and period, $69.3 - 70.0\%$, and Germany comes close to Japan, with $54.4 - 57.7\%$. The three interval estimates just quoted were those obtained via price indexes (using unit values instead would produce kind of opposite ranges for Germany and Japan).

3.4.3 Pass-Through on Consumer Prices

We finally compare our findings about the empirical range of pass-through to *consumer* prices, reported in tables C.13 and C.14 in Appendix C.2. Here several conclusions that hold in common for the three countries considered seem to be shaping out.

Across Frequency As far as NEER pass-through on consumer price levels is concerned, frequency largely does not matter. A general finding is that at this final stage in the pricing chain, relevant for consumers' decision-making and, hence, for any microfounded macroeconomic outcomes, pass-through is low to negligible.

Across Proxy The proxy employed in our impulse response estimates of pass-through on consumer prices does not matter either. For the whole sample and the 1990s (but much less so for the 1980s) empirical ranges along all respective horizons are very close in value, thus producing a very similar time profile in Germany and in Japan.

Across Time In Germany and Japan, proxies accord as well on the tendency towards a decline in the exchange rate pass-through on consumer prices in the 1990s compared to the 1980s. As to the US, there is strong evidence that this particular pass-through has been negligible at all time horizons, over the whole sample period and within each of the two subperiods.

Across Country A major conclusion is thus that there is nowadays a *practically nil* pass-through from exchange rate movements to consumer prices in all three countries examined.

How Do Our Results Compare to Those in Choudhri, Faruquee and Hakura (2002)? Using orthogonalized impulse responses from a somewhat different sample period and VAR specification with seven endogenous and two exogenous variables over quarterly data, Choudhri, Faruquee and Hakura (2002) measure the exchange rate pass-through at various stages of the pricing chain for the six non-US G-7 countries. Are our findings at the relevant horizons similar to theirs?[25] Generally yes, mostly concerning consumer prices for both Japan and Germany and at both horizons of principal interest, one quarter and one year, as well as for Japan at all three levels in the pricing chain and at both mentioned time spans. The latter three authors report[26] pass-through on *import* prices of 80% at one quarter and 134% at one year for Japan and 39% and 77%, respectively, for Germany; our corresponding VAR interval estimates (employing price indexes) are 82.1 – 82.3% and 137.8 – 141.2% for Japan and 94.0 – 100.6% and 205.0 – 219.6% for Germany. Pass-through on *export* prices is, correspondingly, 50% and 50% for Japan and 3% and 16% for Germany in Choudhri *et al.* against our estimates of 74.6 – 74.7% and 69.3 – 70.0% for Japan and 21.3 – 22.2% and 54.4 – 57.7% for Germany. Finally, pass-through from exchange rate changes to *consumer* prices is measured by the three authors at −1% and 4% for Japan and 15%

[25] Due to a lesser similarity/consistency of our VAR specification and sample with those in McCarthy (2000), we would not compare here our pass-through ranges with his related results.

[26] In their Table 1, p. 23.

and 20% for Germany while our estimates are, respectively, $1.2 - 1.3\%$ and $6.0 - 6.2\%$ for Japan $1.4 - 4.2\%$ and $15.0 - 21.4\%$ for Germany.

3.5 Concluding Comments

This last, empirical chapter built on some implications of the NOEM analysis in the two preceding, theoretical chapters as well as on studies of exchange rate pass-through using macrodata to measure and interpret the likely range of this phenomenon in three leading national economies in the world, namely the US, Germany and Japan. We obtained results employing various methods and specifications, and containing a number of interesting aspects to analyze. Focusing on monthly data to comply with a consensual span of predominant real-world price level stickiness and with a more relevant frequency for NER fluctuations recorded for actual economies, we inferred pass-though estimates that are broadly similar – when expressed in quarterly terms – to those extracted in earlier related papers, notably from OLS in Campa-L.Goldberg (2002) and from VARs in Choudhri, Faruquee and Hakura (2002). Yet the following novel features of our work, as well as some key differences along its several dimensions, are worth emphasizing.

An overall conclusion is that the empirical range of exchange rate pass-through on prices varies across (i) economies, (ii) data frequencies, (iii) periods of time, (iv) methods of estimation, (v) aggregate price measures, (vi) stages along the pricing chain and (vii) horizons of analysis. Any generalization thus needs to be careful. Yet abstracting from the specificity of some features of pass-through we commented in detail above, we would like to stress at least three important and rather robust results from our empirical analysis. First, in the three countries we examined, pass-through on import prices has considerably declined in the 1990s relative to the 1980s; but pass-through on export prices has, in essence, remained the same, although with certain country-specific nuances: more precisely, it has somewhat increased in the US, stayed flat in Japan and slightly decreased in Germany; as far as consumer prices are concerned, exchange rate pass-through seems to be nowadays practically negligible over all horizons of up to one year. Grassman's law evoked in the introductory part thus appears to be "weakening" by the end of the 20th century relative to the last decade of the Bretton-Woods era. Second, the econometric method and the measurement proxy used matter for the *precise* magnitudes and time patterns, yet they often – but not always – accord on the *general* trends. Third, the US is quite a particular economy, with import and, hence, consumer price levels that are amazingly insensitive to US dollar depreciations.

As far as our focus on the frequency dimension of pass-through estimates is concerned, a general insight from performing the same calculations with monthly as well as with (corresponding) quarterly data is that when passing from the higher to the lower frequency a lot of short-term dynamics is lost, partly due to an "averaging out" effect.

When monthly fluctuations are strong, the difference in estimates from monthly vs. quarterly data should therefore be substantial. Conversely, for less volatile monthly data, quarterly estimates should offer good approximations. This intuitive logic is supported by the evidence for a difference in the magnitudes, and sometimes in the trends, of estimated pass-through at different data frequency the present empirical work revealed.

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Appendix A

Proofs to Chapter 1

A.1 Proof of Proposition 1.1 (Equilibrium World Trade-to-Output)

Proof. Under PCP, from (1.33) and the symmetric equation for Foreign, one obtains:

$$(ft)_{H,s}^{P}+(ft)_{F,s}^{*,P}=\frac{2}{\left(S_s^P\right)^{1-\varphi}+1}+\frac{2}{\left(\frac{1}{S_s^P}\right)^{1-\varphi}+1}=$$

$$=\frac{2}{\left(S_s^P\right)^{1-\varphi}+\frac{\left(S_s^P\right)^{1-\varphi}}{\left(S_s^P\right)^{1-\varphi}}}+\frac{2}{\frac{1}{\left(S_s^P\right)^{1-\varphi}}+\frac{\left(S_s^P\right)^{1-\varphi}}{\left(S_s^P\right)^{1-\varphi}}}=\frac{2}{\frac{\left(S_s^P\right)^{2(1-\varphi)}+\left(S_s^P\right)^{1-\varphi}}{\left(S_s^P\right)^{1-\varphi}}}+\frac{2}{\frac{1+\left(S_s^P\right)^{1-\varphi}}{\left(S_s^P\right)^{1-\varphi}}}=$$

$$=\frac{2\left(S_s^P\right)^{1-\varphi}}{\left(S_s^P\right)^{1-\varphi}\left[\left(S_s^P\right)^{(1-\varphi)}+1\right]}+\frac{2\left(S_s^P\right)^{1-\varphi}}{1+\left(S_s^P\right)^{(1-\varphi)}}=\frac{2}{1+\left(S_s^P\right)^{(1-\varphi)}}+\frac{2\left(S_s^P\right)^{1-\varphi}}{1+\left(S_s^P\right)^{(1-\varphi)}}=$$

$$=\frac{2+2\left(S_s^P\right)^{1-\varphi}}{1+\left(S_s^P\right)^{(1-\varphi)}}=\frac{2\left[1+\left(S_s^P\right)^{1-\varphi}\right]}{1+\left(S_s^P\right)^{(1-\varphi)}}=2.$$

Thus, (equally-weighted) world trade *equals* world output in any state of nature that has materialized:

$$\frac{1}{2}\left[(ft)_{H,s}^{P}+(ft)_{F,s}^{*,P}\right]=1,\text{ for }\forall s\in S.$$

This completes our proof. ■

A.2 Proof of Proposition 1.2 (Expected National Trade-to-Output)

Proof. Recall our result under PCP in (1.33):

$$(ft)_{H,s}^{P}=\frac{2}{1+\left(S_s^P\right)^{\varphi-1}}=\frac{2}{1+\left(\frac{M_s}{M_s^*}\right)^{\frac{\varphi-1}{\varphi}}}.$$

There are three *kinds* of state of nature in the model: (i) relative monetary equilibrium, i.e. $s_e \in S_e \subset S \Leftrightarrow M_{s_e} = M^*_{s_e}$, hence $(ft)^P_{H,s_e} = 1$, (ii) relative Home monetary expansion, i.e. $s_H \in S_H \subset S \Leftrightarrow M_{s_H} > M^*_{s_H}$, and (iii) relative Foreign monetary expansion, i.e. $s_F \in S_F \subset S \Leftrightarrow M_{s_F} < M^*_{s_F}$. The expected trade share in Home therefore is:

$$\begin{aligned} E_0\left[(ft)^P_{H,s}\right] &= \left[1-\sum_{s_H}\Pr(s_H)-\sum_{s_F}\Pr(s_F)\right]\times 1+ \\ &+\sum_{s_H}\Pr(s_H)\frac{2}{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}+\sum_{s_F}\Pr(s_F)\frac{2}{1+\left(\frac{M_{s_F}}{M^*_{s_F}}\right)^{\frac{\varphi-1}{\varphi}}}, \end{aligned}$$

where $1-\sum_{s_H}\Pr(s_H)-\sum_{s_F}\Pr(s_F)$ is the total probability of the states $s_e \in S_e \subset S$ with $\frac{M_{s_e}}{M^*_{s_e}} = \frac{M^*_{s_e}}{M_{s_e}} = 1$.

Since we have assumed a *jointly symmetric* distribution of money shocks, for each state s_H where $\frac{M_{s_H}}{M^*_{s_H}} > 1$ there is exactly one mirror state s_F where $\frac{M_{s_F}}{M^*_{s_F}} = \left[\frac{M_{s_H}}{M^*_{s_H}}\right]^{-1}$ and $\Pr(s_H) = \Pr(s_F)$. Therefore we write:

$$\begin{aligned} E_0\left[(ft)^P_{H,s}\right] &= 1-2\sum_{s_H}\Pr(s_H)+\sum_{s_H}\Pr(s_H)\left[\frac{2}{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}+\frac{2}{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{-\frac{\varphi-1}{\varphi}}}\right]= \\ &= 1-2\sum_{s_H}\Pr(s_H)+2\sum_{s_H}\Pr(s_H)\left[\frac{1}{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}+\frac{1}{1+\frac{1}{\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}}\right]= \\ &= 1-2\sum_{s_H}\Pr(s_H)+2\sum_{s_H}\Pr(s_H)\left[\frac{1}{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}+\frac{\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}{\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}+1}\right]= \\ &= 1-2\sum_{s_H}\Pr(s_H)+2\sum_{s_H}\Pr(s_H)\left[\frac{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}{1+\left(\frac{M_{s_H}}{M^*_{s_H}}\right)^{\frac{\varphi-1}{\varphi}}}\right]= \\ &= 1-2\sum_{s_H}\Pr(s_H)+2\sum_{s_H}\Pr(s_H)= \\ &= 1. \end{aligned}$$

The same logic applies to the expected trade-to-output ratio in Foreign, $E_0\left[(ft)^{*,P}_{F,s}\right]$, for no matter what distribution of money shocks provided that it is *jointly symmetric*.

