Fordham University
Department of Economics
Discussion Paper Series

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Discussion Paper No: 2011-04
July 2011

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July 18, 2011

Abstract

Maintaining a weak real exchange rate is a widely emulated growth strategy, in part because of the success of Asian exporters, most recently China. Simulations of a simple two-sector open economy growth model based on Matsuyama (1992) suggest that a weaker real exchange rate can lead to a "growth surge", as workers move into traded goods industries with more "learning by doing" and exit non-traded goods sectors with slower productivity growth. Using the updated total factor productivity (TFP) estimates from Bosworth and Collins (2003), panel estimates for 58 countries reveal the anticipated non-linear relationship between the real exchange rate and TFP growth: real currency depreciation raises TFP and GDP growth up to a point. Manufacturing exports appear to be one channel via which the real exchange rate affects TFP growth. Fears that a weaker real exchange rate might reduce investment and productivity growth by making imported equipment more expensive are not supported.

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Keywords: economic growth, total factor productivity growth, exchange rate policy

JEL Classification: O14, O41, O47 and O57

1 Introduction

Maintaining a weak real exchange rate (RER) has become a widely recommended growth strategy, partly due to the success of Asian exporters. Rodrik (2010) argues that "poor nations" can replicate the "essentials of the Chinese model" by actively using "exchange rates... to stimulate industrialization and growth". Johnson, Ostry and Subramanian (2006) argue that exchange rate policy is a "lever for growth" even in countries with relatively weak institutions. This paper explores how a weak real exchange rate (RER) stimulates economic growth, especially surges in productivity growth. Simulations using a model similar to Matsuyama's (1992) two-sector open economy growth model show that a combination of "learning by doing" in the traded goods sector and a policy lever, such as the RER, which moves workers into traded goods production faster, can lead to a surge in total factor productivity (TFP) growth. Eventually diminishing returns raise wages in the non-traded goods sector and growth slows.

Panel estimates for 58 countries support the non-linear relationship between the real exchange rate and GDP growth anticipated by the model. Moreover, dynamic panel estimation with a parsimonious use of instruments suggests that causality runs from the real exchange rate to productivity growth.[1] Our findings suggest that a 10% real depreciation of

[1] The Balassa-Samuelson effect posits reverse causality: faster productivity growth in the traded goods sector leads to long run RER appreciation. A weaker real exchange rate creates a surge in TFP and GDP growth which over time raises wages in the non-traded sector, leading to an appreciation of the real exchange rate. In the scenario explored by this paper the government attempts to counteract the effect of faster productivity growth in the traded goods sector using policy intervention to slow the RER appreciation.

the exchange rate leads to about 0.2% increase in the average annual TFP growth rate. If TFP growth starts at 1.5%, a 10% real depreciation can raise productivity growth to 1.7%. However, our dynamic panel estimates show that the impact can be twice as large, in the range of 0.3% to 0.5%. These results are of interest because Krugman (1994) and Young (1995) questioned how miraculous Asian growth was in the 1980s as rapid factor accumulation accounted for most of the rise in per capita incomes. However, since 1990 a number of Asian countries, notably China, have enjoyed rapid TFP growth. If China's currency is currently undervalued by 20-30%, as some argue, then fully a third of China's 3% TFP growth can be attributed to its exchange rate policy.[2]

We find some evidence that traded goods production is a key driver of overall productivity growth: holding manufacturing activity constant greatly reduces the effects of the exchange rate policy. Rodrik (2008) finds that weaker real exchange rates are associated with faster per capita GDP growth but his growth drivers are weak institutions and imperfect markets not learning by doing in traded goods production. He does not examine the effects of the real exchange rate on TFP growth, the main focus of this paper.

Kose, Prasad and Terrones (2009) explore the links between financial openness and TFP growth. Using their own TFP estimates over the period 1966-2005, they find that capital account liberalization accelerates TFP growth. To the extent capital inflows also result in RER appreciation, capital account liberalization might lead to a negative association between RER depreciation and TFP growth, but this correlation is not evident in our data.

