EUROPEAN CENTRAL BANK

EUROSYSTEM

WORKING PAPER SERIES

NO 1046 / APRIL 2009

PRODUCTIVITY SHOCKS AND REAL EXCHANGE RATES

A REAPPRAISAL

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ISSN 1725-2806 (online)

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Abstract

We reappraise the relationship between productivity and equilibrium real exchange rates using a panel estimation framework that incorporates a large number of countries and importantly, a dataset that allows explicit consideration of the role of non-traded, as well as traded, sector productivity shocks in exchange rate determination. We find evidence of significant correlation between real exchange rates and productivity differentials in both sectors. But our finding of a significant role for the non-traded sector in exchange rate determination, and of a relatively larger correlation between exchange rates and productivity shocks of a given size emanating from this sector, represent clear contradictions of the widely cited Balassa-Samuelson hypothesis. Our findings remain valid in the face of a number of robustness tests, including the exchange rate regime and numéraire currency.

Keywords: Exchange rate, productivity, Balassa-Samuelson, panel data, emerging market economies

JEL Classification: F31, O47, C23

Non-technical summary

This paper reappraises the relationship between real exchange rates and productivity differentials. Recent abrupt, large changes in many Major and Emerging Market (EME) real exchange rates have served to re-emphasize the importance of a thorough understanding of the relationship between exchange rates and their fundamental determinants.

Purchasing Power Parity (PPP) is widely accepted as a reasonable long-term theory of real exchange rate equilibrium (Lothian and Taylor, 1996). But the incidence of various real shocks, including to productivity, ensure that deviations of equilibrium exchange rates from levels implied by PPP are relatively persistent and often large in magnitude (Rogoff, 1996; Sarno and Taylor, 2002). Consequently, although real exchange rates exhibit a tendency to mean-revert, they do so around a time-varying equilibrium determined, amongst other factors, by intra- and inter-country productivity differentials.

Assessments of the impact of productivity shocks upon real exchange rate equilibria usually afford a prominent role to the Balassa-Samuelson hypothesis (Balassa 1964 and Samuelson 1964). Accordingly, we do likewise. An important prediction of Balassa-Samuelson hypothesis is that Developing countries with relatively low levels of per capita Gross Domestic Product (GDP) will experience persistent real income convergence to the level of real income in the frontier country—typically taken to be the US—and a concurrent appreciation in the real value of their domestic currency, both against the frontier currency and relative to PPP-implied levels. The Balassa-Samuelson hypothesis also assumes that technological innovation and productivity catch-up are concentrated in the traded sector of economies, with wage growth spillovers from the traded to the non-traded sector the principal conduit through which productivity innovations impact the real exchange rate. Consequently, the need to empirically consider the role of non-traded sector productivity differentials is assumed away.

Although the empirical literature in this area is large, existing studies often use blunt proxies of productivity to test theoretical prediction. Much of the existing literature also examines the relationship between productivity shocks and exchange rates for only a limited number of, typically Advanced, countries. Both aspects appear inconsistent with the sense of the theoretical literature. By contrast, we re-evaluate the significance, sign and magnitude of the relationship between productivity shocks and equilibrium real exchange rates within a panel framework that incorporates a large number of countries at various stages of economic development and using disaggregated sector productivity data.

We consider three main issues. First, whether the relationship between labor productivity and the real exchange rate is consistent with the existence of a significant Balassa-Samuelson effect that validates theoretical prediction. Second, whether this relationship is homogeneous across traded and non-traded economic sectors. And third, whether the significance, sign and magnitude of the Balassa-Samuelson effect is invariant across the various country groups within our panel and to differences in exchange rate regime and numéraire currency, and to the inclusion of other, demand-related, explanatory variables.

We reach a number of conclusions that extend the existing literature. Our empirical analysis provides only moderate support for the Balassa-Samuelson hypothesis. Although there is some evidence for both Advanced and EME countries as a whole of a significant, positive relationship between industrial productivity differentials and real exchange rates, it is limited and the magnitude of estimated coefficients is small. In addition, for EMEs this supportive finding disappears once we disaggregate the group into its regional constituents. We also find evidence of a significant correlation between exchange rates and service sector productivity differentials. This result runs counter to the theoretical prediction of Balassa-Samuelson hypothesis even if directionally the effect on exchange rates is similar. As Lee and Tang (2007) argue, this result could partly reflect the role played by the non-traded sector in the distribution and production of traded sector output. It may also reflect shifts in consumer preferences for traded and non-traded sector products, and other demand-side effects related to convergence in income levels towards the frontier country. Finally, we also demonstrate that important differences exist in the relationship between real exchange rates and productivity differentials between currencies under fixed and floating exchange rate regimes.

1 Introduction

This paper reappraises the relationship between real exchange rates and productivity differentials. Recent abrupt, large changes in many Major and Emerging Market real exchange rates have served to re-emphasize the importance of a thorough understanding of the relationship between exchange rates and their fundamental determinants. Although the empirical literature in this area is large, existing studies often use blunt proxies of productivity to test theoretical prediction—for instance, per capita GDP, manufacturing output per employee without explicit consideration of productivity in other sectors, or even simply the service sector component of consumer price indices relative to aggregate producer price indices. By contrast, using a dataset that incorporates sector-based labor productivity series for industry, services and agriculture we explicitly consider the magnitude and significance of productivity shocks to the exchange rate from both traded and non-traded sectors of domestic and foreign economies.

Much of the existing empirical literature also examines the relationship between productivity shocks and exchange rates for only a limited number of, typically Advanced, countries. This seems inconsistent with the sense of the theoretical literature. Consequently, we consider this relationship within a panel framework from the perspective of a large number of countries at various stages of economic development. Our findings shed new light on the relationship between exchange rates and productivity differentials and have clear relevance for both policy-makers and private market participants.

Purchasing Power Parity (PPP) is widely accepted as a reasonable long-term theory of real exchange rate equilibrium (Lothian and Taylor, 1996). But the incidence of various real shocks, including to productivity, ensure that deviations of equilibrium exchange rates from levels implied by PPP are relatively persistent and often large in magnitude (Rogoff, 1996; Sarno and Taylor, 2002). Consequently, although real exchange rates exhibit a tendency to mean-revert, they do so around a time-varying equilibrium determined, amongst other factors, by intra- and inter-country productivity differentials.

Assessments of the impact of productivity shocks upon real exchange rate equilibria usually afford a prominent role to the Balassa-Samuelson hypothesis (henceforth Balassa-Samuelson). Accordingly, we do likewise. An important prediction of Balassa-Samuelson is that Developing countries with relatively low levels of per capita Gross Domestic Product (GDP) will experience persistent real income convergence to the level of real income in the frontier country—typically taken to be the US—and a concurrent appreciation in the real value of their domestic currency, both against the frontier currency and relative to PPP-implied levels. By the same logic, as Balassa-Samuelson assumes that higher income countries are typically the most productive, Advanced country currencies will on average trade at a level in excess of that implied by PPP (Taylor and Taylor, 2004).

Empirical evidence on Balassa-Samuelson is mixed. On the basis of cross-sectional analysis of post-war data, many studies, and particularly the most recent, conclude in favor of a significant, positive correlation between relative prices and a ratio of per capita income levels in the domestic and foreign countries (Balassa, 1964; Froot and Rogoff, 1994; Bergin, Glick and Taylor, 2004; Taylor and Taylor, 2004; Coudert and Couharde, 2005; Maeso-Fernandez, Osbat and Schnatz, 2005; Frankel, 2006). Less supportive cross-sectional evidence is reported, *inter alia*, by Officer (1976) and Bahmani-Oskooee and Niroomand (1996).

The results of time series analyses are more equivocal towards Balassa-Samuelson. This approach typically regresses the real exchange rate on the ratio of either domestic non-traded prices (proxied by CPI services) to traded (producer) price indices, or real value-added per employee, both relative to the same ratio in the frontier country. Supportive findings are reported, *inter alia*, by De Gregorio, Giovannini and Wolf (1994), Chinn (1997), Canzoneri, Cumby and Diba (1999), Fuentes and Meechan (2007) and Mihaljek and Klau (2008). But these contrast with more sceptical results of Froot and Rogoff (1981a, b), Asea and Mendoza (1994), Chinn and Johnson (1999), Chinn (2000), Mihaljek and Klau (2003), Drine and Rault (2005), Cheung, Chinn & Fujii (2007) and Lothian and Taylor (2007).[1,2]

Bahmani-Oskooee and Nasir (2004) find in favor of Balassa-Samuelson for a majority of 44 exchange rates they examine using the Autoregressive Distributed Lag cointegration methodology of Peseran and Shin (1995). But nearly all rejections they do report relate to Developing country exchange rates, for which Balassa-Samuelson should hold most significantly. Bahmani-Oskooee and Nasir argue that these rejections of Balassa-Samuelson may reflect trade and financial market imperfections, rather than an indication that productivity differentials are an insignificant determinant of real exchange rate behavior. The authors provide no empirical support for this hypothesis, however. Lee and Tang (2007) report that the statistical significance of evidence in favor of Balassa-Samuelson depends upon the definition of productivity, with results based upon Total Factor Productivity (TFP)—generally considered to be the most appropriate measure—less supportive than those based upon labor productivity. And Bahmani-Oskooee and Nasir (2005) and Tica and Družić (2006) show that evidence in favor of Balassa-Samuelson also appears sensitive to the choice of numéraire currency, with stronger results often reported versus the euro (previously the Deutschmark) than the US dollar. We consider the issue of exchange rate regime, numéraire currency and other robustness tests of our initial findings, in the empirical section below.

A number of factors may explain the ambiguity of time series evidence on Balassa-Samuelson. In particular, although intuitively appealing and at first glance transparent, Balassa-Samuelson relies upon various relatively stringent assumptions, particularly in the context of Developing country currencies. These include that the Law of One Price (or LOOP) holds continuously in the traded goods sector, and that each economy boasts continuous full employment, frictionless intra-economy labor mobility and perfect capital markets. As it is trivial to cite examples that invalidate one or more of these assumptions, from the perspective of both policy-makers and market participants it is important to establish whether market frictions—among other factors—are significant enough to undermine the predictions of Balassa-Samuelson, at least for time horizons less than the very long term.

Balassa-Samuelson also assumes that technological innovation and productivity catch-up are concentrated in the traded sector of economies. By contrast, non-traded sector productivity is assumed constant. In this way, the non-traded sector is relevant only in as much as wage growth spillovers from the traded sector are the principal conduit through which productivity innovations impact the real exchange rate. Consequently, the need to empirically consider the role of inter-country non-traded sector productivity differentials is typically assumed away. In practice, casual inspection of productivity data suggest merit in testing this assumption (Figure 1.1). And recent IMF advice to a number of Developing countries has included exhortations to reverse weakening productivity trends in the non-traded sector, as a means of spurring aggregate per capita income convergence towards US levels.[3]

In this paper, we use a panel estimation framework and disaggregated sector productivity data

[1] Lothian and Taylor (2007) present a long-span non-linear study of the relationship between two real exchange rates and productivity differentials. Although they find evidence of a significant Balassa-Samuelson effect for sterling-dollar, no such evidence exists for French franc-dollar.