This completes our proof. ■

Appendix B

Derivations and Proofs to Chapter 2

B.1 Derivation of Equilibrium Results

B.1.1 Equilibrium Nominal Exchange Rate

CCP Under CCP, S_s^C is determined by:

$$\underbrace{P_F^C c_{F,s}^C}_{F \text{ export revenues} \Leftrightarrow HCsupply} - S_s^C \cdot \underbrace{P_H^{*,C} c_{H,s}^{*,C}}_{H \text{ export revenues} \Leftrightarrow HCdemand} = 0$$

Substituting for optimal $c_{F,s}^C$ and $c_{H,s}^{*,C}$ above as well as for the H and F CPI definitions further on in the algebraic manipulation derives:

$$S_s^C = \frac{\left(\frac{P_F^C}{P^C}\right)^{1-\nu}}{\left(\frac{P_H^{*,C}}{P^{*,C}}\right)^{1-\nu}} \frac{M_s}{M_s^*} = \frac{\frac{\left(P_F^C\right)^{1-\nu}}{\left(P_H^C\right)^{1-\nu} + \left(P_F^C\right)^{1-\nu}}}{\frac{\left(P_H^{*,C}\right)^{1-\nu}}{\left(P_F^{*,C}\right)^{1-\nu} + \left(P_H^{*,C}\right)^{1-\nu}}} \frac{M_s}{M_s^*} =$$

$$= \frac{\frac{1}{\frac{\left(P_H^C\right)^{1-\nu}}{\left(P_F^C\right)^{1-\nu}} + 1}}{\frac{1}{\frac{\left(P_F^{*,C}\right)^{1-\nu}}{\left(P_H^{*,C}\right)^{1-\nu}} + 1}} \frac{M_s}{M_s^*} = \frac{1 + \left(\frac{P_F^{*,C}}{P_H^{*,C}}\right)^{1-\nu}}{1 + \left(\frac{P_H^C}{P_F^C}\right)^{1-\nu} + 1} \frac{M_s}{M_s^*}$$

Now using the price equalities established earlier, namely $P_H = P_H^* = P_F^* = P_F^*$ to substitute above, one obtains the CCP expression in (2.16).

PCP Under PCP, S_s^P is determined by:

$$S_s^P \cdot \underbrace{\frac{P_F^* c_{F,s}^P}{1-\tau}}_{F \text{ export revenues} \Leftrightarrow HCsupply} - \underbrace{\frac{P_H c_{H,s}^{*,P}}{1-\tau}}_{H \text{ export revenues} \Leftrightarrow HCdemand} = 0$$

Hence:

$$S_s^P c_{F,s}^P = c_{H,s}^{*,P}$$

Substituting for optimal $c_{F,s}^P$ and $c_{H,s}^{*,P}$ and rearranging, we get:

$$S_s^P \left(\frac{\frac{S_s^P P_F^*}{1-\tau}}{P_s^P} \right)^{-\nu} \frac{M_s}{P_s^P} = \left(\frac{\frac{P_H}{S_s^P(1-\tau)}}{P_s^{*,P}} \right)^{-\nu} \frac{M_s^*}{P_s^{*,P}}$$

$$S_s^P \left(\frac{\frac{S_s^P P_F^*}{1-\tau}}{P_s^P} \frac{P_s^{*,P}}{\frac{P_H}{S_s^P(1-\tau)}} \right)^{-\nu} = \frac{M_s^*}{M_s} \frac{P_s^P}{P_s^{*,P}}$$

$$\left(S_s^P\right)^{1-2\nu} \left(\frac{P_s^P}{P_s^{*,P}} \right)^{\nu} = \frac{M_s^*}{M_s} \frac{P_s^P}{P_s^{*,P}}$$

$$S_s^P = \left(\frac{M_s^*}{M_s} \right)^{\frac{1}{1-2\nu}} \left(\frac{P_s^P}{P_s^{*,P}} \right)^{\frac{1-\nu}{1-2\nu}} \tag{B.1}$$

Now we use the CPI definitions derived earlier to substitute for their ratio above:

$$\frac{P_s^P}{P_s^{*,P}} = \left[\frac{\left(1 + \frac{S_s^P}{1-\tau}\right)^{1-\nu}}{\left(1 + \frac{1}{S_s^P(1-\tau)}\right)^{1-\nu}} \right]^{\frac{1}{1-\nu}}$$

So that:

$$S_s^P = \left(\frac{M_s^*}{M_s} \right)^{\frac{1}{1-2\nu}} \left\{ \left[\frac{\left(1 + \frac{S_s^P}{1-\tau}\right)^{1-\nu}}{\left(1 + \frac{1}{S_s^P(1-\tau)}\right)^{1-\nu}} \right]^{\frac{1}{1-\nu}} \right\}^{\frac{1-\nu}{1-2\nu}}$$

$$\left(S_s^P\right)^{1-2\nu} = \frac{M_s^*}{M_s} (1-\tau)^{1-\nu} \left(S_s^P\right)^{1-\nu} \frac{\left(1 + \frac{S_s^P}{1-\tau}\right)^{1-\nu}}{1 + (1-\tau)^{1-\nu} \left(S_s^P\right)^{1-\nu}}$$

$$\left(S_s^P\right)^{-\nu} = \frac{M_s^*}{M_s} \frac{(1-\tau)^{1-\nu} + \left(S_s^P\right)^{1-\nu}}{1 + (1-\tau)^{1-\nu} \left(S_s^P\right)^{1-\nu}}$$

$$S_s^P = \left[\frac{1 + (1-\tau)^{1-\nu} \left(S_s^P\right)^{1-\nu}}{(1-\tau)^{1-\nu} + \left(S_s^P\right)^{1-\nu}} \right]^{\frac{1}{\nu}} \left(\frac{M_s}{M_s^*} \right)^{\frac{1}{\nu}},$$

which is the PCP expression in (2.16).
Under a peg, i.e. with $M_s = M_s^*$ for any $s \in S$, one would further on obtain:

$$\left(S_s^P\right)^{\nu} = \frac{1 + (1-\tau)^{1-\nu} \left(S_s^P\right)^{1-\nu}}{(1-\tau)^{1-\nu} + \left(S_s^P\right)^{1-\nu}}$$

An obvious solution is $S_s^P = 1$. Is it unique, more precisely within the domains for our variables, $0 < S_s^P << \infty$, and parameters $0 < \tau < 1$ and $0 < \nu << \infty$? To prove it, we define two functions (skipping the state s subscript and the PCP P superscript, for convenience here, since we work with our PCP model version and invoicing is thus not ambiguous):

$$g(S) \equiv S^{\nu};$$

$$h(S) \equiv \frac{1 + (1-\tau)^{1-\nu} S^{1-\nu}}{(1-\tau)^{1-\nu} + S^{1-\nu}}.$$

We then analyze these functions, essentially in the vicinity of 1, as follows:

$$g'(S) = \nu S^{\nu-1} > 0,$$

hence $g(S)$ is monotone *increasing* in its domain;

$$g''(S) = \nu(\nu-1) S^{\nu-2}:$$

with elastic demand, $\nu > 1 \Leftrightarrow g''(S) > 0$, hence $g(S)$ is convex;
with inelastic demand, $0 < \nu < 1 \Leftrightarrow g''(S) < 0$, hence $g(S)$ is concave.
Moreover,
when $S \to 0$, $\lim_{S\to 0} g(S) = 0$;
and when $S \to \infty$, $\lim_{S\to\infty} g(S) = \infty$.

We thus have that $g(1) = 1$ and that $g(S < 1) < 1$ and $g(S > 1) > 1$, as the function $g(S)$ increases from close to zero to infinity.

Now,

$$h'(S) = \frac{(1-\nu) S^{-\nu} \left\{ \left[(1-\tau)^{1-\nu} \right]^2 - 1 \right\}}{\left[(1-\tau)^{1-\nu} + S^{1-\nu} \right]^2}.$$

Before being able to conclude about the sign of the above derivative, we need to consider two cases:
with elastic demand, $\nu > 1 \Leftrightarrow h'(S) < 0$, because:
$\left[(1-\tau)^{1-\nu}\right]^2 - 1 > 0$ and $1 - \nu < 0$,
with $S^{-\nu} > 0, \forall \nu$ and $\left[(1-\tau)^{1-\nu} + S^{1-\nu}\right]^2 > 0, \forall \nu$;
hence, $h(S)$ is monotone *decreasing* in its domain when $\nu > 1$;
with inelastic demand, $\nu < 1 \Leftrightarrow h'(S) < 0$ again, because:
$\left[(1-\tau)^{1-\nu}\right]^2 - 1 < 0$ and $1 - \nu > 0$,
with $S^{-\nu} > 0, \forall \nu$ and $\left[(1-\tau)^{1-\nu} + S^{1-\nu}\right]^2 > 0, \forall \nu$;
hence, $h(S)$ is monotone *decreasing* in its domain when $\nu < 1$ as well.

Therefore, no matter what demand is (elastic, i.e. $\nu > 1$, or inelastic, i.e. $\nu < 1$), $h(S)$ is a monotone decreasing function. Since we have shown above that $g(S)$ is monotone increasing (again, no matter whether demand is elastic or inelastic), the two functions will have a unique crossing point, at $S_s^P = 1$. This proves our claim in the main text that, similarly to the CCP model version, under peg implying $M_s = M_s^*, \forall s \in S$ (or whenever there occurs a state of relative monetary equilibrium under float) we can always write $S_s^P = 1$.

B.1.2 Equilibrium Trade Shares

With iceberg costs $0 < \tau < 1$ taken into account, the Home[1] CCP vs. PCP equilibrium trade/GDP ratio is defined by

$$(ft)^C_{H,s} \equiv \frac{(FT)^C_{H,s}}{Y^C_{H,s}} = \frac{(Ex)^{C,cif}_{H,s}+(Im)^{C,cif}_{H,s}}{(DA)^C_{H,s}+(Ex)^{C,cif}_{H,s}} = \frac{S^C_s \cdot \overbrace{P^{*,C}_H}^{\text{FC } cif} \cdot \overbrace{c^{*,C}_{H,s}}^{\text{consumed}} + \overbrace{P^C_F}^{\text{HC } cif} \cdot \overbrace{c^C_{F,s}}^{\text{consumed}}}{P^C_H \cdot c^C_{H,s} + S^C_s \cdot \underbrace{P^{*,C}_H}_{\text{FC } cif} \cdot \underbrace{c^{*,C}_{H,s}}_{\text{consumed}}} =$$

$$= \frac{S^C_s \cdot \overbrace{(1-\tau)\, P^{*,C}_H}^{\text{FC } fob} \cdot \overbrace{\frac{c^{*,C}_{H,s}}{1-\tau}}^{\text{produced}} + \overbrace{(1-\tau)\, P^C_F}^{\text{HC } fob} \cdot \overbrace{\frac{c^C_{F,s}}{1-\tau}}^{\text{produced}}}{P^C_H \cdot c^C_{H,s} + S^C_s \cdot \underbrace{(1-\tau)\, P^{*,C}_H}_{\text{FC } fob} \cdot \underbrace{\frac{c^{*,C}_{H,s}}{1-\tau}}_{\text{produced}}} \quad \text{vs.} \tag{B.2}$$

$$(ft)^P_{H,s} \equiv \frac{(FT)^P_{H,s}}{Y^P_{H,s}} = \frac{\overbrace{(Ex)^{P,fob}_{H,s}}^{\equiv (Ex)^{P,cif}_{H,s}} + \overbrace{(Im)^{P,fob}_{H,s}}^{\equiv (Im)^{P,cif}_{H,s}}}{(DA)^P_{H,s} + \underbrace{(Ex)^{P,fob}_{H,s}}_{\equiv (Ex)^{P,cif}_{H,s}}} = \frac{\overbrace{P^P_H}^{\text{HC } fob} \overbrace{\frac{c^{*,P}_{H,s}}{1-\tau}}^{\text{produced}} + S^P_s \overbrace{P^{*,P}_F}^{\text{FC } fob} \overbrace{\frac{c^P_{F,s}}{1-\tau}}^{\text{produced}}}{P^P_H c^P_{H,s} + \underbrace{P^P_H}_{\text{HC } fob} \underbrace{\frac{c^{*,P}_{H,s}}{1-\tau}}_{\text{produced}}}$$

$$= \frac{\overbrace{\frac{P^P_H}{1-\tau}}^{\text{HC } cif} \overbrace{c^{*,P}_{H,s}}^{\text{consumed}} + \overbrace{\frac{S^P_s P^{*,P}_F}{1-\tau}}^{\text{HC } cif} \overbrace{c^P_{F,s}}^{\text{consumed}}}{P^P_H c^P_{H,s} + \underbrace{\frac{P^P_H}{1-\tau}}_{\text{HC } cif} \underbrace{c^{*,P}_{H,s}}_{\text{consumed}}}, \tag{B.3}$$

where $(Ex)^{C,cif}_{H,s}$ denotes Home exports at *cif* prices, $(Im)^{C,cif}_{H,s}$ Home imports at *cif* prices and $(DA)^C_{H,s}$ Home domestic absorption, with all these three *values* (prices multiplied by quantities) expressed in Home currency under CCP for any state $s \in S$ that has materialized. $(Ex)^{P,fob}_{H,s}$, $(Im)^{P,fob}_{H,s}$ and $(DA)^P_{H,s}$ are, of course, the respective Home-currency values under PCP, with Home exports and imports now measured at *fob* prices. It is important to recall at this point that once a transport and/or tariff friction is considered in our extended NOEM model, the relevant prices for equilibrium trade flows as implied by the invoicing conventions we analyze become the *cif* ones under CCP and the *fob* ones under PCP. However, due to our *symmetric* iceberg costs assumption, we have shown by the last equalities in (B.2) and (B.3) above that the fob values are *exactly equal* to their respective cif values in both our CCP and PCP model versions, so that trade shares can be meaningfully compared across alternative price setting as if calculated on the *same*, *cif* basis. This latter, *cif domestic*-currency value is, furthermore, the appropriate measure to use, since it duly accounts for the difference between quantities *bought* and quantities *consumed* arising from the output lost in transit and thus reflects the *true cost* to the representative consumer.