The next section reviews the literature on exchange rates and growth. Section 3 presents

Both effects are evident in China today: rapid growth of tradable output driving a large trade surplus, but rising real wages leading to a drop in China's PPP to market exchange rate ratio (which fell sharply with the release of the new 2005 PPP GDP estimates).

[2]Estimates of China's TFP growth vary; 3% annually is in line with estimates by Bosworth and Collins (2008).

a simple version of the Matsuyama (1992) model modified to replace agriculture and industry with traded and non-traded goods. Finally, Section 4 presents panel data evidence on the relationship between real exchange rate depreciation and total factor productivity growth.

2 Real Exchange Rates and Productivity Growth

Initially productivity growth was considered central to the Asian growth miracle. In "Making a Miracle", Lucas (1993) stays "sharply focused on neoclassical theories that view the growth miracles as productivity miracles. What happened over the last 30 years that enabled the typical Korean or overseas Chinese worker to produce 6 times the goods and services he could produce in 1960?" However, Young's (1995) "Tyranny of Numbers" growth accounting seemed to show the opposite: high Asian growth rates were almost all factor accumulation; productivity growth was unusually low, leading Krugman (1994) to declare the Asian growth miracle "a myth". China and India appear to be more conventional Asian miracles, however, as they have recently had both rapid TFP and economic growth. Bosworth and Collins (2008) also find that sectoral labor shifts accounted for about 1.2% of per capita growth in both countries, in line with the simulations discussed in the next section.

Though relatively few papers focus on TFP growth, there is a considerable literature linking real exchange rates and per capita GDP growth. Dollar (1992) uses PPP based real exchange rate estimates to show that overvaluation harms growth, while Razin and Collins (1997) and Aguirre and Calderon (2006) find that large over- and under-valuation hurt growth, while modest undervaluation enhances growth. Similarly, Hausmann, Pritchett and Rodrik (2005) demonstrate that rapid growth accelerations are often correlated with real exchange rate depreciations. Rodrik (2008) finds that the growth acceleration takes place, on average, after ten years of steady increase in undervaluation in developing countries.[3] Rodrik argues that a weak real exchange rate compensates for institutional weaknesses and market failures (e.g. knowledge spillovers, credit market imperfections, etc.) which lead to underinvestment in the traded goods sector in developing countries. An undervalued exchange rate raises the profitability of traded goods production and generates faster growth.[4]

Most papers on exchange rate policy focus on per capita GDP growth or investment. An exception is Kose, Prasad and Terrones (2009): using their own TFP growth estimates, they find mixed evidence regarding the impact of financial liberalization on productivity growth. *De jure* liberalization seems to raise TFP growth but *de facto* liberalization (capital inflows) does not; instead, FDI and portfolio equity flows increase TFP growth but external debt does not. To the extent that capital inflows lead to exchange rate appreciation (unless they are sterilized), their findings suggest that exchange rate appreciation might be positively correlated with economic growth.

3 Open Economy Growth with Traded and Non-traded Goods Sectors

Matsuyama's (1992) two-sector open economy model has "learning by doing" in manufacturing but not agriculture. Our use of Matsuyama's model is similar to that of Rodriguez

[3] In Asia, Rodrik (2008) argues that currencies were undervalued by 20%, on average, before the growth spurt and remained undervalued as growth accelerated. In addition, Rodrik (2008) provides panel data evidence that undervaluation leads to an increase in the relative size of the traded goods sector and that the increase in the size of the traded goods sector, caused by undervaluation, promotes economic growth.

[4] Another strand of the literature focuses on real exchange rate volatility. Exchange rate volatility may discourage trade and investment which are important drivers of growth. However, the empirical evidence of the relationship between real exchange rate volatility and growth is inconclusive. See Eichengreen (2008) for a review of the relevant studies.

and Rodrik's (2001): they study how an import tariff can accelerate growth by increasing the share the work force in industry. Similarly, a weaker real exchange rate can raise wages in the traded goods production leading to a more rapid shift of workers out of the traditional or non-traded goods sector (where there is less learning by doing). An important difference between tariffs and the real exchange rate is that the government does not have to decide which sector to protect; a weaker real exchange rate automatically benefits all exporters and import competing industries. Aizenman and Lee (2008) present a more elaborate model, in which the learning by doing externality assumed by Matsuyama (1992) may be linked either to production or investment. They argue that, if this externality happens to be linked to investment, undervaluation may decrease (not increase) productivity growth by raising the cost of imported investment goods.[5] We explore this argument empirically in the next section.