[2] The studies referenced are based upon a mixture of univariate and panel estimation techniques.

[3] For instance, see IMF (2006a, b).

that span the period 1990 to 2004 and 68 countries to re-evaluate the significance, sign and magnitude of productivity shocks on equilibrium real exchange rates. We consider three main issues. First, whether the relationship between labor productivity and the real exchange rate is consistent with the existence of a significant Balassa-Samuelson effect that validates theoretical prediction. Second, whether this relationship is homogeneous across traded and non-traded economic sectors. And third, whether the significance, sign and magnitude of Balassa-Samuelson is invariant across the various country groups within our panel and to differences in exchange rate regime and numéraire currency, and to the inclusion of other, demand-related, explanatory variables.

We reach a number of conclusions that extend the existing literature. Our empirical analysis provides only moderate support for Balassa-Samuelson. Although there is some evidence for both Advanced and EME countries as a whole of a significant, positive relationship between industrial productivity differentials and real exchange rates, it is limited and the magnitude of estimated coefficients is small. In addition, for EMEs this supportive finding disappears once we disaggregate the group into its regional constituents. We also find evidence of a significant correlation between exchange rates and service sector productivity differentials. This result runs counter to the theoretical prediction of Balassa-Samuelson hypothesis even if directionally the effect on exchange rates is similar. Consistent with Lee and Tang (2007), this result could partly reflect the role played by the non-traded sector in the distribution and production of traded sector output. It may also reflect shifts in consumer preferences for traded and non-traded sector products, and other demand-side effects related to convergence in income levels towards the frontier country. We also demonstrate that important differences exist in the relationship between real exchange rates and productivity differentials between currencies under fixed and floating exchange rate regimes.

The remainder of the paper is organized as follows. Section 2 outlines the theoretical Balassa-Samuelson framework. Section 3 details our data series and sources and describes the estimation methodology used in our empirical analysis. Estimation results are reported and discussed in Section 4 and Section 5 presents our conclusions and directions for future research.

2 Theoretical Framework

It is widely accepted that PPP is the benchmark against which other equilibrium exchange rate theories should be compared. For comprehensive surveys of the PPP literature, see Froot and Rogoff (1994), Taylor (1995), Sarno and Taylor (2002), Taylor (2003) and Taylor and Taylor (2004). Strict-form PPP states that variation in the ratio of national price levels, expressed relative to an arbitrary base year, will exactly offset changes in the nominal exchange rate so that the real exchange rate is constant. Assuming baskets of goods used in national price indices are identical between countries, and that these goods are combined into indices using the same methodology and weights, the absolute version of PPP can be written as

$$S = P/P^* \text{ and } Q = SP^*/P \tag{1}$$

where S is the domestic price of foreign currency, P and P^* are the domestic and foreign national price levels and Q is the real exchange rate. Less strict interpretation allows the real exchange rate to deviate from a constant value, albeit in a trend-stationary manner, such that S, P and P^* exhibit a common stochastic trend. Over long data spans and using appropriately powerful tests, empirical studies typically conclude in favor of Absolute PPP (Abuaf and Jorion, 1990; Froot and Rogoff, 1994; Lothian and Taylor, 1996; Taylor, 2002; Sarno and Taylor, 2002). Over shorter time spans, empirical evidence is more equivocal, with deviations of real exchange rates from PPP-implied equilibria relatively persistent (Frenkel, 1980; Rogoff, 1996).

This finding has encouraged analysis of Relative PPP. In contrast to the absolute variant, this relates *changes* in the nominal exchange rate to *changes* in national price levels,

$$\Delta s_t = \alpha + \beta(\Delta p_t - \Delta p_t^*) + \varepsilon_t \tag{2}$$

and allows for a unit root in ε_t. Coakley, Flood, Fuertes and Taylor (2005) conclude in favor of Relative PPP using a nonstationary panel estimator and monthly data over the sample 1970 to 1998 for various Developed and Developing country US dollar exchange rates. They distinguish the effect of national price level changes on exchange rates from the effect of persistent shocks to the error term. Their evidence has important implications for Absolute PPP, if the persistence of deviations from the absolute variant reflects the existence of real variables that cointegrate with spot real exchange rates.[4] Relevant fundamentals may include productivity differentials that impart supply related shocks to the real exchange rate. There are a number of potential channels by which productivity shocks are transmitted to real exchange rates (for instance, Balassa, 1964; Samuelson, 1964; Stockman, 1987; Lee and Tang, 2007). As Balassa-Samuelson is most often cited in the empirical literature we use it as the starting point for our analysis.

Balassa-Samuelson draws its conclusions from a comparison of intra- and inter-economy productivity differentials. Despite an alluring simplicity, the hypothesis makes a number of important—and, in the case of Developing countries, restrictive—assumptions.[5] It focuses on two small open economies, domestic and foreign, assumed to produce an identical basket of traded and non-traded goods and services on the basis of a Cobb-Douglas production function,

$$Y_I = A_I K_I^{\theta_I}, \ I = T, N \tag{3}$$

where Y_I, K_I and A_I are the output-labour ratio, the capital-labour ratio and productivity in sector I respectively; the subscripts T and N denote the traded and non-traded sectors. Transaction costs are set to zero, and artificial barriers to cross-border trade and impediments to intra–economy labor mobility are assumed away. Consumer preferences are assumed to be homothetic. With labor supply assumed homogeneous within both economies, the level of real wages is equivalent across economic sectors and equal to the marginal product of labor,

$$W = (1 - \theta_T) A_T K_T^{\theta_T} \tag{4}$$

$$W = \Pi_N (1 - \theta_N) A_N K_N^{\theta_N} \tag{5}$$

where W is the long-run real wage, measured in terms of traded goods, and Π_N is the relative price of nontraded goods and services. As prices are set equal to marginal costs and, with capital assumed to be perfectly mobile across economies—to eliminate any role for demand-side factors in determining the real exchange rate—the long run real interest rate, R, is set according to international parity conditions,

$$R = \theta_T A_T K_T^{\theta_T - 1} \tag{6}$$

[4] As Sarno (2000) notes, the failure to find evidence in favor of Absolute PPP over shorter time horions may also reflect power problems associated with available testing procedures.

[5] For comprehensive expositions of Balassa-Samuelson, see Froot and Rogoff (1994), Sarno and Taylor (2002), Tica and Družić (2006) and Lee and Tang (2007). We present here only the principal equations and an outline of assumptions and mechanics.

$$R = \Pi_N \theta_N A_N K_N^{\theta_N - 1}. \tag{7}$$

Taking logarithms, totally differentiating equations (4)-(7) and manipulating gives,

$$dk_N = dk_T = dw = da_T(1-\theta_T)^{-1} \tag{8}$$

$$d\pi_N = (1-\theta_N)(1-\theta_T)^{-1} da_T - da_N \tag{9}$$

From equations (8) and (9) a rise in traded sector productivity generates an economy wide increase in the level of wages, and a rise in the relative price of nontraded goods and services. That this outcome is determined only by the supply side of the economy is consistent with the findings of Beveridge and Nelson (1991), who find that the impact upon exchange rate of innovations to supply related variables is more persistent than innovations to demand-side variables. Integrating equation (9) derives an expression for the logarithm of the price of nontraded, p_N, relative to the price of traded goods and services, p_T,

$$p_N - p_T = (1-\theta_N)(1-\theta_T)^{-1} a_T - a_N \tag{10}$$

We can define the price level in the home country, p, as a geometric weighted average of the price of traded and nontraded goods and services,

$$p = p_T + \alpha(p_N - p_T) \tag{11}$$

where p is the price level in the home country, p_T is the price of traded goods and services, p_N is the price of nontraded goods and services, and α is the weight of the nontraded sector in the aggregate price level of the home country. From (1) above, the real exchange rate is defined in logs as,

$$q = s + p^* - p. \tag{12}$$

Substituting (11) into (12) gives,

$$q = s + p_T^* - p_T + \alpha^*(p_N^* - p_T^*) - \alpha(p_N - p_T). \tag{13}$$

Balassa-Samuelson is an explanation of the persistence of deviations of real exchange rates from PPP-based equilibria. It nonetheless maintains that PPP holds continuously in the traded sector of the Home and Foreign countries, so that the LOOP applies and $q_tT = s + p_T^* - p_T$ is a constant term, or unity under the assumption of strict-form traded sector PPP. Canzoneri, Cumby and Diba (1999), Engel (1999), Obstfeld and Rogoff (2000), and Lee and Tang (2007) all provide evidence that refutes this assumption, at least in the context of OECD real exchange rates. Nonetheless, on the basis of Balassa-Samuelson equation (13) can be re-written as,

$$q = q_tT + \alpha^*(p_N^* - p_T^*) - \alpha(p_N - p_T) \tag{14}$$

Using equation (10) we can derive an expression for the long-run real exchange rate,

$$q = \alpha^* \left[(1-\theta_N^*)(1-\theta_T^*)^{-1} a_T^* - a_N^*\right] - \alpha\left[(1-\theta_N)(1-\theta_T)^{-1} a_T - a_N\right] \tag{15}$$

Assuming that productivity growth in the nontraded sector in both countries is close to zero, we can express (15) as

$$q = \psi^* a_T^* - \psi a_T \tag{16}$$

where $\psi^* = \alpha^* \left[(1-\theta_N^*)(1-\theta_T^*)^{-1}\right]$ and $\psi = \alpha \left[(1-\theta_N)(1-\theta_T)^{-1}\right]$. Obstfeld and Rogoff (1996) assume that production functions for traded and nontraded goods and services are identical for both home and foreign countries—that is , $\theta_N = \theta_T$ and $\theta_N^* = \theta_T^*$—and that the weight of nontraded goods and services is equivalent in the home and foreign country price levels—$\alpha = \alpha^*$. As Mihaljek and Klau (2008) argue, these are relatively restrictive assumptions. Nonetheless, they give rise to the typical Balassa-Samuelson estimation equation,

$$q = q_t T - \alpha \left[(p_N - p_T) - (p_N^* - p_T^*)\right] \tag{17}$$

where, from above, $q_t T$ is a constant.