Substitutions for optimal domestic and external demands for H and F output and use of the CPI definitions derive – under *full symmetry* and *separable preferences* – the CCP vs. PCP equilibrium trade shares in the main text.

[1] For Foreign, the respective expressions are symmetric.

The derivation under CCP for Home is:

$$(ft)^C_{H,s} \equiv \frac{(FT)^C_{H,s}}{Y^C_{H,s}} = \frac{(Ex)^{C,cif}_{H,s}+(Im)^{C,cif}_{H,s}}{(DA)^C_{H,s}+(Ex)^{C,cif}_{H,s}} = \frac{S^C_s \cdot \overbrace{P^{*,C}_H}^{\text{FC } cif} \cdot \overbrace{c^{*,C}_{H,s}}^{\text{consumed}} + \overbrace{P^C_F}^{\text{HC } cif} \cdot \overbrace{c^C_{F,s}}^{\text{consumed}}}{P^C_H \cdot c^C_{H,s} + S^C_s \cdot \underbrace{P^{*,C}_H}_{\text{FC } cif} \cdot \underbrace{c^{*,C}_{H,s}}_{\text{consumed}}} =$$

$$= \frac{\overbrace{\frac{M_s}{M^*_s}}^{S^C_s} P^{*,C}_H \overbrace{\frac{1}{2}\left(\frac{P^{*,C}_H}{P^{*,C}}\right)^{-\nu}\frac{M^*_s}{P^{*,C}}}^{c^{*,C}_{H,s}} + P^C_F \overbrace{\frac{1}{2}\left(\frac{P^C_F}{P^C}\right)^{-\nu}\frac{M_s}{P^C}}^{c^C_{F,s}}}{P^C_H \underbrace{\frac{1}{2}\left(\frac{P^C_H}{P^C}\right)^{-\nu}\frac{M_s}{P^C}}_{c^C_{H,s}} + \underbrace{\frac{M_s}{M^*_s}}_{S^C_s} P^{*,C}_H \underbrace{\frac{1}{2}\left(\frac{P^{*,C}_H}{P^{*,C}}\right)^{-\nu}\frac{M^*_s}{P^{*,C}}}_{c^{*,C}_{H,s}}} =$$

Using our earlier result that, under CCP, *Home* and *Foreign* price levels are *equal*, due to the symmetry in the model, i.e. $P^C = P^{*,C}$, and dividing through by $\frac{M_s}{(P^C)^{1-\nu}}$, we obtain:

$$= \frac{P^{*,C}_H \left(P^{*,C}_H\right)^{-\nu} + P^C_F \left(P^C_F\right)^{-\nu}}{P^C_H \left(P^C_H\right)^{-\nu} + P^{*,C}_H \left(P^{*,C}_H\right)^{-\nu}} = \frac{(P^{*,C}_H)^{1-\nu} + (P^C_F)^{1-\nu}}{(P^C_H)^{1-\nu} + (P^{*,C}_H)^{1-\nu}} =$$

Recalling that $P^{*,C}_H = P^C_F$, due to the symmetry again, one can write:

$$= \frac{(P^{*,C}_H)^{1-\nu} + (P^{*,C}_H)^{1-\nu}}{(P^C_H)^{1-\nu} + (P^{*,C}_H)^{1-\nu}} = \frac{2(P^{*,C}_H)^{1-\nu}}{(P^C_H)^{1-\nu} + (P^{*,C}_H)^{1-\nu}} =$$

Now dividing through by $(P^{*,C}_H)^{1-\nu}$, we finally get:

$$= \frac{\frac{2(P^{*,C}_H)^{1-\nu}}{(P^{*,C}_H)^{1-\nu}}}{\frac{(P^C_H)^{1-\nu}}{(P^{*,C}_H)^{1-\nu}} + \frac{(P^{*,C}_H)^{1-\nu}}{(P^{*,C}_H)^{1-\nu}}} = \frac{2}{\left(\frac{P^C_H}{P^{*,C}_H}\right)^{1-\nu} + 1}$$

So under CCP

$$(ft)^C_H = \frac{2}{\left(\frac{P^C_H}{P^{*,C}_H}\right)^{1-\nu} + 1} = \frac{2}{\left(\frac{E_0\left[u_{l,s}M_s\right]}{\frac{1}{1-\tau}E_0\left[u_{l,s}M^*_s\right]}\right)^{1-\nu} + 1} =$$

$$= \frac{2}{(1-\tau)^{1-\nu} + 1} = const \lesseqgtr 1 \text{ for } \nu \gtreqless 1,$$

which is (2.23) in the main text.

The derivation under PCP for Home is:

$$(ft)^P_{H,s} \equiv \frac{(FT)^P_{H,s}}{Y^P_{H,s}} = \frac{\overbrace{(Ex)^{P,fob}_{H,s}}^{\equiv (Ex)^{P,cif}_{H,s}} + \overbrace{(Im)^{P,fob}_{H,s}}^{\equiv (Im)^{P,cif}_{H,s}}}{(DA)^P_{H,s} + \underbrace{(Ex)^{P,fob}_{H,s}}_{\equiv (Ex)^{P,cif}_{H,s}}} = \frac{\overbrace{P^P_H}^{\text{HC } fob} \overbrace{\frac{c^{*,P}_{H,s}}{1-\tau}}^{\text{produced}} + S^P_s \overbrace{P^{*,P}_F}^{\text{FC } fob} \overbrace{\frac{c^P_{F,s}}{1-\tau}}^{\text{produced}}}{P^P_H c^P_{H,s} + \underbrace{P^P_H}_{\text{HC } fob} \underbrace{\frac{c^{*,P}_{H,s}}{1-\tau}}_{\text{produced}}} =$$

$$= \frac{\frac{P^P_H}{1-\tau}\overbrace{\frac{1}{2}\left(\frac{\frac{P^P_H}{S^P_s(1-\tau)}}{P^{*,P}_s}\right)^{-\nu}\frac{M^*_s}{P^{*,P}_s}}^{\equiv c^{*,P}_{H,s}} + \frac{S^P_s P^*_F}{1-\tau}\overbrace{\frac{1}{2}\left(\frac{\frac{S^P_s P^{*,P}_F}{1-\tau}}{P^P_s}\right)^{-\nu}\frac{M_s}{P^P_s}}^{\equiv c^P_{F,s}}}{P^P_H \underbrace{\frac{1}{2}\left(\frac{P^P_H}{P^P_s}\right)^{-\nu}\frac{M_s}{P^P_s}}_{\equiv c^P_H} + \frac{P^P_H}{1-\tau}\underbrace{\frac{1}{2}\left(\frac{\frac{P^P_H}{S^P_s(1-\tau)}}{P^{*,P}_s}\right)^{-\nu}\frac{M^*_s}{P^{*,P}_s}}_{\equiv c^{*,P}_{H,s}}} =$$

Using that, due to symmetry, $P^P_H = P^*_F$,we get:

$$= \frac{1 + S^P_s\left(\frac{\frac{S^P_s}{P^P_s}}{\frac{P^{*,P}_s}{\frac{1}{S^P_s}}}\right)^{-\nu}\frac{M_s}{P^P_s}\frac{P^{*,P}_s}{M^*_s}}{(1-\tau)^{\nu-1}\left(\frac{\frac{1}{P^P_s}}{\frac{P^{*,P}_s}{\frac{1}{S^P_s}}}\right)^{-\nu}\frac{M_s}{P^P_s}\frac{P^{*,P}_s}{M^*_s} + 1} = \frac{1 + \left(S^P_s\right)^{1-2\nu}\frac{M_s}{M^*_s}\left(\frac{P^{*,P}_s}{P^P_s}\right)^{1-\nu}}{(1-\tau)^{1-\nu}(S^P_s)^{-\nu}\frac{M_s}{M^*_s}\left(\frac{P^{*,P}_s}{P^P_s}\right)^{1-\nu} + 1}.$$

Now recall our earlier result (B.1) that

$$S^P_s = \left(\frac{M^*_s}{M_s}\right)^{\frac{1}{1-2\nu}}\left(\frac{P^P_s}{P^{*,P}_s}\right)^{\frac{1-\nu}{1-2\nu}}.$$

Rearranging, we can write it as:

$$\left(S^P_s\right)^{1-2\nu} = \frac{M^*_s}{M_s}\left(\frac{P^P_s}{P^{*,P}_s}\right)^{1-\nu}.$$

Hence:

$$\frac{M_s}{M^*_s}\left(\frac{P^{*,P}_s}{P^P_s}\right)^{1-\nu} = \frac{1}{\left(S^P_s\right)^{1-2\nu}},$$

which we now use to substitute $\frac{M_s}{M^*_s}\left(\frac{P^{*,P}_s}{P^P_s}\right)^{1-\nu}$ out in our PCP Home trade share derivation, as we continue it below:

$$(ft)^P_{H,s} = \frac{1 + \left(S^P_s\right)^{1-2\nu} \frac{1}{\left(S^P_s\right)^{1-2\nu}}}{(1-\tau)^{1-\nu} \left(S^P_s\right)^{-\nu} \frac{1}{\left(S^P_s\right)^{1-2\nu}} + 1} = \frac{2}{(1-\tau)^{1-\nu} \left(S^P_s\right)^{\nu-1} + 1}$$

We can finally write:

$$(ft)^P_{H,s} = \frac{2}{(1-\tau)^{1-\nu} \left(S^P_s\right)^{\nu-1} + 1} =$$

$$= \frac{2}{(1-\tau)^{1-\nu} \underbrace{\left\{ \left(\frac{M^*_s}{M_s}\right)^{\frac{1}{1-2\nu}} \left(\frac{P^P_s}{P^{*,P}_s}\right)^{\frac{1-\nu}{1-2\nu}} \right\}}_{=S^P_s}^{\nu-1} + 1} \neq const \text{ unless } S^P_s = 1,$$

which is (2.24) in the main text.

The respective expressions for Foreign, (2.25) under CCP and (2.26) under PCP, can be derived by analogy.

B.2 Proofs of Propositions

B.2.1 Proof of Proposition 2.1 (Equilibrium World Trade-to-Output)

Proof. Under *CCP*, the proof is immediate from the *constant* H and F trade shares, in (2.23) and (2.25) respectively.