Whereas Matsuyama models agriculture and industry, we focus on employment shifts between a traded or manufacturing goods sector (T) and a non-traded goods sector (N). The real exchange rate is the relative price of traded goods. The RER, q_t, depends on the nominal exchange rate, e_t, the exogenous price of traded goods set in international markets, p_t^*, and the domestic price of non-traded goods, p_t^N:

$$q_t = \frac{e_t p_t^*}{p_t^N}. \tag{1}$$

Governments influence the real exchange rate by managing the nominal exchange, e_t, or by using monetary policy to influence the domestic price of non-traded goods, p_t^N.

Labor is the only mobile factor of production. The total labor supply is assumed to

[5] Aizenman and Lee (2008) also point out that there is no clear empirical evidence that supports an "aggregate investment" externality as opposed to an "aggregate production" externality.

be constant and set to one, $L = 1$. Assuming identical diminishing returns technologies, $0 < \alpha < 1$, and defining l_t as the share of the labor force in manufacturing, the production functions for traded and non-traded goods are

$$Q_t^T = A_t l_t^\alpha \tag{2}$$

$$Q_t^N = B(1 - l_t)^\alpha. \tag{3}$$

The key difference between the two sectors is the productivity level: B in the non-traded goods sector is assumed to be constant, whereas traded goods sector productivity A_t is subject to "learning by doing" in the tradition of Kenneth Arrow. Traded goods sector productivity increases with the level of output, Q_t^T, but is not affected by changes in non-traded output, Q_t^N.

Learning by doing is external to the individual firm but internal to the sector as a whole, so that manufacturing productivity evolves over time according to

$$\dot{A}_t = \delta Q_t^T, \tag{4}$$

in which $\delta > 0$ is the exogenous rate of learning by doing.

Competition and the mobility of labor between the two sectors equalize the marginal products of labor in the two sectors:

$$B(1 - l_t)^{\alpha - 1} = q_t A_t l_t^{\alpha - 1}, \tag{5}$$

in which q_t is the real exchange rate defined in Equation (1). The real exchange rate affects the allocation of labor between the two sectors: a weaker RER (a higher q_t) raises the marginal product of labor in the traded goods sector, increasing real wages in that sector until movement of labor out of the nontraded goods sector equalizes the marginal product of labor (real wage) economy wide.

Substituting (2) into (4) yields the growth rate of productivity in the traded goods sector as a function of the share of labor employed in that sector and the learning-by-doing externality:

$$\frac{\dot{A}_t}{A_t} = \delta l_t^{\alpha}. \tag{6}$$

Equation (5) implicitly defines l_t as a function of q_t, and differentiation ($\frac{\partial l_t}{\partial q_t} > 0$) shows that an increase in the domestic relative price of the traded good leads to an increase in the share of labor employed in the traded goods sector, which then raises productivity via Equation (6).

Total output, Y_t, in foreign prices is

$$Y_t = B(1 - l_t)^{\alpha} + A_t l_t^{\alpha} \tag{7}$$

The time derivative of Equation (7) and Equations (2), (4) and (5) yields the instantaneous rate of growth of output:

$$\frac{\dot{Y}_t}{Y_t} = (\lambda_t + \frac{\alpha(\lambda_t - l_t)}{1 - \alpha})\delta l_t^{\alpha}, \tag{8}$$

in which $\frac{Q_t^T}{Y_t} = \lambda_t$ represents the manufacturing share of output in foreign prices.