The mechanics of Balassa-Samuelson are triggered by a rise in the level of traded sector labor productivity in the domestic economy.[6] With real wage levels equal to their marginal product and equivalent across the whole economy, this shock implies an increase in wages in the domestic economy. Courtesy of the LOOP, traded sector price levels remain unchanged. But absent a commensurate and concurrent increase in domestic non-traded sector productivity, rising wages push up the average price level in this sector as firms act to maintain prices equal to marginal costs. This in turn raises aggregate price levels in the domestic economy and, assuming the nominal exchange rate is constant, appreciates the real value of the domestic currency relative to its PPP-implied level.[7] By implication, currencies of relatively more productive countries may trade above levels implied by PPP for extended periods.

Consistent with the assumptions of Balassa-Samuelson, relatively little consideration is given in the existing empirical literature to the possibility either that relatively large productivity shocks may frequently occur in the non-traded sector of economies, or that productivity shocks emanating from either the traded or non-traded sectors of the domestic economy may be associated with a depreciation of the real exchange rate. Noteworthy exceptions are Bergen, Glick and Taylor (2004), Lee (2007) and Lee and Tang (2007). It is these possibilities, as well as the cross-country consistency of the relationship between productivity differentials and real exchange rates that we explore in the following section.

3 Data Description & Estimation Methodology

Our empirical analysis is performed within a panel framework, using annual data over the sample period 1990 to 2004 and incorporating 64 countries. Of these, 21 are defined as Advanced, 24 as EMEs and 19 as Other countries. The large number of cross-sections in our study and inclusion of Developing country data are two key contributions compared with the existing empirical literature linking real exchange rates and productivity differentials. In terms of recent studies, although Bahmani-Oskooee and Nasir (2004) report the results of a univariate Balassa-Samuelson analysis for 44 real exchange rates, they proxy productivity differentials using per capita GDP. Consequently, they are not able to draw conclusions on the relevance of sector-based productivity shocks and also are not able to differentiate the impact of productivity shocks on the real exchange rate from demand-side shocks.

Similar to our analysis below, Lee and Tang (2007) adopt a panel estimation approach and exploit sector-based productivity series, using both labor productivity and TFP. But their panel includes only a maximum of twelve OECD countries, over the sample period 1970 to 1997. Their methodological

[6] Although the hypothesis actually relates to Total Factor Productivity, data limitations normally lead researchers to focus upon labor productivity. We follow this precedent.

[7] For ease of exposition, this discussion omits consideration of second-round effects on wages and prices due, *inter alia*, to the central bank reaction function.

approach also differs from ours. Consequently, valid comparisons between our empirical results and those of Lee and Tang (2007) are limited to our Advanced country group. And as Lee and Tang (2007) emphasize, analysis of the relationship between productivity differentials and real exchange rates, including within Balassa-Samuelson, has most relevance to EMEs, which is where we concentrate much of our analysis.

Table 1 provides a list of countries included in our panel. Categorization of countries into the three groups is made as follows. Advanced economies are designated as those in the highest PPP-based per capita income quartile in our sample; this includes the EU-15 countries, as well as Australia, Canada, Iceland, Japan, New Zealand and Norway.[8] EMEs are defined according to the MSCI investable index classification system.[9] Finally, remaining countries are designated into the Other Country category; these countries have both a relatively low level of per capita income and less developed capital markets compared with Advanced and EME countries. In addition, we exclude data for any country i during bouts of hyper-inflation which, consistent with Cagan's definition, are identified as years when the annual rate of inflation in country i measured using consumer prices exceeds 30% (Cagan, 1956).

Table 2 details the variables used in the paper. Real exchange rates are expressed against the US dollar, calculated using GDP deflators and defined as the foreign price of domestic currency. Following, *inter alia*, Marston (1987), we use a sector database that explicitly separates productivity series, defined as real value-added per employee, between the industrial, agricultural and service sectors.[10] These series are taken from the World Bank's World Development Indicators (WDI) 2007 database.

Some discussion of issues relating to data availability and coverage is appropriate. These issues present a number of challenges and although we work around data imperfections, we recognize their potential to affect our results. First, in the absence of comprehensive TFP data for more than a few countries within our panel, we use labor productivity data. Although second-best, this approach is consistent with a large majority of existing empirical studies. Second, although industrial output is dominated by manufacturing output it also includes smaller, primarily non-traded sub-components such as electricity, gas and water, and construction. As a result, this proxy for the traded sector is imperfect; a lack of employment data for a large number of the countries included in our panel prohibits use of manufacturing productivity data. Again, though, our approach is consistent with the existing literature. Third, service sector productivity data are taken to be representative of the non-traded sector, whereas industry and agriculture are both considered traded sectors. The service sector includes sub-sectors such as retailing and wholesaling for which traded goods are an important element. Nonetheless, in 2006 trade in services represented just 19% of total world trade (IMF, 2007), suggesting that our use of services as a proxy for the non-traded sector is reasonable. Fourth, the relationship between real exchange rates and agricultural productivity data is likely to be distorted by subsidy arrangements such as the EU Common Agricultural Policy (Mihaljek and Klau, 2003). Nonetheless, our results are qualitatively similar whether we include or exclude agricultural sector productivity data from our analysis, and on balance choose to retain this sector for completeness.

By way of motivating our use of sector productivity data, a core assumption in the existing empirical literature—often made only implicitly—is that the level of non-traded productivity in the

[8] As all analyses are conducted relative to the US, this country is not included in this list.

[9] See www.mscibarra.com for further details. Noteworthy exceptions are Hungary, India and Taiwan, which were all excluded for reasons of data availability. Venezuela was included despite not being part of the MSCI index, in order to ensure sufficient country members in our Latin America EME sub-panel.

[10] Marston (1987) uses data disaggregated into ten sectors whereas as our database does not allow this degree of disaggregation. However, whereas we consider sixty four dollar-based exchange rates, his study analyzes only yen-dollar and so is more limited from this perspective.

domestic economy relative to the foreign economy is constant. In reality, annual average labor productivity growth in the non-traded sector during our sample period was 2.05% in the US, our income frontier country, 1.60% in Advanced countries, 2.01% in EMEs and 0.53% in Other countries (see Figure 1.1 and Table 5).[11] With the exception of Other countries, the null hypothesis of zero average labor productivity growth in the service sector during our sample period is rejected at the 5% significance level. This finding therefore validates our use of disaggregated sector data.[12] For the industrial sector, the comparable labor productivity growth data are 1.33% in the US, 1.06% in Advanced countries, 2.59% in EMEs and 2.87% for Other countries; from Figure 1.1, the industry-led acceleration in EME and Other country traded sector productivity growth since 2001 has been striking. So, for the US and Advanced countries a second core assumption of the existing empirical literature—that productivity growth in the industry sector exceeds service sector productivity growth—is also rejected over our sample period, albeit not at standard levels of statistical significance. And over our sample as a whole, there is a negative correlation between industrial and service sector productivity growth and real exchange rates in both Advanced countries and EMEs, which also contradicts the prediction of Balassa-Samuelson (Table 5).

We construct dummies to control for European Economic and Monetary Union (EMU), as well as for currency crises (CRISIS) that periodically afflict some of the real exchange rates in our panel. Our EMU dummy variable is set equal to one from 1999 onwards and to zero previously for the twelve EU countries that joined in that year.[13] There is no universally accepted definition of a currency crisis, and a trade-off exists between definitions that reveal too many crisis episodes—that is, Type I errors—or too few—Type II—episodes. We have chosen a definition based on the behavior of the real exchange rate: crisis periods are defined as years when the real value of the domestic currency versus the US dollar changes by more than 3 country-specific standard deviations. This is a less arbitrary approach than, *inter alia*, Frankel and Rose (1996), who employ a common devaluation threshold of 25% and therefore do not account for exchange rate-specific volatilities; the financial crisis of 2007 and 2008 demonstrates the importance of accounting for differences in exchange rate volatilities. Tables 3.1 - 3.3 detail the classification of exchange rate regime by country, and Table 4 lists the incidence of currency crises by country during our sample.[14] As Table 4 highlights, there are nine currency crises during our sample and according to our definition: five occur in Central and Latin America (Argentina, Colombia, Ecuador, Honduras, Panama); three in Asia (Indonesia, Korea and Malaysia); and the other in Egypt.

The primary focus of our empirical investigation is upon the determinants of the behavior of equilibrium real exchange rates. Consistent with the findings of Beveridge and Nelson (1991), we concentrate our investigation upon the relationship between exchange rates and inter-country and intra-sector productivity differentials. But to test the robustness of our findings—specifically, whether our results suffer from omitted variable bias—we also analyze whether our findings are sensitive to inclusion of three demand-related variables: the Terms of Trade, defined as the ratio of individual

[11] Although we combine industrial and agricultural sectors in Figure 1.1 to generate aggregate traded sector labor productivity series, this is for illustrative purposes only. In our empirical analysis, industry and agriculture are considered separately, under the general heading of traded sectors.

[12] Although Other country non-traded sector productivity growth is not significantly different from zero, we persist with this group as part of our analysis as it may have important level effects for real exchange rates.

[13] Reflecting its later entry, our EMU dummy for Greece equals one from 2001 onwards, and zero before.

[14] We adopt the classification of Reinhart and Rogoff (2004) for all countries except Canada. In this case, we disagree with their classification of a fixed exchange rate regime throughout our sample.

country export to import prices, both expressed in domestic currency terms;[15] Net Foreign Assets (NFAs); and government final consumption expenditure.[16] As above, all three variables are calculated relative to the same series for the US. We also test the robustness of our empirical findings using various numéraire currencies and between fixed and floating exchange rate arrangements.