Under *PCP*, from (2.24) for Home and (2.26) for Foreign, and using as a shorthand below $c \equiv (1-\tau)^{1-\nu}$, one obtains:

$$(ft)^P_{H,s} + (ft)^{*,P}_{F,s} = \frac{2}{(1-\tau)^{1-\nu}\left(S^P_s\right)^{1-\nu}+1} + \frac{2}{(1-\tau)^{1-\nu}\left(\frac{1}{S^P_s}\right)^{1-\nu}+1} =$$

$$= \frac{2}{c\left(S^P_s\right)^{1-\nu} + \frac{\left(S^P_s\right)^{1-\nu}}{\left(S^P_s\right)^{1-\nu}}} + \frac{2}{c\frac{1}{\left(S^P_s\right)^{1-\nu}} + \frac{\left(S^P_s\right)^{1-\nu}}{\left(S^P_s\right)^{1-\nu}}} = 2\left[\frac{1}{1+c\left(S^P_s\right)^{1-\nu}} + \frac{\left(S^P_s\right)^{1-\nu}}{c+\left(S^P_s\right)^{1-\nu}}\right] =$$

$$= 2\left[\frac{1}{1+(1-\tau)^{1-\nu}\left(S^P_s\right)^{1-\nu}} + \frac{\left(S^P_s\right)^{1-\nu}}{(1-\tau)^{1-\nu}+\left(S^P_s\right)^{1-\nu}}\right].$$

Thus, in any state of nature that has materialized (equally-weighted) world trade is:

$$(ft)^P_{W,s} \equiv \frac{1}{2}(ft)^P_{H,s} + \frac{1}{2}(ft)^{*,P}_{F,s} = \frac{1}{2}\left[(ft)^P_{H,s} + (ft)^{*,P}_{F,s}\right] =$$

$$\frac{1}{1+(1-\tau)^{1-\nu}\left(S^P_s\right)^{1-\nu}} + \frac{\left(S^P_s\right)^{1-\nu}}{(1-\tau)^{1-\nu}+\left(S^P_s\right)^{1-\nu}}, \text{ for } \forall s \in S.$$

This completes our proof. ■

B.2.2 Proof of Proposition 2.2 (Expected Trade-to-Output under PCP)

Proof. Write the equilibrium trade shares we derived for Home, (2.24), and Foreign, (2.26), under PCP as functions of the exchange rate (skipping below the P superscript for convenience since now, in the PCP case, there is no ambiguity on invoicing):

$$ft_H(S_s) = \frac{2}{(1-\tau)^{1-\nu} S_s^{\nu-1}+1} \quad \text{and} \quad ft_F(S_s) = \frac{2}{(1-\tau)^{1-\nu} S_s^{1-\nu}+1}.$$

With symmetry, as assumed:

$$ft_H(S_s) = ft_F\left(\frac{1}{S_s}\right).$$

Symmetry in our particular context here implies that for each state of nature s there is a symmetric state s' such that:

1. the exchange rate is inverse: $S_{s'} = \frac{1}{S_s}$;
2. the two states have the same probability: $\pi_s = \pi_{s'}$.

Let us first focus on Home. The expected trade share *across the two symmetric states in the pair* is:

$$\begin{aligned} E_0\left[ft_{H,(s,s')}(S_s)\right] &= \pi_s ft_H(S_s) + \pi_s ft_H(S_{s'}) = \\ &= \pi_s \frac{2}{(1-\tau)^{1-\nu} S_s^{\nu-1}+1} + \pi_s \frac{2}{(1-\tau)^{1-\nu} S_s^{1-\nu}+1} = \\ &= \pi_s \frac{2}{(1-\tau)^{1-\nu}+1}\left[\frac{(1-\tau)^{1-\nu}+1}{(1-\tau)^{1-\nu} S_s^{\nu-1}+1} + \frac{(1-\tau)^{1-\nu}+1}{(1-\tau)^{1-\nu} S_s^{1-\nu}+1}\right] = \\ &= \pi_s ft_{H,peg} F(S_s). \end{aligned}$$

The expectation is thus equal to the *identical* (and fixed for any given jointly symmetric distribution) probability of s and s' occurring, $\pi_s = \pi_{s'}$, times the *constant* trade share under peg (or CCP), $ft_{H,peg} = \frac{2}{(1-\tau)^{1-\nu}+1}$, times the *function*

$$F(S_s) \equiv \frac{(1-\tau)^{1-\nu}+1}{(1-\tau)^{1-\nu} S_s^{\nu-1}+1} + \frac{(1-\tau)^{1-\nu}+1}{(1-\tau)^{1-\nu} S_s^{1-\nu}+1}.$$

For a benchmark, consider what would be the value of the above expectation if the trade share was a constant, as under PCP with peg implying $M_s = M_s^*, \forall s$ so that $ft_H(S_s) = ft_H(S_{s'}) = ft_{H,peg}$. Then one would have:

$$E_0\left[ft_{H,(s,s')}(S_s)\right] = 2\pi_s ft_{H,peg}.$$

Making use of local analysis around $F(1)$, we shall now show that $F(S_s) \geq 2$, which would mean that the expected trade share for each *pair of symmetric states* of relative monetary disequilibrium under float and PCP exceeds the corresponding trade share under peg.

One can easily prove that:

$$F(S_s) = F\left(\frac{1}{S_s}\right) \qquad \text{and} \qquad F(1) = 2,$$

i.e. that $F(S_s)$ is a symmetric function equal to 2 when the exchange rate is 1. We further write:

$$\begin{aligned} F'(S_s) &= (\nu-1)(1-\tau)^{1-\nu}\left[(1-\tau)^{1-\nu}+1\right] \times \\ &\times \left(-\frac{S_s^{\nu-2}}{\left[(1-\tau)^{1-\nu} S_s^{\nu-1}+1\right]^2} + \frac{S_s^{-\nu}}{\left[(1-\tau)^{1-\nu} S_s^{1-\nu}+1\right]^2}\right), \\ F'(1) &= 0, \end{aligned}$$

so that $F(S_s)$ is flat at 1, i.e. it attains a local extremum at 1. Moreover:

$$\begin{aligned} F''(S_s) &= (\nu-1)(1-\tau)^{1-\nu}\left[(1-\tau)^{1-\nu}+1\right] \times \\ &\times \left[\begin{array}{c} -(\nu-2)\frac{S_s^{\nu-3}}{\left[(1-\tau)^{1-\nu} S_s^{\nu-1}+1\right]^2} + 2(\nu-1)\frac{S_s^{\nu-2}(1-\tau)^{1-\nu} S_s^{\nu-2}}{\left[(1-\tau)^{1-\nu} S_s^{\nu-1}+1\right]^3} - \\ -\nu\frac{S_s^{-\nu-1}}{\left[(1-\tau)^{1-\nu} S_s^{1-\nu}+1\right]^2} + 2(\nu-1)\frac{(1-\tau)^{1-\nu} S_s^{-\nu} S_s^{-\nu}}{\left[(1-\tau)^{1-\nu} S_s^{1-\nu}+1\right]^3} \end{array}\right], \end{aligned}$$

$$F''(1) = \frac{2(\nu-1)^2(1-\tau)^{2(1-\nu)}}{\left[(1-\tau)^{1-\nu}+1\right]^2}\left[1-(1-\tau)^{\nu-1}\right] = \left[\frac{\sqrt{2}(\nu-1)(1-\tau)^{1-\nu}}{(1-\tau)^{1-\nu}+1}\right]^2\left[1-(1-\tau)^{\nu-1}\right].$$

$\left[\frac{\sqrt{2}(\nu-1)(1-\tau)^{1-\nu}}{(1-\tau)^{1-\nu}+1}\right]^2$ being always positive, we now have to consider two cases, in addition to the trivial third case of unit substitutability when the trade share is constant at 1.

- *Elastic* import demand, $\nu > 1$. In this case $1-(1-\tau)^{\nu-1} > 0 \Rightarrow F''(S_s) > 0$ so that $F(S_s)$ is *convex* around $S_s = 1$, which proves that the function $F(S_s)$ attains a local *minimum* $F(1) = 2$. Then it follows that $F(S_s) \geq 2$, at least around $S_s = 1$ (the region in which we are interested in, particularly under price rigidity compatible with relatively small money shocks as assumed in this paper). Finally, summing over *all* pairs of symmetric states, we obtain:

$$E_0\left[ft_{H,(s,s')}(S_s)\right] \geq ft_{H,peg} \Leftrightarrow F(S_s) \geq 2.$$

  The same arguments apply for Foreign's expected trade share. Adding up for the two countries in the model leads to the conclusion that expected trade-to-output for the world is *lower under peg* than under float, with trade costs and import demand elasticity accounted for.

- *Inelastic* import demand, $0 < \nu < 1$. In this case $1-(1-\tau)^{\nu-1} < 0 \Rightarrow F''(S_s) < 0$ so that $F(S_s)$ is *concave* around $S_s = 1$, which proves that the function $F(S_s)$ attains a local *maximum* $F(1) = 2$. Then it follows that $F(S_s) \leq 2$, at least around $S_s = 1$ (the region in which we are interested in). Finally, summing over *all* pairs of symmetric states, we obtain:

$$E_0\left[ft_{H,(s,s')}(S_s)\right] \leq ft_{H,peg} \Leftrightarrow F(S_s) \leq 2.$$

  The same arguments apply for Foreign's expected trade share. Adding up, again, expected world trade-to-output is *higher under peg* than under float, once accounting for trade costs and import demand inelasticity as in our extended NOEM framework here.

This completes our proof. ■

Appendix C

Data and Results in Chapter 3

C.1 Data: Definitions, Graphs, Descriptive Statistics

C.1.1 Definitions of the Data

Country Codes

- US: United States
- BD: Germany
- JP: Japan

Data Sources

- IFS: *International Financial Statistics*, International Monetary Fund (IMF), via Datastream
- MEI: *Main Economic Indicators*, Organization for Economic Cooperation and Development (OECD), via Datastream

Variable Codes and Sources

- PMI: import price index, IFS (USI76.X.F, BDI76.X.F, JPI76.X.F)
- PMU: unit value of imports, IFS (BDI75...F, JPI75...F)
- PXI: export price index, IFS (USI76...F, BDI76...F, JPI76...F)
- PXU: unit value of exports, IFS (BDI74...F, JPI74...F)
- NEER: nominal effective exchange rate index, IFS (USI..NEUE, BDI..NEUE, JPI..NEUE)
- REER: real effective exchange rate index, IFS (USI..REUE, BDI..REUE, JPI..REUE)
- NEERInv: inverse of the nominal effective exchange rate index $\equiv \frac{1}{\text{NEER}}$
- CPI: consumer price index, IFS (USI64...F, BDI64...F, JPI64...F)
- Nominal GDP (quarterly), IFS (USI99B.CB, BDI99B.CB, JPI99B.CB)
- GDP deflator (quarterly), IFS (USI99BIRH, BDI99BIRH, JPI99BIRH)

- Real GDP: nominal GDP divided by the GDP deflator $\equiv \frac{\text{nominal GDP}}{\text{GDP deflator}}$
- IPI: industrial production index, IFS (USI66..IG, BDI66..IG, JPI66..IG)
- Employment (monthly, for the US and Japan): employment volume index, MEI (USOEM040G, JPOEM040G)
- Employment (quarterly, for Germany): employment volume index, MEI (BDOEM040H)
- C-G Cost: Campa-L.Goldberg (2002) cost competitiveness proxy $\equiv \frac{\text{NEER} \times \text{CPI}}{\text{REER}}$
- M1 (for the US and Japan): narrow money M1, IFS (USI34...A, JPI34...A)
- CC (for Germany): currency in circulation, IFS (BDL34A.NA)
- DD (for Germany): demand deposits, IFS (BDL34B.NA)
- M1 (for Germany): narrow money $\equiv$ CC + DD

Notation for Transformed Data

- SA: seasonally adjusted series (via the Census X12 procedure) used in estimation, after finding evidence for seasonality
- dl: first difference in natural logarithms of a series (i.e. percentage change)

C.1.2 Graphs of the Data

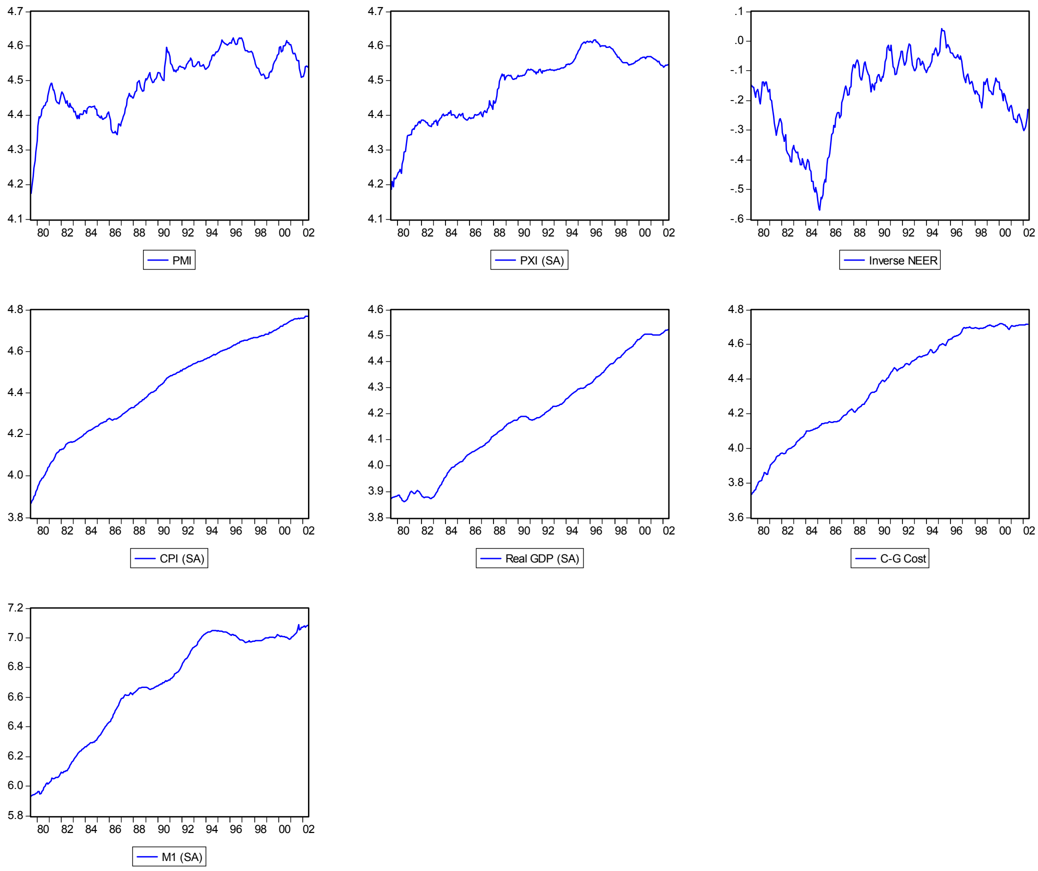

Figure C.1: Graphs of (the Natural Logarithms of) the US Time Series Used in the Pass-Through Estimations: whole sample (1979:07-2002:06, 276 monthly observations)