Since learning by doing in the traded goods sector is the only source of productivity growth over the longer term, overall (economy-wide) productivity growth depends only on the share of labor, l_t, in that sector. This implies a steady state overall TFP growth of

$$T\hat{F}P_t = \delta l_t^{1+\alpha}. \tag{9}$$

However, during the transition changing the RER changes the labor share l_t, so overall productivity growth also depends on the rate at which l_t changes over time (i.e. how fast changes in the RER, q_t, move labor out of the non-traded goods sector with fixed productivity level B into the dynamic traded goods sector). The instantaneous rate of growth of overall TFP is given by

$$\frac{T\dot{F}P_t}{TFP_t} = \frac{(A_t - B)\dot{l}_t + l_t \dot{A}_t}{l_t A_t + (1 - l_t)B}, \tag{10}$$

where $TFP_t = l_t A_t + (1 - l_t)B$.

The relationship between output growth, TFP growth and the RER described by Equations (8) and (10) is nonlinear as illustrated in Figure 1 using plausible parameters. The surge in TFP and GDP growth occurs because, initially, depreciation of the RER leads to rapid reallocation of labor into the traded goods sector, accelerating learning by doing. For this particular calibration of the model parameters overall productivity growth converges to about 3%, the rate observed in China today. Diminishing returns in the non-traded goods sector ($\alpha < 1$) eventually offset the weak RER driven growth enhancing effect of transfering workers to higher productivity in traded goods sector employment so growth settles to it's long run trend.

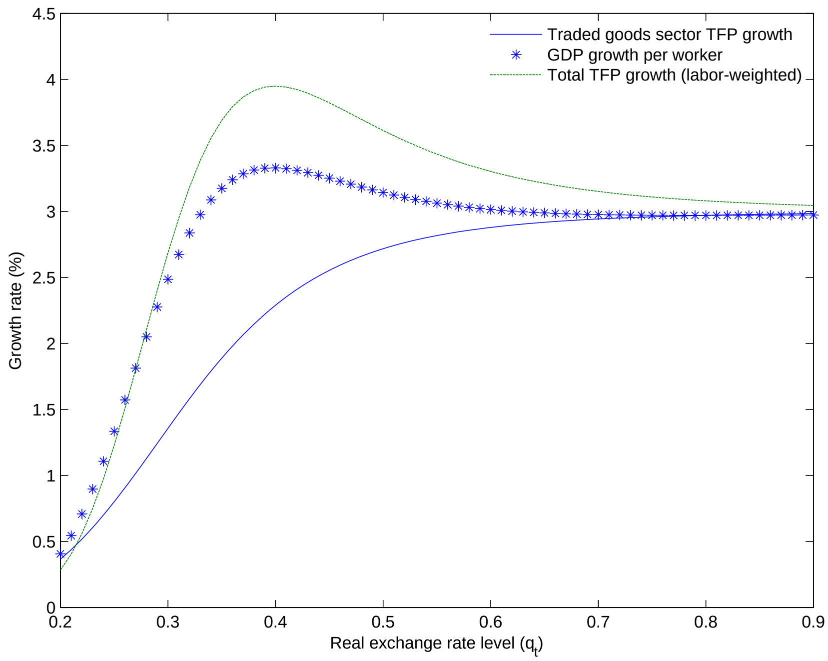

Figure 1: A real exchange rate driven shift of labor into traded goods creates a surge in TFP and GDP growth. (*Parameter values:* $\alpha = 0.8; \delta = 0.03; A_0 = 3; B = 1$)

4 Empirical Results

This section provides estimates of the impact of real exchange rate changes on TFP growth using a panel of 58 developing countries for the period 1975 - 2004. The TFP growth rates are from an updated version of the Bosworth and Collins (2003) dataset.[6] The data on real exchange rates is based on our own trade-weighted estimates as explained in the appendix.[7] The remaining variables are from the World Development Indicators (WDI) database (World Bank, 2010). Following standard practice five-year averages are used to capture long-term as opposed to transitory and business cycle fluctuations.