Our empirical estimations use the Generalized Method of Moments (GMM) dynamic panel methodology of Blundell and Bond (1998), which is intended for stationary panels where the number of cross-sections is large and time T is fixed. To this end, we use the tests of Levin, Lin and Chui (2002) and Im, Peseran and Shin (2003) to investigate the stationarity assumption, and conclude that for all series, the null hypothesis of a unit root is rejected, validating our approach.[17]

The basic estimation equation is:

$$\begin{aligned} \ln Q_{i,t} &= \alpha \ln Q_{i,t-1} + \beta_1(\ln A_t^{Agri}) + \beta_2(\ln A_{t-1}^{Agri}) + \beta_3(\ln A_t^{Indu}) + \beta_4(\ln A_{t-1}^{Indu}) \\ &\quad + \beta_5(\ln A_t^{Serv}) + \beta_6(\ln A_{t-1}^{Serv}) + \sum_{j=1}^{2} \gamma_j' X_{i,t}^j + u_{i,t} \end{aligned} \tag{18}$$

for $i = 1, ..., 63$ and $t = 1990, ..., 2004$ and where $Q_{i,t}$ is the real dollar exchange rate of country i at time t, $A_{i,t}^{Agri} = (A_{US,t}^{Agri} - A_{i,t}^{Agri})$, $A_{i,t}^{Indu} = (A_{US,t}^{Indu} - A_{i,t}^{Indu})$, and $A_{i,t}^{Serv} = (A_{US,t}^{Serv} - A_{i,t}^{Serv})$ denote labor productivity in country i in the agricultural, industrial and service sectors, respectively, and US subscripts denote the same series for the US. A strictly exogenous vector of dummy variables (EMU, CRISIS and time dummies) is denoted by $X_{i,t}^j$. The error term $u_{i,t} = \eta_i + \upsilon_{i,t}$ can be decomposed into the usual fixed effects representation, where η_i is the country-specific term and the error term $\upsilon_{i,t}$ varies across time and country; it is also assumed that $\eta_i + \upsilon_{i,t}$ is independently distributed across i and that the error components structure $E(\eta_i) = 0$, $E(\upsilon_{i,t}) = 0$, $E(\upsilon_{i,t}\eta_i) = 0$ and $E(\upsilon_{i,t}\upsilon_{i,s}) = 0$ for $i = 1, ...N$, $t = 2, ..., T$, and for all $t \neq s$. Consistent with the aforementioned stationarity assumption, the coefficient for the lagged dependent variable, α, is assumed to be less than unity. All variables, with the exception of $X_{i,t}^j$, are assumed to be endogenous, and lags two and three of each variable are used as instruments.[18] We estimate the covariance matrix using a robust one-step procedure, and the resulting standard error estimates are consistent in the presence of any pattern of heteroskedasticity and autocorrelation within panels. Reported Hansen J-statistics, which are robust for heteroskedasticity and autocorrelation, confirm the validity of our instruments. Arellano and Bond (1991) m-test statistics for autocorrelation in error terms are also reported.[19]

[15] Arguably, shocks to the Terms of Trade could be classified as both demand- and supply related (for instance, DeLoach, 2001).

[16] We are grateful to an anonymous referee for this suggestion.

[17] The unit root tests conducted on sub-samples (regions) confirm the full sample results. In the interests of brevity, unit root test results are not reported but are available on request.

[18] For the real exchange rate only lag 3 is used. We use as few instruments as possible to avoid overparametrizing the models. We also test longer lags as instruments, but find the results to be qualitatively similar.

[19] Arellano and Bond (1991, pp.282, 287) argue that the asymptotic power of the AR-test depends on the efficiency of the estimators used. Their Monte Carlo analysis reveals that even with a low degree of serial correlation, the AR-test is subject to a significant Type I error, i.e. rejecting the null hypothesis when it is true. With a similar type of dataset to ours (N=100, T=7) and low degree of serial correlation (rho = 0.3), the null hypothesis of no serial correlation is rejected at the 5% significance level 92 times out of 100 cases in Arellano and Bond (1991). Consequently, a rejection of the null hypothesis of no serial correlation would not necessary call into question the specification of our estimation equations.

4 Empirical Results

Our empirical analysis begins by reporting in Table 6 the results of a traditional Balassa-Samuelson analysis, albeit in a large panel context. We regress real exchange rates on industrial sector real value-added per employee—explicitly overlooking for now the potential role of non-traded sector productivity shocks—our CRISIS and EMU dummies, time dummies, and a constant term. Results are presented for all countries (column 1) and for each of the country sub-groups (columns 2-4).[20] We find evidence of a significant correlation between inter-country industrial sector productivity differentials and real exchange rates only for our EME sub-panel.But the magnitude of the estimated relationship for EME exchange rates—given by the sum of estimated coefficients on the contemporaneous and lagged productivity terms—is small compared with the economic share of the industrial sector in this country grouping (see Figure 1.2, which presents data on Gross Value Added in traded and non-traded sectors of country groups in our panel).[21]

Although statistically insignificant, the negative correlation between productivity and Advanced country real exchange rates contradicts Balassa-Samuelson. In addition, the significance and relative magnitude of estimated constant terms for both Advanced and EME sub-panels implies that the importance of other fundamental exchange rate determinants—purposefully not included in our regressions—is high relative to inter-country productivity differentials, as measured here. These variables may be either intra-sector productivity differentials, or demand-side variables. Candidate demand-side variables suggested by the empirical literature include the Terms of Trade, government spending, and net foreign assets (NFAs) (Froot and Rogoff, 1991a,b; Rogoff, 1992; De Gregorio, Giovaninni and Wolf, 1994; De Gregorio and Wolf, 1994; and Lee, 2007). We return to this issue below.

Tables 7.1-7.3 introduce sector productivity series into our empirical analysis. As productivity data for sector i have been scaled by the relative size of this sector in the domestic and foreign economies, the magnitude of estimated coefficients for the various sectors are directly comparable. For the overall panel, as well as the Advanced, EME and Other country sub-panels we perform two sets of estimations. First, we regress real exchange rates on all three of our sector productivity series concurrently (column 1). Second, we include each of these regressors individually (columns 2-4). As with Table 6, we include a contemporaneous and lagged term of all productivity differentials, lagged exchange rate levels and contemporaneous CRISIS, EMU and time dummies.

Estimation results for the whole panel indicate a statistically significant relationship between real exchange rates and non-traded sector productivity differentials. The sign of this correlation is *directionally* consistent, yet *theoretically* inconsistent with the assumptions underlying Balassa-Samuelson. Although the combined magnitude of estimated non-traded sector coefficients is small compared with its average economic share in our panel of countries (Figure 1.2), our correlation finding is consistent with the results of Lee and Tang (2007) in the part of their analysis that focuses upon Total Factor productivity. While they find evidence of a negative correlation between productivity differentials and *traded sector* real exchange rates, its impact on the *aggregate* real exchange rate is outweighed by a positive correlation in the non-traded sector. This result may reflect the importance of the non-traded sector in the distribution and production of traded sector output (Lee and Tang, 2007). By contrast,

[20] We do not discuss estimation results for EMU and CRISIS dummies in detail, but evidence of statistical significance is generally consistent with priors. Note also that although we estimated all equations with the real exchange rate and relative productivity variables lagged at a maximum of 4 lags, we found lags beyond the first to be statistically insignificant in most cases. Therefore, we exploit the most parsimonious specification.

[21] The coefficient on the lagged real exchange rate for Other countries suggests the possibility of a unit root in the sub-section of our panel.

we find no evidence of a statistically significant relationship between traded sector productivity differentials and real exchange rates. Consequently, for the panel as a whole the impact of non-traded sector shocks to the real exchange rate dominates shocks emanating from the traded sector.

Evidence from the Advanced country sub-panel of a significant relationship between productivity shocks emanating from either sector and exchange rates is scarce (Table 7.2). Indeed, with only a small reverse Balassa-Samuelson effect between traded (agricultural) sector productivity differentials and real exchange rates is evident for the regression incorporating all three of our sector productivity series concurrently. We discuss the theoretical interpretation of this result below. By contrast, but consistent with our whole panel findings, regressing each of our sector productivity series individually against Advanced country real exchange rates results in a significant and relatively large explanatory role for non-traded sector productivity differentials (column 4). As above, this finding is consistent with the results of Lee and Tang (2007).

A positive correlation between the real exchange rate and both traded and non-traded sector productivity differentials is also apparent for the EME sub-panel (Table 7.3). Although not shown, for the Other country sub-panel none of the sectors exhibit a significant correlation with real exchange rates.

In Tables 8.1-8.3 we focus our analysis upon the EMEs. *A priori* we would expect the relationship between productivity differentials and real exchange rates, whether consistent or not with Balassa-Samuelson, to be statistically and economically most significant for this country group. We sub-divide the EME country group into Asia (for which we have nine country members), Latin America (seven) and Central and Eastern Europe (CEE, nine). Only for Latin America (Table 8.2) do our results provide evidence of a significant correlation between real exchange rates and traded sector productivity differentials. By contrast, results for all three sub-groups suggest a significant correlation between non-traded sector productivity differentials and real exchange rates, with the sign implying once more that a positive domestic productivity shock is consistent with a real appreciation of the domestic currency. The absolute magnitude of this correlation is largest for the CEEs (Table 8.3), although it is low in all three cases relative to the economic share of this sector across the EMEs.

In summary, our empirical results are based upon a large panel incorporating both Advanced and Developing countries, and real value-added data that allow explicit consideration of sector dynamics. They provide an important insight into the relationship between productivity differentials and real exchange rates. The results so far provide relatively little support for Balassa-Samuelson, consistent with a substantial proportion of the existing literature (Froot and Rogoff, 1994; Isard and Symansky, 1996; Rogoff, 1996). Although there is evidence for EME countries of a significant, positive relationship between traded sector productivity differentials and real exchange rates, the magnitude of estimated coefficients is small, and once we disaggregate the EME group into its regional constituents this supportive finding largely disappears.

Our lack of evidence in favor of Balassa-Samuelson may partly reflect violation of one or more of the assumptions underlying this hypothesis.[22] We have already discussed the documented failure of the LOOP. In addition, one can reasonably question the assumption of perfectly mobile cross-border capital flows for many EMEs in our database, as well as most countries in the Other sub-panel. Trade liberalization, including accession to the World Trade Organization, will also have impacted the relationship between real exchange rates and intra- and inter-country productivity differentials for

[22] An interesting extension of our analysis would be a formal investigation to identify which assumptions of Balassa-Samuelson are rejected by the data. Unfortunately, data limitations for many of the countries in our panel preclude this analysis.

many countries within our EME and Other country sub-panels and therefore potentially undermined any evidence in favor of Balassa-Samuelson. Assuming that the impact of trade liberalization is uniform across sectors, it implies a decline in home relative to foreign product prices, and therefore a real depreciation of the exchange rate. Alternatively, evidence of a negative correlation between Home traded sector productivity innovations and the real exchange rate may indicate the presence of a high elasticity of substitution between domestic and foreign output, meaning that domestic producers have to reduce prices in order for foreign consumers to absorb increases in output due to increasing productivity (Lee, 2007).

We also find evidence of a significant, positive correlation between exchange rates and service sector productivity differentials for EMEs and, when this series is included alone in regressions, Advanced countries. There are a number of potential explanations for this finding. In particular, although we have assumed thus far that this correlation is indicative of a significant supply side relationship, our results do not necessarily preclude the presence also of significant demand-led effects, even if Balassa-Samuelson explicitly rules out this possibility by assuming that preferences are homothetic. For instance, demand-led effects may exist if preferences shift towards the consumption of relatively higher cost non-traded goods and services as domestic income levels converge towards the frontier country. This shift in preferences in turn will exert upward pressure on the prices of non-traded sector output, thereby appreciating the real exchange rate. This relationship is often termed the Penn effect.[23] In addition, it is possible that intra- and inter-country productivity shocks are a less important determinant of real exchange rates than other explanatory variables suggested in the literature. We consider this second possibility further below, alongside other tests of the robustness of our findings.