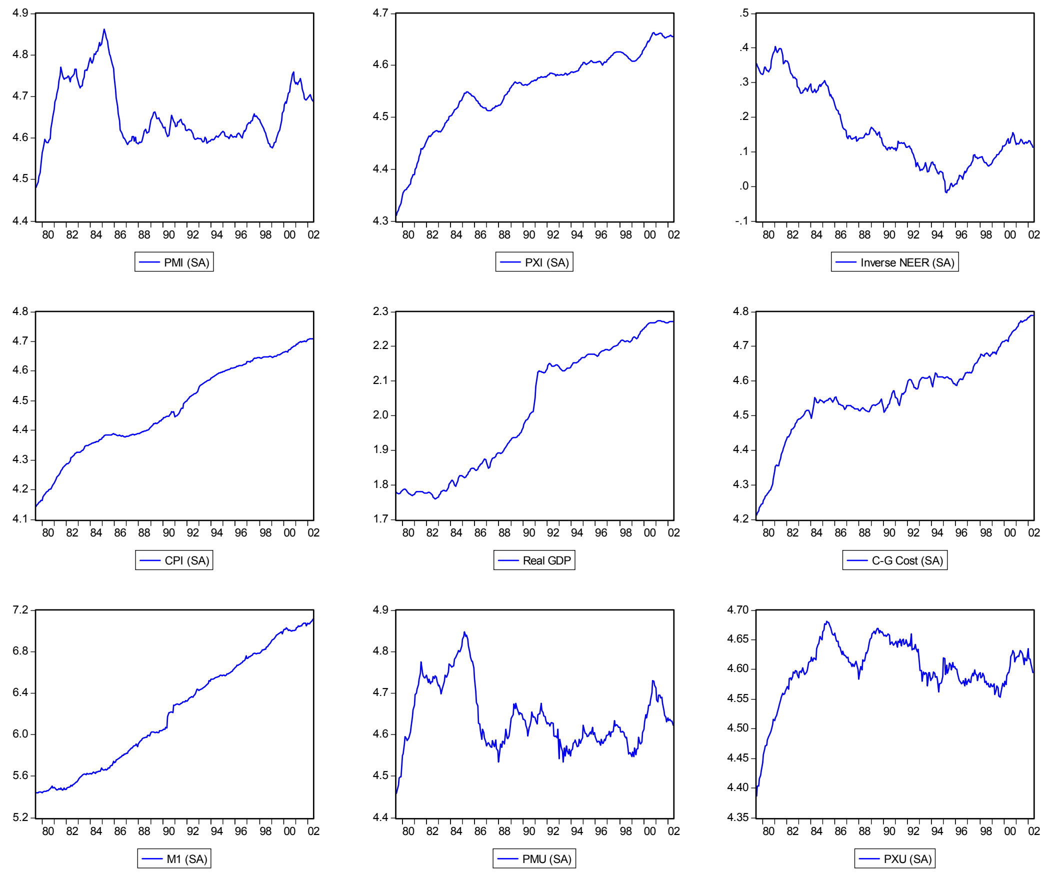

Figure C.2: Graphs of (the Natural Logarithms of) the German Time Series Used in the Pass-Through Estimations: whole sample (1979:07-2002:06, 276 monthly observations)

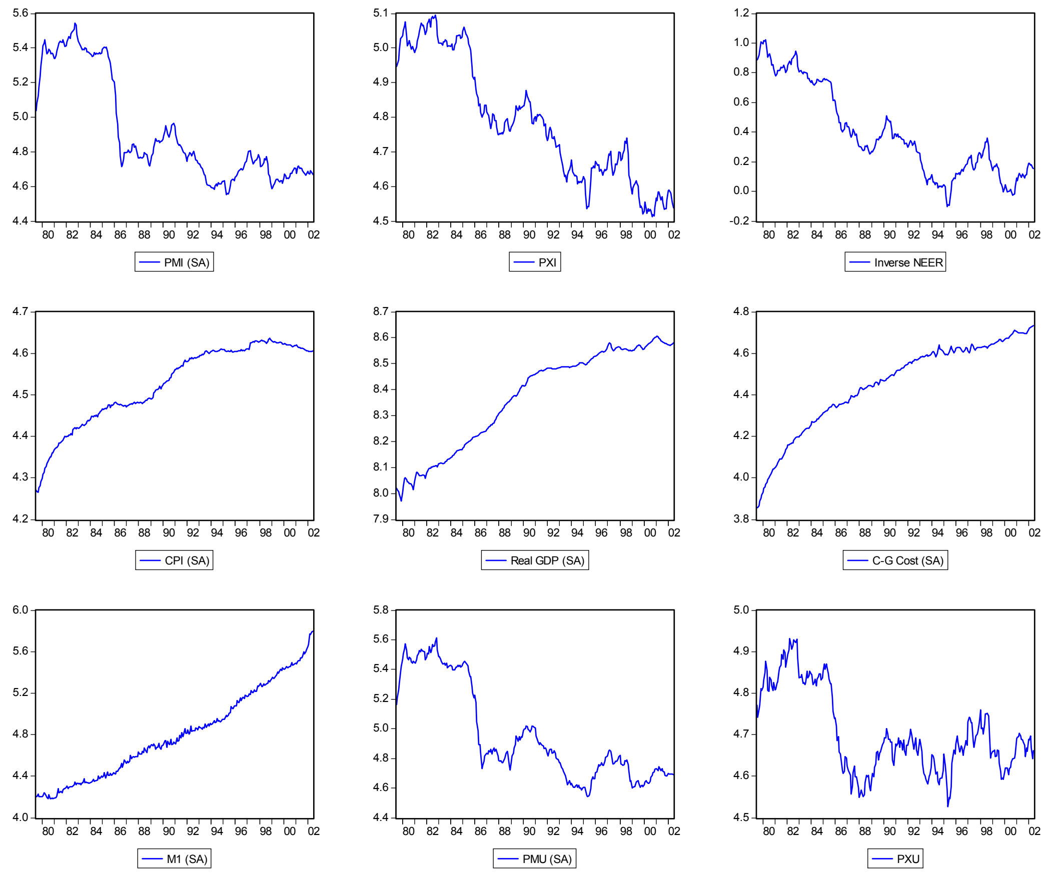

Figure C.3: Graphs of (the Natural Logarithms of) the Japanese Time Series Used in the Pass-Through Estimations: whole sample (1979:07-2002:06, 276 monthly observations)

C.1.3 Descriptive Statistics of the Data

	PMI	PXI (SA)	Inverse NEER	CPI (SA)	Real GDP (SA)	C-G Cost (SA)	M1 (SA)
Whole Sample: 1979:07 - 2002:06							
Mean	0.0014	0.0013	-0.0002	0.0033	0.0024	0.0036	0.0042
Median	0.0010	0.0007	-0.0025	0.0028	0.0026	0.0032	0.0039
Maximum	0.0414	0.0292	0.0570	0.0140	0.0093	0.0193	0.0418
Minimum	-0.0265	-0.0164	-0.0498	-0.0049	-0.0073	-0.0099	-0.0340
Std. Dev.	0.0103	0.0062	0.0185	0.0028	0.0026	0.0051	0.0068
Skewness	0.7532	1.2333	0.2946	1.3028	-0.7841	0.3089	-0.0401
Kurtosis	4.7477	7.2955	3.0668	5.6308	4.8702	3.3070	8.9630
Jarque-Bera	61.2238	282.1515	4.0433	157.6730	68.5053	5.4738	408.9822
Probability	0.0000	0.0000	0.1324	0.0000	0.0000	0.0648	0.0000
Sum	0.3943	0.3650	-0.0604	0.9118	0.6524	0.9950	1.1603
Sum Sq. Dev.	0.0289	0.0106	0.0941	0.0022	0.0019	0.0072	0.0126
Observations	276	276	276	276	276	276	276
1980s Subsample: 1979:07 - 1990:12							
Mean	0.0032	0.0025	0.0010	0.0045	0.0022	0.0051	0.0057
Median	0.0017	0.0016	-0.0007	0.0037	0.0026	0.0044	0.0058
Maximum	0.0414	0.0292	0.0570	0.0140	0.0093	0.0193	0.0214
Minimum	-0.0265	-0.0164	-0.0498	-0.0049	-0.0073	-0.0088	-0.0164
Std. Dev.	0.0122	0.0080	0.0204	0.0033	0.0033	0.0052	0.0059
Skewness	0.7001	0.7545	0.2906	0.7200	-0.6920	0.3119	-0.3230
Kurtosis	3.6623	4.5980	2.6828	3.7839	3.7820	3.3685	3.8148
Jarque-Bera	13.7964	27.7752	2.5209	15.4567	14.5319	3.0181	6.2167
Probability	0.0010	0.0000	0.2835	0.0004	0.0007	0.2211	0.0447
Sum	0.4382	0.3502	0.1404	0.6207	0.3092	0.6984	0.7916
Sum Sq. Dev.	0.0205	0.0088	0.0568	0.0015	0.0015	0.0037	0.0047
Observations	138	138	138	138	138	138	138
1990s Subsample: 1991:01 - 2002:06							
Mean	-0.0003	0.0001	-0.0015	0.0021	0.0025	0.0021	0.0027
Median	0.0000	0.0000	-0.0031	0.0021	0.0026	0.0020	0.0020
Maximum	0.0194	0.0092	0.0437	0.0067	0.0058	0.0141	0.0418
Minimum	-0.0233	-0.0076	-0.0494	-0.0020	-0.0026	-0.0099	-0.0340
Std. Dev.	0.0074	0.0032	0.0164	0.0014	0.0018	0.0046	0.0073
Skewness	-0.3440	0.2148	0.1707	0.0779	-0.3136	0.1568	0.3255
Kurtosis	3.2934	3.1210	3.4153	3.7047	2.6167	2.9255	11.9605
Jarque-Bera	3.2163	1.1454	1.6620	2.9947	3.1064	0.5973	464.1032
Probability	0.2003	0.5640	0.4356	0.2237	0.2116	0.7418	0.0000
Sum	-0.0439	0.0148	-0.2008	0.2911	0.3432	0.2967	0.3687
Sum Sq. Dev.	0.0076	0.0014	0.0369	0.0003	0.0004	0.0029	0.0072
Observations	138	138	138	138	138	138	138

Figure C.4: Descriptive Statistics of (the First Differences in Natural Logarithms of) the US Time Series Used in the Pass-Through Estimations