Table 1 reports regressions of TFP growth on the real effective exchange rate and several standard control variables. According to the country fixed effects panel data estimates reported in Column 1.1, 10% depreciation of the real exchange rate (i.e. an increase in the variable Log of RER) is associated with a 0.2% increase in the average annual TFP growth rate, confirming the predictions of the model. The control variables openness and secondary

[6] The Bosworth and Collins (2003) dataset includes 62 developing countries, we exclude four of these from our sample: Nigeria, Singapore and Taiwan due to lack of data (on government consumption, secondary school enrollment and trade-weighted exchange rates, respectively) and Nicaragua, which is an outlier due to a brush with hyperinflation. The countries included are Algeria, Argentina, Bangladesh, Bolivia, Brazil, Cameroon, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Cyprus, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Ethiopia, Ghana, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Iran, Islamic Rep., Israel, Jamaica, Jordan, Kenya, Korea, Rep., Madagascar, Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Mozambique, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela, RB, Zambia, Zimbabwe, Algeria, Argentina, Bangladesh, Bolivia, Brazil, Cameroon, Chile, China, Colombia, Costa Rica, Cote d'Ivoire, Cyprus, Dominican Republic, Ecuador, Egypt, Arab Rep., El Salvador, Ethiopia, Ghana, Guatemala, Guyana, Haiti, Honduras, India, Indonesia, Iran, Islamic Rep., Israel, Jamaica, Jordan, Kenya, Korea, Rep., Madagascar, Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Mozambique, Nicaragua, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Rwanda, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela, RB, Zambia, Zimbabwe.

[7] The real exchange rate data used in this paper are available at `http://www.fordham.edu/economics/mcleod/TradeWeightedRER.xlsx`. We have reproduced all regressions using the REER data from the World Bank WDI but the WDI only provides RER estimates for 29 countries. These estimates are available upon request from the authors.

school enrolment have a positive impact, whereas government consumption reduces TFP growth. Initial real PPP GDP per capita (defined as the real PPP GDP per capita in the first year of each five-year period) is a proxy for structural development and the coefficient on this variable shows that countries at a lower stage of development tend to have, on average, higher TFP growth rates (Column 1.3). The results are similar if the lagged real PPP GDP per capita is used (Column 1.4).[8]

Table 2 explores the interaction of trade and the RER and provides alternate estimates of the equations in Table 1. The first column of Table 2 reports the same regression as in Column 1.3 of Table 1. The equation reported in Column 2.2 includes the change in the share of manufactures exports in PPP GDP. A one-percent increase in the share of manufactures exports is associated with a 0.11% increase in the average TFP growth rate. The coefficient on the RER is no longer significant, pointing to interaction between the two variables. This result seems to suggest that the RER affects TFP growth through the change in manufactures exports. As a robustness check, Columns 2.3 and 2.4 report regressions based on the same specifications and estimated in first differences. The results are very similar to the levels equations.

Table 2 also presents dynamic panel estimates using the generalized method of moments (GMM) and various instruments. These estimates allow us to test the direction of causality between TFP growth and the RER. Recall that the Balassa - Samuelson effect implies causality running from exogenous rapid productivity growth in the traded goods sector to a real exchange rate appreciation driven by higher wages in both sectors. Columns 2.1 through 2.4 indicate a positive correlation between TFP growth and the RER, contrary to the correlation predicted by the Balassa - Samuelson effect. Columns 2.5-2.8 present four

[8]We prefer initial real PPP GDP per capita to lagged real PPP GDP per capita to economize on observations lost due to using one lag.

Table 1: **TFP growth and the real exchange rate, five-year averages (1975 - 2004)**

Dependent Variable:	TFP growth			
(Robust standard errors in parentheses)	1.1	1.2	1.3	1.4
Log of RER	0.02***	0.018***	0.022***	0.018***
	(0.007)	(0.007)	(0.005)	(0.006)
Openness		0.005	0.016***	0.011**
		(0.006)	(0.005)	(0.006)
Government consumption (share of GDP)		-0.18**	-0.20***	-0.19***
		(0.09)	(0.07)	(0.07)
Secondary school enrollment		0.001	0.04***	0.07***
		(0.01)	(0.02)	(0.02)
Log of initial real PPP GDP per capita			-0.047***	
			(0.012)	
Lagged log of real PPP GDP per capita				-0.055***
				(0.014)
Constant	-0.1***	-0.05	0.31***	0.36***
	(0.03)	(0.03)	(0.1)	(0.11)
Number of observations	334	312	310	267
Number of countries	58	58	58	58
R^2	0.04	0.06	0.18	0.21
Estimation method	Country fixed effects			