Robustness Tests

Fixed versus Floating Exchange Rate Regime To consider the robustness of our results, we first separate currencies into those governed by fixed and floating exchange rate regimes, using the *de facto* regime definitions of Reinhart and Rogoff (2004). One of the key stylized facts of floating exchange rates, and particularly those involving the US dollar, has been their excessive volatility relative to underlying fundamentals (Obstfeld and Rogoff, 2000; Norrbin and Pipatchaipoom, 2006).[24] Table 9 presents the results of this analysis. It reveals interesting differences in the relationship between productivity differentials and real exchange rates between our two regimes that may reflect, *inter alia*, the difference in exchange rate volatility between them.[25] In particular, although the aggregate correlation between these series is positive and relatively large for All *floating* currencies, this result is due primarily to service sector productivity differentials, as well as agriculture; there is no significant correlation between real exchange rates and industrial sector productivity differentials,

[23] The Penn effect is typically analysed using GDP per capita data. Arguably, as we are directly controlling for productivity shocks that orginate in the service sector of the domestic and foreign economies, our study is better placed to isolate the significance and magnitude of this effect.

[24] Within our panel of countries there has been a trend shift from relatively fixed to more freely floating exchange rate arrangements. One important factor has been the substantial increase in capital mobility experienced by these countries, and the consequent rise in the cost of preserving and defending a fixed exchange rate system. In addition, as Edwards and Savastano (1999) note, a growing consensus argues that the exchange rate should play a central role in restoring and preserving equilibrium in shock-prone EME countries.

[25] The sum of total countries included in this analysis, as reported in Table 7, is greater than the total number of countries in our panel as some countries switch between fixed and floating rate arrangements during our sample. The same is true of the EME sub-group as well.

again contradicting the predictions of Balassa-Samuelson. For EME floating regime currencies, this result remains apparent, although the magnitude of estimated significant coefficients is smaller.

The positive correlation between service sector productivity differentials and real exchange rates is smaller for All *fixed* regime currencies, and disappears for EME fixed regime currencies. In its place, a significant correlation appears between real exchange rates and industrial sector productivity differentials. However, the sign of this relationship is negative, again contradicting Balassa-Samuelson and indicating that positive domestic productivity innovations generate a depreciation in the value of the domestic currency. From a theoretical perspective, there are at least two possible explanations for this negative Balassa-Samuelson effect. First, in the context of relatively fast traded sector productivity in the Home economy, our finding is consistent with the presence of pricing-to-market (PTM) strategies that contradict the LOOP (Krugman, 1987; Marston, 1990; Bergin and Feenstra, 2000; Bussière and Peltonen, 2008). Consistent with Beningo and Thoenissen (2002), PTM strategies are particularly likely in the presence of a low elasticity of substitution between domestic and foreign traded sector output and a bias of domestic consumers towards home-produced goods (Obstfeld and Rogoff, 2000). In the event of a positive productivity shock in the domestic traded goods sector, both characteristics require domestic producers to lower prices in order to encourage consumers in the foreign economy to absorb the associated increase output. This effect will dominate any positive impact that the traded sector productivity shock exerts on non-traded prices, which the mainstay of Balassa-Samuelson.

Numéraire Currency To investigate the sensitivity of estimation results to our choice of the US dollar as numéraire currency, we re-estimate our regressions using both the Deutschmark (euro) and the Japanese yen in place of the dollar. As with our regime analysis above, the justification for this analysis is that empirical tests using the dollar as numéraire may be adversely affected by perceived excessive US dollar volatility. Consistent with this assertion, and using various testing methodologies, Jorion and Sweeney (1996), Papell (1998), Papell and Theodoridis (2001), Chortareas and Kapetanios (2004), Bahmani-Oskooee and Nasir (2005) and Tica and Družić (2006) all conclude that tests of PPP are sensitive to the choice of numéraire currency. Tables 10.1 - 10.2 present the results of this analysis. By contrast, our main results remain qualitatively robust to the choice of numéraire currency (compare Tables 10.1 - 10.2 with Table 7.1 that uses the US dollar as numéraire). In particular, for both the Deutschmark (euro) and yen, service sector productivity exhibits a positive correlation with the real exchange rate. In addition, agriculture productivity differentials are also positively correlated with the real exchange rate when the Deutschmark is used as numéraire.

Demand-Side Variables Thus far, we have concentrated upon sector productivity differentials as the sole determinants of shocks to real exchange rates relative to equilibrium. Although this approach is consistent with the findings of Beveridge and Nelson (1991), in order to further assess the robustness of our results we report in Table 11 the results of re-estimated regressions for all panels including three additional, demand-side variables: the Terms of Trade; General Government Final Consumption Expenditure and NFAs.[26,27] Other studies to consider the impact of these variables upon real exchange rates include Mussa (1984)—this study, as well as Frenkel and Mussa (1986),

[26] Another strand of the relevant literature considers deviations from PPP due to real interest differentials (for instance, Baxter, 1994, and Clarida and Gali, 1994). We do not pursue this avenue here. We also do not consider the possibility that the persistence of exchange rate deviations from PPP may also reflect a number of important statistical issues, including the low power of conventional unit root tests (Lothian and Taylor, 1996), the relatively short data span and data measurement error.

[27] Results for sub-panels are not reported but are available on request.

provides a theoretical justification for inclusion of demand-side variables in augmented PPP models—Froot and Rogoff (1994), Faruqee (1995), Chinn (1998) and Osbat et al. (2003).

There are at least two channels through which Terms of Trade shocks can be transmitted to the real exchange rate. First, due to changes in consumer preferences in favor (against) of the output of the domestic country that raise (reduce) its Terms of Trade, and appreciate (depreciate) the real exchange rate. Second, due either to a shift in foreign demand patterns vis-à-vis higher value exports of the domestic economy, or due to a commodity price shock that significantly impacts the production base of the domestic economy. Some researchers use the real oil price as a substitute for the Terms of Trade (for instance, Amano and van Norden, 2003, Chen and Chen, 2007). But a priori the sign of the estimated relationship between the real oil price and exchange rate is more equivocal than for the Terms of Trade, for instance depending upon the oil import dependency of a country.

To the extent that increases in government expenditure are concentrated upon the non-traded goods sector, this will tend to raise the price of non-traded goods and services and therefore lead to a short-term appreciation of the real exchange rate. But adverse credibility effects may reverse this impact in the longer term.

In equilibrium, a country with negative NFAs must maintain a trade surplus to finance the outflow of interest and dividend payments. This trade surplus is achieved, assuming imperfect substitutability between traded goods and services of Home and Foreign countries, via a real exchange rate depreciation. Likewise, in equilibrium countries reporting a positive NFA position must have an offsetting trade deficit (Gagnon, 1996; Bénassy-Quéré, Béreau and Mignon, 2008). Alternatively, the relationship between NFAs and real exchange rates has been explored within New Open Economy Macroeconomics models that incorporate the assumption of imperfect risk sharing across countries (Selaive and Tuesta (2003).

From Table 11, inclusion of demand-related variables does not materially alter our previous results regarding the correlation between productivity series and real exchange rates. In addition, we find that none of the demand-side variables exert a statistically significant impact upon real exchange rates. This finding is a little surprising with respect to the Terms of Trade, given the results reported by much of the existing literature. However, Chinn (1997) does report findings consistent with ours. The absence of statistical significance for government spending is consistent with much of the literature (Rogoff, 1992; Gagnon, 1996). And the lack of statistically significant correlation between NFAs and the real exchange rates is unsurprising, given that existing empirical evidence is mixed (Faruqee, 1995; Obstfeld and Rogoff, 1995; Bénassy-Quéré, Béreau and Mignon, 2008).

Alternative Estimation Methods As a final test of the robustness of our original results, we present in Tables 12.1 and 12.2 results from dynamic pooled panel Ordinary Least Squares and fixed effects panel estimations, respectively. Again, the results remain qualitatively the same as for the dynamic GMM panel estimator used previously. Taking all of the robustness tests together, therefore, we can reasonably conclude that although our results run counter to the prevalent theoretical prediction of the relationship between productivity differentials and real exchange rates, they are nonetheless robust.[28]

[28] We also investigate whether our dynamic GMM panel models are overfitted, for instance by estimating additional models using 4-year averages of the key variables. Overall, our main results remain qualitatively unchanged. We are grateful to an anonymous referee for this suggestion.

5 Conclusions

In this paper we reappraised the relationship between real exchange rates and productivity differentials. We report evidence of a significant relationship between these variables, suggesting that real exchange rates oscillate around a time-varying equilibrium level determined by intra- and inter-country productivity differentials. But our analysis offers only modest support for Balassa-Samuelson, the principle hypothesis in the relevant theoretical exchange rate literature. Indeed, once we account for differences in exchange rate regime, we actually find evidence of a reverse Balassa-Samuelson effect for EME fixed exchange rates, indicating that relatively higher productivity growth in the domestic traded sector is correlated with a real depreciation of the exchange rate. This finding may indicate the existence of a high elasticity of substitution between domestic and foreign output, implying that relatively more productive traded sector domestic firms are required to lower prices in order to encourage consumers in the foreign economy to absorb the associated increase in output.

In addition, whereas many studies overlook the sector distribution of productivity shocks, our analysis makes clear the importance of understanding the source of shocks between the traded and non-traded sectors of domestic and foreign economies. For many of our country sub-panels, we find evidence of a significant relationship between non-traded sector productivity differentials—proxied using service sector data—and real exchange rates. Although the sign of this correlation is directionally consistent with Balassa-Samuelson, it is inconsistent with the theoretical priors that underpin this hypothesis. As argued by Lee and Tang (2007), this result could partly reflect the role played by the non-traded sector in the distribution and production of traded sector output. It may also reflect shifts in consumer preferences for traded and non-traded sector products, and other demand-side effects related to convergence in income levels towards the frontier country. This finding is relevant to both policy-makers and private sector market participants, and indicates that one-size-fits-all analysis of prospective intra- or inter-regional exchange rate constellations based upon blunt productivity proxies is ill-advised.

The obvious extension to our empirical work is to consider whether inclusion of sector-based productivity series in a non-linear framework can contribute to solving one of the key puzzles in empirical exchange rate analysis; namely, the persistence of half-live deviations from estimated equilibria. This issue is addressed in a companion paper using an innovative panel estimation technique and disaggregated, output-based sector productivity data (Peltonen, Popescu, Sager and Taylor, 2009).