	PMI (SA)	PXI (SA)	Inv. NEER (SA)	CPI (SA)	Real GDP	C-G Cost (SA)	M1 (SA)	PMU (SA)	PXU (SA)
Whole Sample: 1979:07 - 2002:06									
Mean	0.0008	0.0013	-0.0009	0.0021	0.0018	0.0021	0.0061	0.0007	0.0008
Median	0.0010	0.0010	0.0000	0.0016	0.0013	0.0019	0.0055	0.0001	0.0011
Maximum	0.0325	0.0153	0.0201	0.0148	0.0330	0.0229	0.1101	0.0512	0.0309
Minimum	-0.0271	-0.0044	-0.0298	-0.0192	-0.0114	-0.0186	-0.0278	-0.0707	-0.0265
Std. Dev.	0.0089	0.0025	0.0075	0.0028	0.0044	0.0059	0.0124	0.0142	0.0082
Skewness	-0.0106	0.9954	-0.4155	-0.4188	2.7623	0.1917	2.7914	-0.1264	-0.1340
Kurtosis	3.6190	6.1576	3.8152	17.5472	19.6336	4.4596	23.1006	5.3884	4.1461
Jarque-Bera	4.4117	160.2334	15.5830	2441.7026	3532.7668	26.1884	5004.8099	66.3387	15.9314
Probability	0.1102	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
Sum	0.2247	0.3514	-0.2437	0.5717	0.4972	0.5842	1.6748	0.1812	0.2100
Sum Sq. Dev.	0.0218	0.0018	0.0153	0.0021	0.0052	0.0095	0.0420	0.0557	0.0185
Observations	276	276	276	276	276	276	276	276	276
1980s Subsample: 1979:07 - 1990:12									
Mean	0.0013	0.0019	-0.0018	0.0024	0.0018	0.0026	0.0062	0.0015	0.0019
Median	0.0014	0.0018	-0.0014	0.0018	0.0021	0.0027	0.0036	0.0020	0.0017
Maximum	0.0325	0.0153	0.0201	0.0118	0.0135	0.0229	0.1101	0.0512	0.0192
Minimum	-0.0271	-0.0044	-0.0259	-0.0026	-0.0114	-0.0138	-0.0278	-0.0406	-0.0155
Std. Dev.	0.0108	0.0029	0.0076	0.0025	0.0039	0.0062	0.0147	0.0142	0.0065
Skewness	-0.1074	0.8619	-0.2621	0.7983	-0.1409	0.2336	3.2712	0.1249	0.1632
Kurtosis	2.8952	5.3773	3.5594	4.2142	3.9325	4.2246	22.3350	3.6233	3.2053
Jarque-Bera	0.3285	49.5833	3.3794	23.1333	5.4559	9.8776	2395.7122	2.5930	0.8551
Probability	0.8485	0.0000	0.1846	0.0000	0.0654	0.0072	0.0000	0.2735	0.6521
Sum	0.1772	0.2656	-0.2495	0.3274	0.2493	0.3649	0.8492	0.2030	0.2582
Sum Sq. Dev.	0.0160	0.0012	0.0079	0.0009	0.0020	0.0053	0.0296	0.0274	0.0057
Observations	138	138	138	138	138	138	138	138	138
1990s Subsample: 1991:01 - 2002:06									
Mean	0.0003	0.0006	0.0000	0.0018	0.0018	0.0016	0.0060	-0.0002	-0.0003
Median	0.0002	0.0004	0.0009	0.0015	0.0011	0.0013	0.0062	-0.0008	-0.0005
Maximum	0.0182	0.0058	0.0169	0.0148	0.0330	0.0196	0.0390	0.0474	0.0309
Minimum	-0.0214	-0.0033	-0.0298	-0.0192	-0.0043	-0.0186	-0.0241	-0.0707	-0.0265
Std. Dev.	0.0065	0.0019	0.0072	0.0030	0.0048	0.0055	0.0095	0.0143	0.0095
Skewness	0.0528	0.1613	-0.5735	-1.0367	4.1784	0.0663	0.2422	-0.3665	-0.0348
Kurtosis	3.6373	2.7312	4.3032	23.0755	24.8301	4.6507	5.1679	6.9923	3.7546
Jarque-Bera	2.3998	1.0138	17.3294	2342.1161	3141.7227	15.7691	28.3744	94.7347	3.3023
Probability	0.3012	0.6023	0.0002	0.0000	0.0000	0.0004	0.0000	0.0000	0.1918
Sum	0.0475	0.0858	0.0057	0.2444	0.2479	0.2193	0.8256	-0.0218	-0.0481
Sum Sq. Dev.	0.0057	0.0005	0.0071	0.0012	0.0032	0.0042	0.0125	0.0281	0.0124
Observations	138	138	138	138	138	138	138	138	138

Figure C.5: Descriptive Statistics of (the First Differences in Natural Logarithms of) the German Time Series Used in the Pass-Through Estimations

	PMI (SA)	PXI (SA)	Inv. NEER (SA)	CPI (SA)	Real GDP	C-G Cost (SA)	M1 (SA)	PMU (SA)	PXU (SA)
Whole Sample: 1979:07 - 2002:06									
Mean	-0.0011	-0.0015	-0.0026	0.0013	0.0020	0.0032	0.0058	-0.0015	-0.0003
Median	-0.0002	0.0000	-0.0004	0.0007	0.0018	0.0029	0.0042	0.0007	0.0008
Maximum	0.0736	0.0486	0.0685	0.0156	0.0327	0.0273	0.1021	0.0746	0.0563
Minimum	-0.1035	-0.0614	-0.0931	-0.0060	-0.0164	-0.0178	-0.0643	-0.1322	-0.0651
Std. Dev.	0.0236	0.0163	0.0255	0.0032	0.0055	0.0065	0.0237	0.0270	0.0192
Skewness	-0.5970	-0.3818	-0.4655	1.2045	1.7768	0.1695	0.2574	-0.8611	-0.2295
Kurtosis	5.1758	3.6047	3.7489	5.5234	12.8803	4.1259	3.9226	5.7197	3.3532
Jarque-Bera	70.8343	10.9093	16.4181	139.9590	1267.8560	15.8990	12.8360	119.1737	3.8568
Probability	0.0000	0.0043	0.0003	0.0000	0.0000	0.0004	0.0016	0.0000	0.1454
Sum	-0.3124	-0.4055	-0.7304	0.3474	0.5604	0.8893	1.6077	-0.4265	-0.0711
Sum Sq. Dev.	0.1531	0.0731	0.1784	0.0029	0.0084	0.0115	0.1540	0.2012	0.1016
Observations	276	276	276	276	276	276	276	276	276
1980s Subsample: 1979:07 - 1990:12									
Mean	-0.0001	-0.0011	-0.0036	0.0022	0.0032	0.0048	0.0039	-0.0008	-0.0006
Median	0.0017	0.0000	-0.0006	0.0018	0.0029	0.0042	0.0035	0.0014	0.0008
Maximum	0.0736	0.0347	0.0610	0.0132	0.0327	0.0215	0.0712	0.0746	0.0390
Minimum	-0.1035	-0.0458	-0.0776	-0.0060	-0.0164	-0.0078	-0.0643	-0.1322	-0.0488
Std. Dev.	0.0281	0.0150	0.0245	0.0036	0.0069	0.0057	0.0239	0.0325	0.0188
Skewness	-0.6564	-0.4681	-0.6364	0.6893	1.4970	0.3189	0.0028	-0.9231	-0.3067
Kurtosis	4.6810	3.2456	3.6892	3.7690	9.0100	2.6641	3.3645	4.9742	2.9196
Jarque-Bera	26.1573	5.3869	12.0468	14.3276	259.2307	2.9875	0.7641	42.0083	2.2010
Probability	0.0000	0.0676	0.0024	0.0008	0.0000	0.2245	0.6825	0.0000	0.3327
Sum	-0.0170	-0.1466	-0.4959	0.2970	0.4366	0.6560	0.5404	-0.1079	-0.0854
Sum Sq. Dev.	0.1078	0.0309	0.0822	0.0018	0.0066	0.0044	0.0780	0.1445	0.0485
Observations	138	138	138	138	138	138	138	138	138
1990s Subsample: 1991:01 - 2002:06									
Mean	-0.0021	-0.0019	-0.0017	0.0004	0.0009	0.0017	0.0077	-0.0023	0.0001
Median	-0.0016	-0.0010	-0.0003	0.0001	0.0012	0.0017	0.0066	0.0003	0.0004
Maximum	0.0392	0.0486	0.0685	0.0156	0.0115	0.0273	0.1021	0.0543	0.0563
Minimum	-0.0585	-0.0614	-0.0931	-0.0048	-0.0119	-0.0178	-0.0518	-0.0660	-0.0651
Std. Dev.	0.0181	0.0175	0.0265	0.0025	0.0033	0.0069	0.0234	0.0203	0.0197
Skewness	-0.4487	-0.3040	-0.3450	1.9763	-0.6099	0.3199	0.5424	-0.4912	-0.1666
Kurtosis	3.4701	3.6712	3.7354	11.8419	5.5588	4.9245	4.3721	4.1799	3.6959
Jarque-Bera	5.9005	4.7166	5.8469	539.3653	46.2045	23.6492	17.5911	13.5551	3.4229
Probability	0.0523	0.0946	0.0537	0.0000	0.0000	0.0000	0.0002	0.0011	0.1806
Sum	-0.2954	-0.2589	-0.2346	0.0503	0.1238	0.2332	1.0672	-0.3185	0.0143
Sum Sq. Dev.	0.0450	0.0421	0.0959	0.0009	0.0015	0.0065	0.0750	0.0565	0.0531
Observations	138	138	138	138	138	138	138	138	138

Figure C.6: Descriptive Statistics of (the First Differences in Natural Logarithms of) the Japanese Time Series Used in the Pass-Through Estimations

C.2 Test and Estimation Results

	Test A	Test B	Test C	Test D	Conclusion
United States					
PMI	0	0	1	0	0
PXI	1	1	1	0	1
NEER	0	0	1	0	0
CPI	1	1	1	1	1
Real GDP	1	1	1	0	1
IPI	0	0	1	0	0
Employment	0	0	1	0	0
C-G Cost	1	1	1	1	1
M1	1	1	1	1	1
Germany					
PMI	1	1	1	0	1
PMU	1	1	1	0	1
PXI	1	1	1	0	1
PXU	1	1	1	1	1
NEER	1	1	1	0	1
CPI	1	1	1	1	1
Real GDP	0	0	1	0	0
IPI	0	0	1	0	0
C-G Cost	1	1	1	0	1
M1	1	1	1	1	1
Japan					
PMI	1	1	1	0	1
PMU	1	1	1	0	1
PXI	0	0	1	0	0
PXU	0	0	1	0	0
NEER	0	0	1	0	0
CPI	1	1	1	1	1
Real GDP	1	1	1	0	1
IPI	0	0	0	0	0
Employment	0	0	1	0	0
C-G Cost	1	1	1	0	1
M1	1	1	1	1	1

Table C.1: Seasonality Test (Census X12) Results

EXPLANATORY NOTE TO TABLE C.1: A: test for the presence of seasonality (coded 1 in the table when found) assuming stability; B: nonparametric test for the presence of seasonality assuming stability; C: moving seasonality test; D: combined test for the presence of identifiable seasonality.

	ADF	PP	KPSS	Conclusion
United States				
PMI	I(1)	I(1)	I(1)	I(1)
PXI (SA)	I(1):1,3; I(0):2,4	I(1)	I(1):1,3; I(2):2,4	I(1)
Inv. NEER	I(1)	I(1)	I(1):2,4; I(0):1,3	I(1)
CPI (SA)	I(1):1,3; I(2):2,4	I(1):1,3; I(0):2,4	I(1):1,3; I(2):2,4	I(1)
Real GDP (SA)	I(1)	I(1)	I(1)	I(1)
IPI	I(1)	I(1)	I(1)	I(1)
Employment	I(1)	I(1)	I(1):3,4; I(?):1,2	I(1)
C-G Cost (SA)	I(2)	I(1):1,3; I(0):2,4	I(1):1,3; I(2):2,4	I(1)
M1 (SA)	I(1)	I(1)	I(1):1,3; I(2):2,4	I(1)
Germany				
PMI (SA)	I(1)	I(1)	I(1):3,4; I(2):1,2	I(1)
PMU (SA)	I(1)	I(1)	I(1):3,4; I(2):1,2	I(1)
PXI (SA)	I(1)	I(1)	I(1):4; I(2):1,2,3	I(1)
PXU (SA)	I(1)	I(1)	I(2):3,4; I(?):1,2	I(1)
Inv. NEER (SA)	I(1)	I(1)	I(1):4; I(2):1,2,3	I(1)
CPI (SA)	I(1)	I(1):1,2; I(2):3,4	I(2):3,4; I(?):1,2	I(1)
Real GDP	I(1)	I(1)	I(1):3,4; I(?):1,2	I(1)
IPI	I(1)	I(1):1,2,3; I(0):4	I(1):3,4; I(?):1,2	I(1)
C-G Cost (SA)	I(1):1,2; I(0):3; I(2):4	I(1)	I(1):4; I(?):1,2,3	I(1)
M1 (SA)	I(1)	I(1)	I(1):1,2; I(?):3,4	I(1)
Japan				
PMI (SA)	I(1)	I(1)	I(1):3,4; I(2):1,2	I(1)
PMU (SA)	I(1)	I(1)	I(1):3,4; I(2):2; I(?):1	I(1)
PXI	I(1)	I(1)	I(1):3,4; I(2):1,2	I(1)
PXU	I(1)	I(1)	I(1)	I(1)
Inv. NEER	I(1)	I(1)	I(1):2,3,4; I(2):1	I(1)
CPI (SA)	I(1)	I(1)	I(2):3,4; I(?):1,2	I(1)
Real GDP (SA)	I(1):1,3; I(0):2,4	I(1)	I(1):3; I(2):4; I(?):1,2	I(1)
IPI	I(1):1,3; I(0):2,4	I(1):1,3; I(0):2,4	I(1):3; I(2):4; I(?):1,2	I(1)
Employment	I(1)	I(1):1,3; I(0):2,4	I(2):3,4; I(?):1,2	I(1)
C-G Cost (SA)	I(0)	I(1):1,2; I(2):3,4	I(1):1; I(2):3,4; I(?):2	I(?)
M1 (SA)	I(1):1,2,4; I(2):3	I(1):1,2,3; I(0):for 4	I(2):3,4; I(?):1,2	I(1)

Table C.2: Stationarity Test Results

EXPLANATORY NOTE TO TABLE C.2: For the *Augmented Dickey-Fuller (ADF)* tests, the most common (auto)*regression*-based method of testing for unit roots, specification 1 imposes constant, trend and 12 lags; 2 – constant and 12 lags; 3 – constant, trend and automatic selection of the lag structure using the modified Akaike criterion; 4 – constant and automatic selection of the lag structure using the modified Akaike criterion. For the *Phillips-Perron (PP)* and the *Kwiatkowski-Phillips-Schmidt-Shin (KPSS)* tests, which are among the most frequently used *nonparametric* (kernel) methods of testing for (non)stationarity, specification 1 imposes constant, trend and the AR spectral - GLS detrended data method of estimating the frequency zero spectrum; 2 – constant and the AR spectral - GLS detrended data method; 3 – constant, trend and the Bartlett kernel method of estimating the frequency zero spectrum; 4 – constant and the Bartlett kernel method.

(log-levels)	US (1969:01-)	Germany (1958:01-)	Japan (1957:01-)
Obstfeld-Rogoff (2000) *quarterly* sample (1982-1998)	0.31	0.43	0.29
our largest *quarterly* sample (-2003:1)	0.41	0.45	−0.62
our whole *quarterly* sample (1979:3-2002:2)	−0.08	0.95	0.81
our 1980s *quarterly* subsample (1979:3-1990:4)	0.10	0.90	0.89
our 1990s *quarterly* subsample (1991:1-2002:2)	0.22	0.76	−0.05
our largest *monthly* sample (-2003:03)	0.41	0.45	−0.62
our whole *monthly* sample (1979:07-2002:06)	−0.07	0.95	0.81
our 1980s *monthly* subsample (1979:07-1990:12)	0.10	0.90	0.88
our 1990s *monthly* subsample (1991:01-2002:06)	0.23	0.76	−0.06

Table C.3: ToT-NEER Correlations

Pass-Through on the *Import Price Index* Following NEER Depreciation, %			
Panel I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)			
	United States	Germany	Japan
month 1	3.6	58.6	57.9
month 2	9.1	19.1	8.2
month 3	5.6	9.1	1.6
quarter 1	18.3	86.8	67.8
end-quarter 2, cumulative	19.9	97.9	86.9
end-quarter 3, cumulative	25.5	109.8	93.4
year 1, cumulative	24.4	109.0	100.0
Panel II: *Early* Sample Period (July 1979 - December 1990, 138 observations)			
	United States	Germany	Japan
month 1	2.5	71.9	64.0
month 2	9.5	16.7	17.2
month 3	9.0	15.1	7.4
quarter 1	21.0	103.7	88.6
end-quarter 2, cumulative	31.6	115.7	112.3
end-quarter 3, cumulative	39.6	127.3	113.3
end-year 1, cumulative	33.3	130.0	121.9
Panel III: *Late* Sample Period (January 1991 - June 2002, 138 observations)			
	United States	Germany	Japan
month 1	4.9	35.6	49.3
month 2	11.3	11.7	0.2
month 3	−1.5	−3.1	−5.2
quarter 1	14.6	44.1	44.3
end-quarter 2, cumulative	12.9	49.0	55.5
end-quarter 3, cumulative	15.4	57.3	55.2
end-year 1, cumulative	27.4	57.0	52.8

Table C.4: OLS Estimates of the Pass-Through on Import Prices Obtained Using Import Price Indices

Pass-Through on the *Unit Value of Imports* Following NEER Depreciation, %		
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)		
	Germany	Japan
month 1	41.2	51.0
month 2	43.5	47.5
month 3	−4.0	−11.5
quarter 1	80.6	87.0
end-quarter 2, cumulative	116.6	97.4
end-quarter 3, cumulative	121.8	102.6
year 1, cumulative	110.3	104.3
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)		
	Germany	Japan
month 1	74.8	61.8
month 2	19.4	59.5
month 3	15.0	−17.8
quarter 1	109.2	103.4
end-quarter 2, cumulative	131.1	127.9
end-quarter 3, cumulative	165.1	115.6
end-year 1, cumulative	155.4	124.7
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)		
	Germany	Japan
month 1	−3.9	37.9
month 2	44.1	39.1
month 3	−35.2	−10.2
quarter 1	5.0	66.7
end-quarter 2, cumulative	54.5	58.3
end-quarter 3, cumulative	52.2	62.5
end-year 1, cumulative	57.3	53.2

Table C.5: OLS Estimates of the Pass-Through on Import Prices Obtained Using Import Unit Values

(log-levels, largest sample)	United States	Germany	Japan
ToT	ns: ADF, PP	ns: ADF, PP	ns: ADF, PP
PPP	ns: ADF (except 2 at 5%), PP	ns: ADF, PP	ns: ADF, PP
QTM	ns: ADF, PP	ns: ADF, PP	ns: ADF, PP
Import Prices /CPI	ns: ADF, PP	ns: ADF, PP	ns: ADF, PP

Table C.6: Cointegrating Relations Checks via Unit Root Tests

Explanatory Note to Table C.6: ns means nonstationarity found by all four specifications (see the explanatory note to Table C.2) of the ADF and the PP tests. To obtain a more direct relevance of results, the German data for the quantity theory of money (QTM) test end in 1998:12, when the *IFS* DEM-denominated series for currency in circulation and demand deposits comprising M1 were discontinued.

(log-levels)	United States	Germany	Japan
ToT: largest sample	0, 1 or 2	0, 1 or 2	0
PPP: largest sample	0 (or 1)	0 or 1	0, 1 or 3
QTM: largest sample	0 or 1	0 or 1	0, 1 or 2
Import and Consumer Prices: largest sample	0, 1 or 2	0 or 1	0 or 1
VAR: whole sample (1979:07-2002:06; 276)	2, 4 or 5	2, 3 or 5	2, 3 or 5
same but *unit values* instead of price indexes	n.a.	1 (or 2)	2, 3, 4 or 5
VAR: 1980s subsample (1979:07-1990:12; 138)	0, 1 or 2	1 (or 2)	1, 2 or 5
same but *unit values* instead of price indexes	n.a.	1, 2, 3, 4 or 5	1, 4 or 4
VAR: 1990s subsample (1991:01-2002:06; 138)	1, 2 or 3	2	2 or 3
same but *unit values* instead of price indexes	n.a.	2	2, 3 or 4

Table C.7: Cointegrating Relations Test Results from Johansen's Procedure

Explanatory Note to Table C.7: The respective cells indicate the number of cointegrating relations identified by the five specifications of Johansen's procedure *summary* test in EViews; any number in parentheses means that it has been found just once. To obtain a more direct relevance of results, the German data for the quantity theory of money (QTM) test as well as for the VAR tests in the whole sample and during the 1990s end in 1998:12, when the *IFS* DEM-denominated series for currency in circulation and demand deposits comprising M1 were discontinued.

Whole Sample Period (July 1979 - June 2002, 276 observations)				
US				
	dlM1(SA)	dlNEERInv	dlPMI	dlPXI(SA)
dlNEERInv	0.12			
dlPMI	0.02	0.12		
dlPXI(SA)	0.13	−0.07	0.24	
dlCPI(SA)	−0.01	−0.03	0.50	0.26
Germany				
	dlM1(SA)	dlNEERInv(SA)	dlPMI(SA)	dlPXI(SA)
dlNEERInv(SA)	0.11			
dlPMI(SA)	−0.09	0.57		
dlPXI(SA)	−0.14	0.46	0.78	
dlCPI(SA)	−0.08	0.02	0.37	0.28
Japan				
	dlM1(SA)	dlNEERInv	dlPMI(SA)	dlPXI
dlNEERInv	0.04			
dlPMI(SA)	0.01	0.68		
dlPXI	0.05	0.93	0.68	
dlCPI(SA)	−0.13	−0.02	0.13	0.02

Table C.8: Pairwise Monthly Correlation Matrix for the Estimated VARs

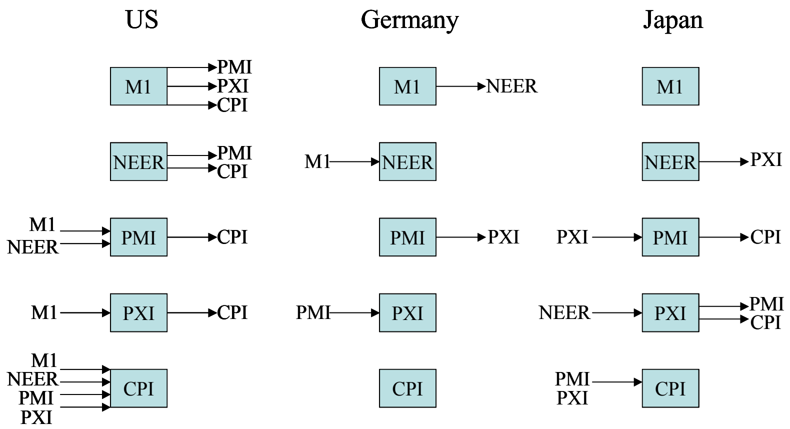

Figure C.7: Summary of Pairwise Granger Causality Test Results (with 12 lags and at a 10% significance level threshold) for the Time Series Used in the VAR Pass-Through Estimates: *raw* data, largest sample (ending in 1998:12 for German pairs involving M1 – see the last sentence in the explanatory note to Table C.7)

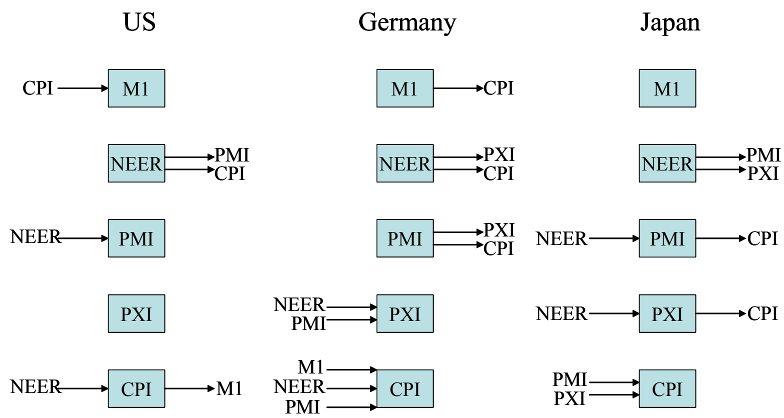

Figure C.8: Summary of Pairwise Granger Causality Test Results (with 12 lags and at a 10% significance level threshold) for the Time Series Used in the VAR Pass-Through Estimates: *seasonally adjusted* data when seasonality found, largest sample (ending in 1998:12 for German pairs involving M1 – see the last sentence in the explanatory note to Table C.7)