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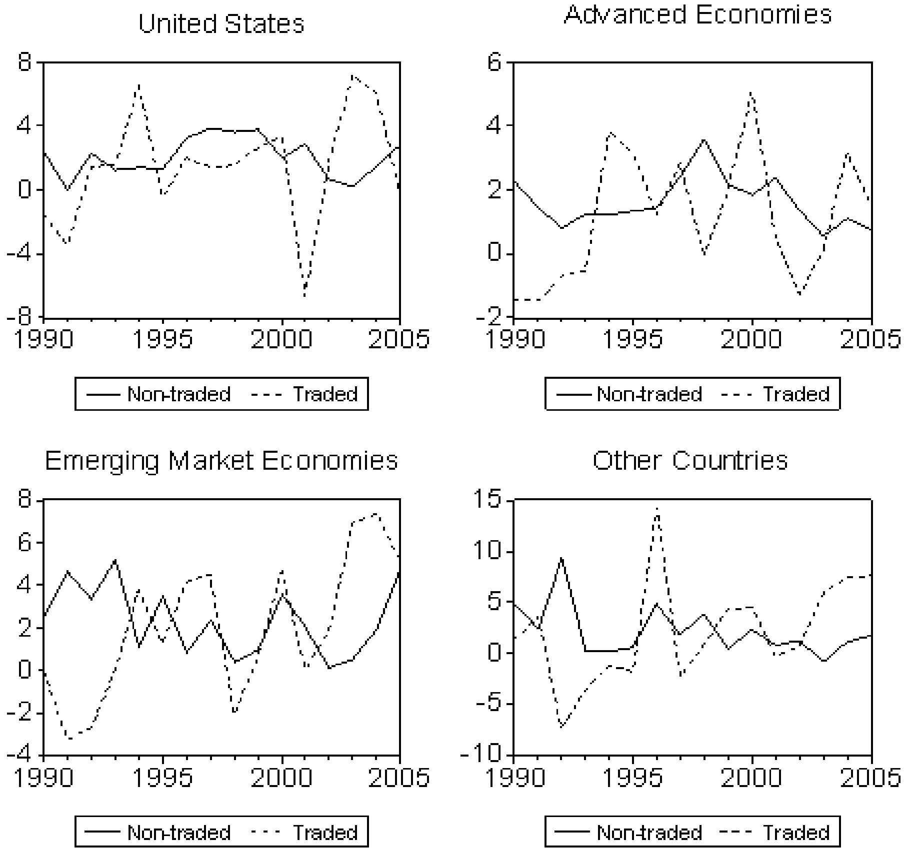

Figure 1.1 Annual Productivity Growth in Traded and Non-traded Sectors (%)

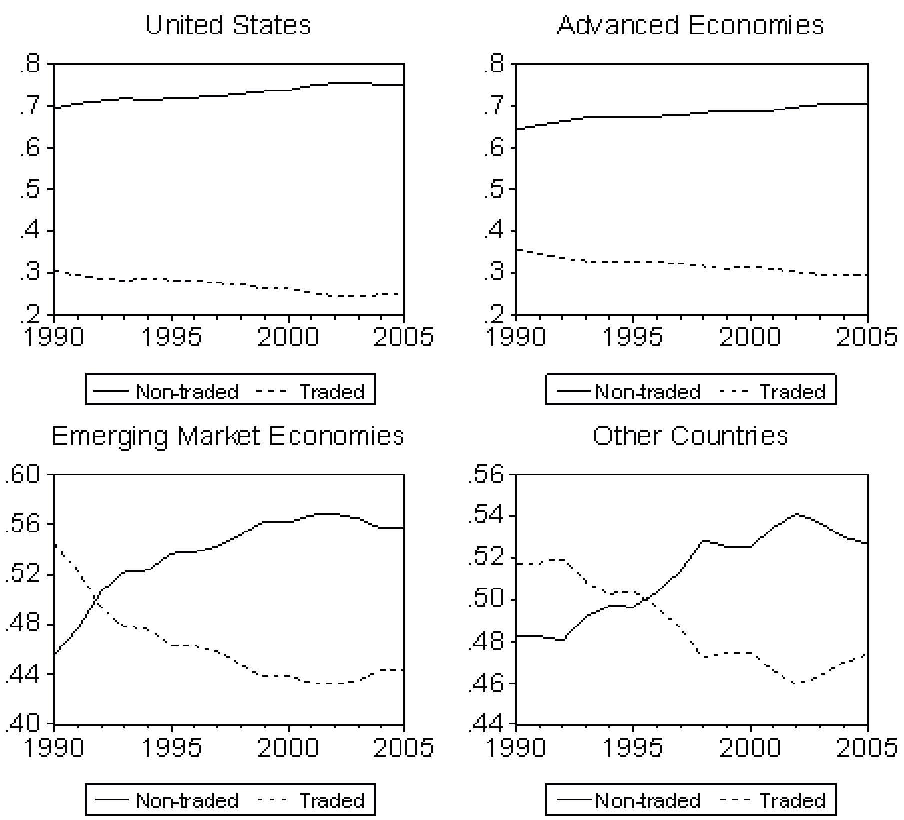

Figure 1.2 Share of Traded and Non-Traded Sectors in Gross Value Added

Table 1. Data Series & Sources

Series	*Source*
GDP (constant price, local currency (lc))	World Bank WDI 2007
GDP (current price, lc)	"
GDP per capita (constant price, PPP-based)	"
GDP Deflator	"
Agriculture, Value Added (constant price, lc)	"
Agriculture, Value Added (current price, lc)	"
Industry, Value Added (constant price, lc)	"
Industry, Value Added (current price, lc)	"
Services, Value Added (constant price, lc)	"
Services, Value Added (current price, lc)	"
Value Added series for the United States	Bureau of Economic Analysis
Employment in Agriculture (% of total employment)	World Bank WDI 2007
Employment in Industry (% of total employment)	"
Employment in Services (% of total employment)	"
Labor Force, total	"
Exchange Rate versus US Dollar (end period)	Bloomberg, IMF IFS
Exchange Rate versus euro / Deutsche Mark (end period)	"
Exchange Rate versus Japanese yen (end period)	"
Terms of Trade	World Bank WDI 2007
Net Foreign Assets	"
General Government Final Consumption Expenditure	"
Dummy variables for EMU; Currency Crises	Own Calculation
De facto exchange rate regime classification	Reinhart and Rogoff 2004

Table 2. Country Classifications

Advanced	*Emerging Market Economies*			*Other*
	Asia	CEE	Latin America	
Australia	China	Czech Republic	Argentina	Azerbaijan
Austria	Indonesia	Estonia	Brazil	Bangladesh
Belgium	Korea	Hungary	Chile	Barbados
Canada	Malaysia	Poland	Colombia	Bolivia
Denmark	Pakistan	Romania	Mexico	Costa Rica
Finland	Philippines	Slovak Republic	Peru	Dominican Republic
France	Singapore	Slovenia	Venezuela	Ecuador
Germany	Sri Lanka	Turkey		Egypt
Greece	Thailand			El Salvador
Iceland				Honduras
Italy				Kenya
Japan				Kyrgyz Republic
Luxembourg				Mongolia
Netherlands				Morocco
New Zealand				Panama
Norway				Paraguay
Portugal				Trinidad & Tobago
Spain				Uruguay
Sweden				Vietnam
Switzerland				
United Kingdom				

Table 3.1. De Facto Exchange Rate Regime Classifications for Advanced Economies

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Australia	O	O	O	O	O	O	O	O	O	O	O	O
Austria	X	X	X	X	X	X	X	X	X	O	O	O
Belgium	X	X	X	X	X	X	X	X	X	O	O	O
Canada	O	O	O	O	O	O	O	O	O	O	O	O
Denmark	X	X	X	X	X	X	X	X	X	X	X	X
Finland	X	X	X	X	X	X	X	X	X	O	O	O
France	X	X	X	X	X	X	X	X	X	O	O	O
Germany	na	na	O	O	O	O	O	O	O	O	O	O
Greece	X	X	X	X	X	X	X	X	X	X	X	O
Iceland	X	X	X	X	X	X	X	X	X	X	X	O
Italy	X	X	X	X	X	X	X	X	X	O	O	O
Japan	O	O	O	O	O	O	O	O	O	O	O	O
Luxembourg	X	X	X	X	X	X	X	X	X	O	O	O
Netherlands	X	X	X	X	X	X	X	X	X	O	O	O
New Zealand	O	O	O	O	O	O	O	O	O	O	O	O
Norway	O	O	O	O	O	O	O	O	O	O	O	O
Portugal	X	X	X	X	X	X	X	X	X	O	O	O
Spain	X	X	X	X	X	X	X	X	X	O	O	O
Sweden	X	X	X	O	O	O	O	O	O	O	O	O
Switzerland	na	na	O	O	O	O	O	O	O	O	O	O
United Kingdom	O	X	X	O	O	O	O	O	O	O	O	O

Note: *De facto* exchange rate regime classification based on Reinhart and Rogoff (2004). O denotes floating regime, defined as Reinhart and Rogoff's regimes 3-5; X denotes fixed regime, defined as Reinhart and Rogoff's regimes 1-2. For Canada, we classify the exchange rate regime as floating, replacing the fixed regime classification of Reinhart and Rogoff.

Table 3.2. De Facto Exchange Rate Regime Classifications for Emerging Market Economies

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Argentina	na	na	X	X	X	X	X	X	X	X	X	X
Brazil	na	na	na	na	na	na	X	X	X	O	O	O
Chile	O	O	O	O	O	O	O	O	O	O	O	O
China	O	O	O	X	X	X	X	X	X	X	X	X
Colombia	O	O	O	O	O	O	O	O	O	O	O	O
Czech Republic	na	na	na	na	X	X	O	O	O	O	O	O
Estonia	na	na	na	na	X	X	X	X	X	X	X	X
Hungary	na	na	na	O	X	X	X	X	X	O	O	O
Indonesia	X	X	X	X	X	X	X	X	O	O	O	O
Korea	X	X	X	X	X	X	X	X	O	O	O	O
Malaysia	X	X	X	X	X	X	X	X	O	X	X	X
Mexico	X	X	X	X	O	O	O	O	O	O	O	O
Pakistan	X	X	X	X	X	X	X	X	X	X	X	X
Peru	na	na	na	O	X	X	X	X	X	X	X	X
Philippines	X	X	X	O	O	O	X	X	O	O	O	O
Poland	na	na	na	na	na	O	O	O	O	O	O	O
Romania	na	na	na	na	na	O	O	O	O	O	O	O
Singapore	X	X	X	X	X	X	X	X	X	O	O	O
Slovak Republic	na	na	na	na	na	na	na	na	na	na	na	na
Slovenia	na	na	na	na	na	X	X	X	X	X	X	X
Sri Lanka	X	X	X	X	X	X	X	X	X	X	O	O
Thailand	X	X	X	X	X	X	X	O	O	O	O	O
Turkey	O	O	O	O	O	O	O	O	O	O	O	O
Venezuela	O	O	O	O	O	O	O	X	X	X	X	X

Note: *De facto* exchange rate regime classification based on Reinhart and Rogoff (2004). O denotes floating regime, defined as Reinhart and Rogoff's regimes 3-5; X denotes fixed regime, defined as Reinhart and Rogoff's regimes 1-2.

Table 3.3. De Facto Exchange Rate Regime Classifications for Other Economies

Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Azerbaijan	na	na	na	na	na	na	na	X	X	X	X	X
Bangladesh	na	na	na	na	na	na	na	na	na	na	na	na
Barbados	na	na	na	na	na	na	na	na	na	na	na	na
Bolivia	X	X	X	X	X	X	X	X	X	X	X	na
Costa Rica	O	X	X	X	X	X	X	X	X	X	X	X
Dominican Republic	na	na	O	X	X	X	X	X	X	X	X	X
Ecuador	O	O	O	O	O	O	O	X	O	O	X	X
Egypt	O	O	X	X	X	X	X	X	X	X	X	X
El Salvador	X	X	X	X	X	X	X	X	X	X	X	X
Honduras	O	O	O	O	O	O	O	O	O	X	X	X
Kyrgyz Republic	na	na	na	na	na	O	O	O	O	O	X	X
Mongolia	na	na	na	na	na	O	O	O	X	X	X	X
Morocco	X	X	X	X	X	X	X	X	X	X	X	X
Panama	X	X	X	X	X	X	X	X	X	X	X	X
Paraguay	O	X	X	X	X	X	X	X	X	O	O	O
Trinidad and Tobago	na	na	na	na	na	na	na	na	na	na	na	na
Uruguay	O	X	O	O	O	O	X	X	X	X	X	X
Vietnam	na	na	na	na	na	na	na	na	na	na	na	na

Note: *De facto* exchange rate regime classification based on Reinhart and Rogoff (2004). O denotes floating regime, defined as Reinhart and Rogoff's regimes 3-5; X denotes fixed regime, defined as Reinhart and Rogoff's regimes 1-2.

Table 4. Currency Crises in the Estimation Sample

Country	1990	1991	1994	1996	1998	2000	2002	2003	2004
Argentina							X		
Colombia			X						
Ecuador						X			
Egypt		X							
Honduras	X								
Indonesia					X				
Korea					X				
Malaysia					X				
Panama				X					

Notes: Table shows the currency crisis periods in the estimation sample, defined as the changes in real effective exchange rate against the US dollar that are larger than three country-specific standard errors of the real exchange rate.

Table 5. Descriptive Statistics

Sample 1990-2004, log difference		
United States	Mean	Std. Dev.
Productivity Agriculture	0.0259	0.2203
Productivity Industry	0.0133	0.0311
Productivity Services	0.0205	0.0123
Advanced	Mean	Std. Dev.
RER	−0.0035	0.1057
Productivity Agriculture	−0.0095	0.1351
Productivity Industry	0.0106	0.0513
Productivity Services	0.0160	0.0253
EME	Mean	Std. Dev.
RER	−0.0121	0.1174
Productivity Agriculture	−0.0176	0.2845
Productivity Industry	0.0259	0.0923
Productivity Services	0.0201	0.0688
Other countries	Mean	Std. Dev.
RER	0.0156	0.1373
Productivity Agriculture	−0.0349	0.3144
Productivity Industry	0.0287	0.1395
Productivity Services	0.0053	0.0943

Table 6. Estimation Using Industry Productivity Proxy

	All	Advanced	EME	Other
RER(-1)	0.9480***	0.7389***	0.9224***	0.9922***
	(0.0302)	(0.0666)	(0.0302)	(0.0135)
Industry	0.0454	−0.0370	−0.2153**	0.1273
	(0.0885)	(0.0892)	(0.0913)	(0.1101)
Industry(-1)	0.0105	0.020	0.2632***	−0.0818
	(0.0853)	(0.0836)	(0.0756)	(0.1151)
Crisis	0.3864***	*na*	0.3775***	0.3985***
	(0.1284)		(0.1877)	(0.1646)
EMU	0.0182	0.0250*	*na*	*na*
	(0.0129)	(0.0148)		
Constant	0.2068	1.1837***	0.2975**	0.0207
	(0.1379)	(0.3070)	(0.1448)	(0.0586)
Observations	890	320	333	237
Number of countries	63	21	24	18
Number of instruments	123	115	118	120
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0000	0.0005	0.0007	0.0708
AR2 test p-value	0.0550	0.9873	0.1132	0.2902

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Industry is real value-added per employee in this sector. Productivity expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 7.1. Estimation Using Sector Productivity Proxies

	All			
RER(-1)	0.9510*** (0.0289)	0.9731*** (0.0213)	0.9480*** (0.0302)	0.9689*** (0.0252)
Agriculture	0.0112 (0.0300)	−0.0215 (0.0291)		
Agriculture(-1)	0.0049 (0.0258)	0.0237 (0.0259)		
Industry	0.0098 (0.0765)		0.0454 (0.0885)	
Industry(-1)	0.0406 (0.0753)		0.0105 (0.0853)	
Services	0.2424** (0.1175)			0.2588* (0.1383)
Services(-1)	−0.1878 (0.1148)			−0.2325* (0.1377)
Crisis	0.3566*** (0.1219)	0.3999*** (0.1286)	0.3864*** (0.1284)	0.3640*** (0.1216)
EMU	0.0166 (0.0113)	0.0183* (0.0099)	0.0182 (0.0129)	0.0200** (0.0101)
Constant	0.1687 (0.1348)	0.0821 (0.1002)	0.2068 (0.1379)	0.0974 (0.1176)
Observations	886	886	890	890
Number of countries	63	63	63	63
Number of instruments	244	123	123	123
Hansen test p-value	0.99	0.98	0.99	0.99
AR1 test p-value	0.0000	0.0000	0.0000	0.0000
AR2 test p-value	0.037	0.0486	0.055	0.049

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 7.2. Estimation Using Sector Productivity Proxies

	Advanced			
RER(-1)	0.7633*** (0.0464)	0.7256*** (0.0659)	0.7389*** (0.0666)	0.6940*** (0.0557)
Agriculture	−0.0749*** (0.0328)	−0.1271*** (0.0376)		
Agriculture(-1)	0.0622** (0.0291)	0.1007*** (0.0275)		
Industry	−0.0118 (0.1006)		−0.037 (0.1235)	
Industry(-1)	−0.0001 (0.0877)		0.020 (0.0836)	
Services	0.0371 (0.2343)			0.4823* (0.2565)
Services(-1)	0.0688 (0.2032)			−0.3012 (0.2163)
Crisis	*na*	*na*	*na*	*na*
EMU	0.0201 (0.0139)	0.0254 (0.0161)	0.0250* (0.0148)	0.0273* (0.0163)
Constant	1.0882*** (0.2155)	1.2843*** (0.3133)	1.1837*** (0.3070)	1.3753*** (0.2616)
Observations	320	320	320	320
Number of countries	21	21	21	21
Number of instruments	222	115	115	115
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0003	0.0002	0.0005	0.0002
AR2 test p-value	0.9984	0.9875	0.9873	0.8262

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 7.3. Estimation Using Sector Productivity Proxies

	EME			
RER(-1)	0.8861*** (0.0486)	0.9583*** (0.0286)	0.9224*** (0.0302)	0.9288*** (0.0411)
Agriculture	−0.0072 (0.0151)	−0.006 (0.0179)		
Agriculture(-1)	0.0177 (0.0189)	0.0167 (0.0190)		
Industry	−0.1199 (0.0826)		−0.2153** (0.0913)	
Industry(-1)	0.1333* (0.0697)		0.2632*** (0.0756)	
Services	0.4845*** (0.1544)			0.5032*** (0.1480)
Services(-1)	−0.3974*** (0.1137)			−0.4582*** (0.1282)
Crisis	0.2802* (0.1583)	0.3789* (0.1948)	0.3775** (0.1877)	0.2957* (0.1712)
EMU	*na*	*na*	*na*	*na*
Constant	0.4485** (0.2247)	0.1164 (0.1371)	0.2975** (0.1448)	0.2675 (0.1916)
Observations	332	332	332	332
Number of countries	24	24	24	24
Number of instruments	232	118	118	118
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0008	0.0008	0.0007	0.0009
AR2 test p-value	0.0926	0.1003	0.1132	0.1090

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 8.1. Estimation Using Sector Productivity Proxies

	EME Asia			
RER(-1)	0.6491*** (0.0864)	0.8142*** (0.0542)	0.7636*** (0.0615)	0.6934*** (0.0835)
Agriculture	0.0427 (0.0300)	−0.0148 (0.0417)		
Agriculture(-1)	0.0088 (0.0442)	0.0408 (0.0292)		
Industry	−0.0331 (0.0953)		0.0607 (0.0941)	
Industry(-1)	0.0427 (0.0656)		0.006 (0.0550)	
Services	0.4641*** (0.1380)			0.4402*** (0.1533)
Services(-1)	−0.3439*** (0.1208)			−0.3675*** (0.1279)
Crisis	0.2803*** (0.0869)	0.3220*** (0.1171)	0.3382*** (0.1206)	0.2960*** (0.0951)
Constant	1.6240*** (0.3938)	0.8669*** (0.2352)	1.1497*** (0.2963)	1.4757*** (0.3993)
Observations	134	134	135	135
Number of countries	9	9	9	9
Number of instruments	128	104	105	105
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0128	0.0318	0.0243	0.0143
AR2 test p-value	0.3996	0.4185	0.4309	0.4206

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 8.2. Estimation Using Sector Productivity Proxies

EME Latin America

RER(-1)	0.9746*** (0.0236)	0.9403*** (0.0244)	0.9376*** (0.0289)	0.9755*** (0.091)
Agriculture	0.0157 (0.0175)	−0.0029 (0.0179)		
Agriculture(-1)	−0.0148 (0.0145)	0.0020 (0.0171)		
Industry	−0.1199 (0.1758)		−0.2867** (0.1211)	
Industry(-1)	0.1520 (0.1544)		0.3244** (0.1405)	
Services	0.5201* (0.2890)			0.5553** (0.2583)
Services(-1)	−0.5104*** (0.1910)			−0.5534*** (0.1694)
Crisis	0.1675 (0.2753)	0.2469 (0.3230)	0.2446 (0.3016)	0.1659 (0.2709)
Constant	0.0417 (0.1221)	0.2109 (0.1319)	0.2218 (0.1406)	0.0407 (0.0923)
Observations	98	98	98	98
Number of countries	7	7	7	7
Number of instruments	98	94	94	94
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0217	0.0263	0.0231	0.0261
AR2 test p-value	0.8261	0.4235	0.9234	0.5008

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 8.3. Estimation Using Sector Productivity Proxies