Pass-Through on the *Import Price Index* Following NEER Depreciation, %			
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)			
	United States	Germany	Japan
month 1	2.5 – 3.5	52.0 – 54.1	53.5 – 53.6
month 2	10.2 – 11.2	31.8 – 33.6	26.8 – 27.0
month 3	6.2 – 6.9	9.8 – 13.2	16.8 – 17.9
quarter 1	19.0 – 21.6	94.0 – 100.6	82.1 – 82.3
end-quarter 2, cumulative	15.8 – 19.4	121.7 – 132.8	107.5 – 108.3
end-quarter 3, cumulative	19.8 – 23.7	173.6 – 184.1	112.9 – 115.7
year 1, cumulative	21.6 – 26.7	205.0 – 219.6	137.8 – 141.2
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)			
	United States	Germany	Japan
month 1	1.2 – 2.6	65.7 – 72.0	53.9 – 54.5
month 2	10.2 – 11.8	35.2 – 38.7	32.8 – 33.4
month 3	8.3 – 9.5	18.1 – 24.3	0.0 – 0.6
quarter 1	19.9 – 23.6	120.3 – 133.7	87.5 – 87.8
end-quarter 2, cumulative	23.3 – 27.6	169.7 – 191.1	126.6 – 129.7
end-quarter 3, cumulative	32.1 – 41.3	240.7 – 260.9	149.0 – 149.3
end-year 1, cumulative	22.7 – 35.0	271.2 – 310.7	180.8 – 182.1
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)			
	United States	Germany	Japan
month 1	4.4 – 5.8	33.3 – 36.2	45.7 – 46.0
month 2	10.4 – 11.2	16.3 – 21.1	4.9 – 6.2
month 3	(−2.0) – (−1.5)	(−2.5) – (−1.3)	(−12.5) – (−11.2)
quarter 1	13.3 – 15.2	47.4 – 55.0	38.2 – 41.0
end-quarter 2, cumulative	7.5 – 10.5	31.3 – 40.4	37.6 – 38.8
end-quarter 3, cumulative	19.3 – 21.1	53.5 – 61.5	47.2 – 53.1
end-year 1, cumulative	31.8 – 33.3	58.1 – 71.8	54.5 – 60.1

Table C.9: VAR Estimates of the Pass-Through on Import Prices Obtained Using Import and Export Price Indices

Pass-Through on the *Unit Value of Imports* Following NEER Depreciation, %		
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)		
	Germany	Japan
month 1	33.3 – 33.9	49.5 – 49.8
month 2	50.2 – 52.8	64.5 – 65.0
month 3	5.1 – 9.4	4.7 – 5.2
quarter 1	92.8 – 97.4	119.3 – 119.5
end-quarter 2, cumulative	140.2 – 146.7	120.5 – 122.1
end-quarter 3, cumulative	178.1 – 186.2	116.0 – 119.2
year 1, cumulative	205.9 – 221.7	130.6 – 134.7
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)		
	Germany	Japan
month 1	58.5 – 67.0	58.6 – 59.5
month 2	35.2 – 48.5	80.1 – 84.1
month 3	18.1 – 32.8	(−1.7) – (−0.7)
quarter 1	120.3 – 143.4	137.9 – 141.9
end-quarter 2, cumulative	169.8 – 187.2	173.0 – 178.0
end-quarter 3, cumulative	240.7 – 258.5	185.6 – 190.8
end-year 1, cumulative	268.6 – 314.8	214.3 – 220.4
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)		
	Germany	Japan
month 1	(−0.6) – 6.8	35.9 – 36.5
month 2	64.1 – 72.3	40.2 – 40.4
month 3	(−30.0) – 23.5	(−10.4) – (−8.3)
quarter 1	40.9 – 48.1	65.7 – 68.3
end-quarter 2, cumulative	107.3 – 110.0	39.1 – 41.7
end-quarter 3, cumulative	113.7 – 116.6	54.2 – 60.8
end-year 1, cumulative	148.8 – 152.9	60.0 – 67.4

Table C.10: VAR Estimates of the Pass-Through on Import Prices Obtained Using Import and Export Unit Values

Pass-Through on the *Export Price Index* Following NEER Depreciation, %			
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)			
	United States	Germany	Japan
month 1	(−2.8) – (−2.5)	12.7 – 13.2	55.0 – 55.3
month 2	1.3 – 1.5	6.6 – 7.0	21.4 – 21.6
month 3	4.4 – 4.6	2.0 – 2.2	(−20.0) – (−19.6)
quarter 1	3.0 – 3.5	21.3 – 22.2	74.6 – 74.7
end-quarter 2, cumulative	4.7 – 5.3	22.1 – 29.1	71.6 – 72.5
end-quarter 3, cumulative	13.3 – 14.4	42.7 – 45.3	60.5 – 62.0
year 1, cumulative	13.7 – 15.4	54.4 – 57.7	69.3 – 70.0
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)			
	United States	Germany	Japan
month 1	(−7.4) – (−6.0)	12.5 – 13.7	52.1 – 53.3
month 2	0.4 – 2.3	6.3 – 6.8	22.1 – 22.4
month 3	3.2 – 4.1	3.5 – 4.4	(−9.5) – (−9.3)
quarter 1	(−2.8) – (−1.8)	22.9 – 24.1	64.6 – 66.4
end-quarter 2, cumulative	(−2.4) – 0.3	37.5 – 39.0	64.1 – 65.0
end-quarter 3, cumulative	9.2 – 11.3	58.9 – 61.7	55.0 – 56.9
end-year 1, cumulative	11.7 – 15.9	75.1 – 78.6	58.8 – 59.4
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)			
	United States	Germany	Japan
month 1	2.0 – 2.5	11.5 – 11.9	50.7 – 51.3
month 2	2.3 – 2.4	5.8 – 7.1	10.5 – 12.1
month 3	2.2 – 2.4	(−0.9) – 0.1	(−3.9) – (−3.3)
quarter 1	6.7 – 7.0	16.4 – 19.0	58.0 – 59.6
end-quarter 2, cumulative	7.8 – 8.1	8.5 – 13.0	59.6 – 60.8
end-quarter 3, cumulative	13.2 – 14.2	11.0 – 15.7	69.2 – 73.9
end-year 1, cumulative	16.5 – 17.6	15.3 – 21.8	69.4 – 71.2

Table C.11: VAR Estimates of the Pass-Through on Export Prices Obtained Using Import and Export Price Indices

Pass-Through on the *Unit Value of Exports* Following NEER Depreciation, %		
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)		
	Germany	Japan
month 1	10.5 – 11.5	24.2 – 24.4
month 2	11.9 – 12.7	51.5 – 51.6
month 3	6.9 – 9.0	2.6 – 2.7
quarter 1	30.4 – 32.3	78.4 – 78.5
end-quarter 2, cumulative	40.8 – 44.0	61.6 – 62.6
end-quarter 3, cumulative	66.7 – 68.3	50.0 – 51.2
year 1, cumulative	75.7 – 78.1	57.2 – 58.8
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)		
	Germany	Japan
month 1	4.7 – 6.3	29.6 – 31.1
month 2	11.9 – 15.4	52.1 – 53.1
month 3	(−0.7) – 6.5	(−3.8) – (−2.3)
quarter 1	19.2 – 25.1	79.2 – 80.6
end-quarter 2, cumulative	37.9 – 45.3	78.5 – 82.2
end-quarter 3, cumulative	61.2 – 74.6	78.8 – 80.4
end-year 1, cumulative	80.6 – 88.1	77.2 – 78.8
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)		
	Germany	Japan
month 1	6.5 – 10.0	15.4 – 15.7
month 2	12.6 – 14.9	43.0 – 43.8
month 3	12.3 – 13.9	(−0.7) – 0.2
quarter 1	34.2 – 36.1	58.0 – 59.3
end-quarter 2, cumulative	38.7 – 49.7	37.3 – 38.6
end-quarter 3, cumulative	62.3 – 67.1	43.2 – 46.1
end-year 1, cumulative	70.1 – 78.0	44.3 – 46.5

Table C.12: VAR Estimates of the Pass-Through on Export Prices Obtained Using Import and Export Unit Values

Pass-Through on the *Consumer Price Index* Following NEER Depreciation, %			
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)			
	United States	Germany	Japan
month 1	0.0 – 0.6	0.0 – 3.1	0.0 – 0.1
month 2	(−0.3) – (−0.1)	3.1 – 4.4	(−0.6) – (−0.6)
month 3	(−1.3) – (−1.2)	1.4 – 2.6	1.2 – 1.3
quarter 1	(−1.6) – (−0.7)	5.4 – 9.1	0.7 – 0.8
end-quarter 2, cumulative	(−3.0) – (−1.9)	6.5 – 11.9	1.9 – 2.1
end-quarter 3, cumulative	(−1.4) – 0.0	10.6 – 17.3	4.8 – 4.9
year 1, cumulative	(−1.8) – 0.3	15.0 – 21.4	6.0 – 6.2
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)			
	United States	Germany	Japan
month 1	0.0 – 0.7	0.0 – 4.0	(−0.4) – 0.0
month 2	(−0.9) – (−0.6)	4.8 – 5.6	(−1.3) – (−1.0)
month 3	(−2.2) – (−2.0)	4.2 – 4.6	3.1 – 3.1
quarter 1	(−3.1) – (−1.9)	9.4 – 13.8	1.5 – 1.9
end-quarter 2, cumulative	(−4.7) – (−3.2)	22.0 – 27.8	4.3 – 4.8
end-quarter 3, cumulative	(−1.3) – 0.9	29.7 – 35.9	7.6 – 8.2
end-year 1, cumulative	(−3.4) – (−0.2)	42.1 – 50.1	8.5 – 9.2
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)			
	United States	Germany	Japan
month 1	0.0 – 0.1	0.0 – 3.1	0.0 – 0.9
month 2	0.0 – 0.2	(−1.0) – 0.4	(−1.3) – (−1.1)
month 3	(−1.0) – (−0.8)	(−4.0) – (−2.0)	(−0.2) – (−0.1)
quarter 1	(−0.7) – 0.1	(−3.8) – 1.2	(−1.3) – (−0.4)
end-quarter 2, cumulative	(−2.0) – (−0.8)	(−15.4) – (−7.0)	(−1.0) – 0.0
end-quarter 3, cumulative	(−2.0) – (−0.8)	(−14.2) – (−6.8)	(−1.0) – 0.0
end-year 1, cumulative	0.1 – 1.3	(−14.8) – (−5.7)	(−0.5) – 0.8

Table C.13: VAR Estimates of the Pass-Through on Consumer Prices Obtained Using Import and Export Price Indices

Pass-Through on the *Consumer Price Index* Following NEER Depreciation, %		
PANEL I: *Whole* Sample Period (July 1979 - June 2002, 276 observations)		
	Germany	Japan
month 1	0.0 – 2.2	0.0 – 0.5
month 2	4.5 – 5.6	(−0.6) – (−0.6)
month 3	2.2 – 3.0	1.5 – 1.6
quarter 1	7.2 – 10.2	0.9 – 1.4
end-quarter 2, cumulative	8.6 – 12.3	2.2 – 2.7
end-quarter 3, cumulative	10.8 – 15.6	4.7 – 5.3
year 1, cumulative	15.1 – 19.7	5.9 – 6.8
PANEL II: *Early* Sample Period (July 1979 - December 1990, 138 observations)		
	Germany	Japan
month 1	0.0 – 3.5	0.0 – 1.6
month 2	3.5 – 4.9	(−2.1) – (−1.6)
month 3	6.1 – 7.5	5.0 – 5.6
quarter 1	10.4 – 14.8	3.7 – 4.8
end-quarter 2, cumulative	21.2 – 26.9	6.6 – 7.8
end-quarter 3, cumulative	27.1 – 33.2	9.2 – 11.4
end-year 1, cumulative	37.3 – 45.3	12.8 – 15.6
PANEL III: *Late* Sample Period (January 1991 - June 2002, 138 observations)		
	Germany	Japan
month 1	0.0 – 8.1	(−1.2) – 0.0
month 2	(−0.1) – 1.7	(−1.2) – (−1.2)
month 3	(−2.7) – (−1.2)	0.2 – 0.3
quarter 1	(−3.2) – 7.2	(−1.0) – (−0.5)
end-quarter 2, cumulative	(−13.0) – 1.2	(−0.8) – (−0.2)
end-quarter 3, cumulative	(−12.9) – 1.6	(−0.6) – 0.2
end-year 1, cumulative	(−13.2) – 2.8	0.0 – 1.0

Table C.14: VAR Estimates of the Pass-Through on Consumer Prices Obtained Using Import and Export Unit Values