EME Central and Eastern Europe				
RER(-1)	0.6802*** (0.1148)	0.7660*** (0.0930)	0.7818*** (0.0973)	0.6837*** (0.1165)
Agriculture	0.0167 (0.0631)	0.0382 (0.0628)		
Agriculture(-1)	−0.0347 (0.0565)	−0.0517 (0.0672)		
Industry	0.0363 (0.1500)		−0.0652 (0.1410)	
Industry(-1)	−0.0924 (0.1327)		0.0372 (0.1131)	
Services	0.6644*** (0.2482)			0.6633*** (0.1946)
Services(-1)	−0.4947** (0.2493)			−0.4932*** (0.1772)
Crisis	*na*	*na*	*na*	*na*
Constant	1.3685** (0.5406)	0.9672** (0.4328)	0.8782** (0.4442)	1.3427** (0.5334)
Observations	100	100	100	100
Number of countries	8	8	8	8
Number of instruments	100	94	93	93
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0573	0.0630	0.0647	0.0875
AR2 test p-value	0.3852	0.7095	0.5903	0.5036

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 9. Controlling for Exchange Rate Regime Effects

	Floating		Fixed	
	All	EME	All	EME
RER(-1)	0.8201*** (0.1209)	0.7323*** (0.1236)	1.0088*** (0.0424)	0.8096*** (0.1273)
Agriculture	0.1250 (0.0929)	0.0728*** (0.0246)	0.0559 (0.0390)	0.0023 (0.0186)
Agriculture(-1)	−0.1005 (0.0803)	−0.0762 (0.0523)	−0.0513 (0.0346)	0.0303 (0.0235)
Industry	−0.0323 (0.1538)	−0.1106 (0.1504)	0.0448 (0.0870)	−0.1627** (0.0730)
Industry(-1)	0.0552 (0.0909)	0.1073 (0.1132)	0.0329 (0.0761)	0.1357* (0.0772)
Services	0.6597** (0.2949)	0.9629*** (0.2058)	0.2265 (0.1529)	0.0996 (0.1700)
Services(-1)	−0.6383* (0.3693)	−0.8026*** (0.2594)	−0.2591* (0.1541)	−0.1025 (0.1486)
Crisis	0.2322** (0.1174)	0.1222 (0.1205)	0.3682** (0.1719)	0.2658*** (0.0336)
EMU	0.0871*** (0.0246)	*na*	*na*	*na*
Constant	0.8891 (0.5779)	1.2925** (0.6160)	−0.0165 (0.2128)	0.8958 (0.5904)
Observations	274	108	360	132
Number of countries	48	19	46	18
Number of instruments	183	119	182	132
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0018	0.0083	0.0153	0.0244
AR2 test p-value	0.3384	0.2502	0.0415	0.5807

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the US. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Exchange rate regimes determined according to the regime definitions of Reinhardt and Rogoff (2004), except for Canada, in which case floating regime is used instead of fixed regime.

Table 10.1. Estimation Using Sector Productivity Proxies (relative to Germany)

	All			
RER(-1)	0.9625*** (0.0242)	0.9775*** (0.0176)	0.9553*** (0.0277)	0.9783*** (0.0221)
Agriculture	0.0757*** (0.0263)	0.0463*** (0.0179)		
Agriculture(-1)	−0.0626*** (0.0236)	−0.0369** (0.0151)		
Industry	0.0734 (0.0810)		0.0180 (0.0906)	
Industry(-1)	−0.0256 (0.0760)		0.0440 (0.0858)	
Services	0.3969*** (0.1248)			0.3202* (0.1859)
Services(-1)	−0.3555*** (0.1241)			−0.2911 (0.1956)
Crisis	0.3021*** (0.1466)	0.3723*** (0.1618)	0.3596*** (0.1558)	0.3209*** (0.1439)
EMU	0.0133 (0.0114)	0.0185* (0.0104)	0.0180 (0.0130)	0.0195** (0.0098)
Constant	0.1028 (0.1087)	0.0179 (0.0811)	0.1294 (0.1233)	0.0254 (0.0996)
Observations	795	795	797	797
Number of countries	63	63	63	63
Number of instruments	213	110	110	110
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0000	0.0000	0.0000	0.0000
AR2 test p-value	0.0481	0.0667	0.0633	0.0464

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to Germany. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 10.2. Estimation Using Sector Productivity Proxies (relative to Japan)

	All			
RER(-1)	0.9623*** (0.0236)	0.9791*** (0.0164)	0.9619*** (0.0230)	0.9814*** (0.0184)
Agriculture	0.0225 (0.0304)	−0.0043 (0.0236)		
Agriculture(-1)	−0.0068 (0.0262)	0.0113 (0.0215)		
Industry	0.0060 (0.0812)		0.0664 (0.0929)	
Industry(-1)	0.0407 (0.0777)		−0.0143 (0.0877)	
Services	0.2621** (0.1218)			0.2505* (0.1396)
Services(-1)	−0.2115* (0.1166)			−0.2263 (0.1381)
Crisis	0.3524*** (0.1226)	0.3987*** (0.1297)	0.3873*** (0.1290)	0.3627*** (0.1221)
EMU	−0.0031 (0.0114)	0.0008 (0.0110)	0.0008 (0.0132)	0.0003 (0.0108)
Constant	0.1313 (0.1006)	0.0524 (0.0693)	0.1375 (0.0953)	0.0425 (0.0782)
Observations	850	850	853	853
Number of countries	63	63	63	63
Number of instruments	226	115	115	115
Hansen test p-value	0.99	0.98	0.99	0.99
AR1 test p-value	0.0000	0.0000	0.0000	0.0000
AR2 test p-value	0.0290	0.0381	0.0432	0.0378

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to Japan. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table. Hansen test p-value is the p-value for a test of over-identifying restrictions under the null hypothesis of instrument validity. AR1 and AR2 test p-values are the p-values for the test for first- and second-order serial correlation in the first-differenced residuals under the null hypothesis of no serial correlation.

Table 11. Estimation Using Other Control Variables

	All			
RER(-1)	0.9581***	0.9514***	0.9442***	0.9440***
	(0.0422)	(0.0344)	(0.0353)	(0.0305)
Agriculture	0.0340	0.0105	0.0305	0.0114
	(0.0244)	(0.0307)	(0.0225)	(0.0282)
Agriculture(-1)	−0.0176	0.0042	−0.0070	0.0001
	(0.0200)	(0.0279)	(0.0189)	(0.0235)
Industry	−0.0028	−0.0657	0.0087	−0.0141
	(0.1027)	(0.0905)	(0.0757)	(0.0665)
Industry(-1)	0.1113	0.1339*	0.0727	0.0566
	(0.0704)	(0.0803)	(0.0732)	(0.0647)
Services	0.3439**	0.3432**	0.2884**	0.2568***
	(0.1363)	(0.1461)	(0.1189)	(0.1146)
Services(-1)	−0.3179**	−0.2989**	−0.2228*	−0.2000*
	(0.1449)	(0.1417)	(0.1181)	(0.1119)
TOT	−0.0329	−0.0344		
	(0.0349)	(0.0491)		
NFA	0.0093		0.0017	
	(0.0064)		(0.0061)	
GovSpend	0.0316			0.0404
	(0.0395)			(0.0294)
Crisis	0.3014**	0.3434***	0.2856**	0.3622**
	(0.1273)	(0.1195)	(0.1241)	(0.1240)
EMU	0.0206	0.0115	0.0309*	0.0186
	(0.0176)	(0.0104)	(0.0175)	(0.0115)
Constant	0.2926	0.3347	0.1928	0.2029
	(0.2846)	(0.3456)	(0.1634)	(0.1442)
Observations	581	710	742	886
Number of countries	49	49	63	63
Number of instruments	383	278	304	286
Hansen test p-value	0.99	0.99	0.99	0.99
AR1 test p-value	0.0003	0.0000	0.0002	0.0000
AR2 test p-value	0.0765	0.0597	0.0392	0.0405

Notes: Table shows the results of a Blundell-Bond (1998) dynamic panel GMM estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. TOT stands for terms-of-trade, NFA stands for net foreign assets to GDP ratio, and GovSpend for General Government Final Consumption Expenditure to GDP ratio.

Table 12.1. OLS Estimation Using Sector Productivity Proxies

	All			
RER(-1)	0.9175***	0.9315***	0.9270***	0.9256***
	(0.0259)	(0.0255)	(0.0258)	(0.0259)
Agriculture	0.0233	−0.0075		
	(0.0157)	(0.0119)		
Agriculture(-1)	−0.0085	0.0129		
	(0.0157)	(0.0117)		
Industry	0.0109		−0.0009	
	(0.0476)		(0.0418)	
Industry(-1)	0.0464		0.0542	
	(0.0493)		(0.0441)	
Services	0.3225***			0.2953***
	(0.0939)			(0.0895)
Services(-1)	−0.2567***			−0.2420***
	(0.0943)			(0.0886)
Crisis	0.3847***	0.4166***	0.4170***	0.3888***
	(0.1284)	(0.1337)	(0.1331)	(0.1294)
EMU	0.0022	−0.0002	−0.0044	0.0016
	(0.0135)	(0.0132)	(0.0134)	(0.0130)
Constant	0.3293***	0.2776**	0.3094**	0.3036***
	(0.1217)	(0.1210)	(0.1208)	(0.1218)
Observations	886	886	890	890
Number of countries	63	63	63	63
R-squared	0.87	0.86	0.87	0.87
Root MSE	0.1003	0.1027	0.1021	0.1008

Notes: Table shows the results of dynamic pooled panel OLS estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table.

Table 12.2. Fixed Effects Estimation Using Sector Productivity Proxies

	All			
Agriculture	0.0649	0.0442		
	(0.0399)	(0.0320)		
Agriculture(-1)	0.0412	0.0055		
	(0.0380)	(0.0282)		
Industry	−0.0271		−0.0328	
	(0.1102)		(0.1080)	
Industry(-1)	0.2218**		0.1921*	
	(0.1124)		(0.1095)	
Services	0.3463*			0.3310*
	(0.1949)			(0.1829)
Services(-1)	0.1180			0.0516
	(0.1870)			(0.1703)
Crisis	0.4755**	0.5208***	0.5215**	0.4895**
	(0.2327)	(0.2507)	(0.2475)	(0.2449)
EMU	0.0659***	0.0453*	0.0270	0.0507*
	(0.0247)	(0.0264)	(0.0280	(0.0266)
Constant	4.5425***	4.6288***	4.6985***	4.6423***
	(0.0394)	(0.0446)	(0.0489)	(0.0450)
Observations	889	889	893	893
Number of countries	63	63	63	63
R-squared	0.21	0.13	0.13	0.16
Root MSE	0.2491	0.2603	0.2595	0.2549

Notes: Table shows results of a fixed effects panel estimation. Robust standard errors reported in parentheses. *,**,*** denote significance at the 10%, 5% and 1% levels, respectively. RER is the real exchange rate versus the US dollar. Agriculture, Industry and Services are real value-added per employee in each of these three sectors. All productivity series expressed relative to the United States. CRISIS and EMU are dummies to proxy for currency crises and the impact of European Economic & Monetary Union. All series except dummy variables are in log levels. Estimates for time dummies are omitted from the table.

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