**** indicates statistical significance at the 1%; ** at the 5%; and * at the 10% level.*

Data sources: *The TFP estimates are from an updated version of estimates presented in Bosworth and Collins (2003) that end in 2003. All other variables are obtained from the World Development Indicators as downloaded in August 2009. Computation of trade-weighted RERs is described in the appendix. The estimates use five-year averages, so that T = 6: 75-79, 80-84, 85-89, 90-94, 95-99 and 00-04, except for TFP, which is the average of 2000-03. Openness is defined as the ratio of the sum of exports and imports to PPP GDP. Using international prices reduces the effect of exchange rate fluctuations on the trade shares. Initial real GDP per capita is the natural log of real PPP GDP per capita in the first year of each five-year period (following Prasad et al., 2006).*

estimates computed using the Arellano - Bond (1991) difference GMM and the Blundell - Bond (1998) system GMM estimator.

For the difference GMM estimates all variables are differenced and the first difference of the RER is instrumented by its own second or third (or both) lags in levels, one excluded exogenous instrument - the real interest rate in the US, and all exogenous variables included in the regression equation. For the system GMM estimates, the equation in levels and the equation in first differences are estimated as a system, with the RER level instrumented by the second and third lag of its first difference.[9] Similarly, the PPP GDP share of manufactures exports is instrumented either by its own lagged differences in Column 2.6 or by both lagged levels and differences in equation 2.8. An additional excluded exogenous instrument for each country's manufacturing export share is the total world manufacturing export share of world GDP. The dynamic GMM regressions include the logarithm of initial TFP growth, i.e. the TFP level in the first year of each five-year period.[10]

Longer lags of the endogenous variables turn out to be good exogenous instruments. The Hansen J test of the overidentifying restrictions indicates that the instruments as a group are exogenous (the Hansen J test is equivalent to the Sargan statistic if the errors are normally distributed). Tests for second-order autocorrelation in the differenced equation (which is equivalent to testing for first-order autocorrelation in the equation in levels) does not reject the null hypothesis of no autocorrelation.

[9] Limiting the number of lags used as instruments in the GMM regressions keeps the instrument count low and improves the performance of the Hansen J test for joint validity of those instruments. Using too many instruments can overfit the endogenous variables and bias the coefficient estimates (see Roodman 2007).

[10] Kose, Prasad and Terrones (2009) interpret this as convergence to a common technological frontier.

Table 2: **TFP growth and the real exchange rate, five-year averages (1975-2004)**

Dependent Variable:	TFP growth							
(Robust standard errors in parentheses)	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8
Log of RER	0.022***	0.013	0.016**	0.016	0.031**	0.028	0.054**	0.027
	(0.005)	(0.009)	(0.007)	(0.012)	(0.014)	(0.024)	(0.022)	(0.017)
Openness	0.016***	0.017**	0.016***	0.019**	0.018***	0.033***	0.007*	0.006
	(0.005)	(0.007)	(0.006)	(0.009)	(0.007)	(0.012)	(0.004)	(0.004)
Government consumption (share of GDP)	-0.20***	-0.23***	-0.29***	-0.25***	-0.31***	-0.32***	-0.07	-0.08
	(0.07)	(0.06)	(0.06)	(0.07)	(0.08)	(0.09)	(0.05)	(0.05)
Secondary school enrollment	0.04***	0.03**	-0.004	-0.005	0.02	-0.02	0.03**	0.03***
	(0.02)	(0.01)	(0.023)	(0.025)	(0.03)	(0.03)	(0.02)	(0.01)
Log of initial real PPP GDP per capita	-0.047***	-0.038***	-0.094***	-0.078***	-0.042	-0.005	-0.026***	-0.021***
	(0.012)	(0.01)	(0.014)	(0.013)	(0.032)	(0.040)	(0.007)	(0.006)
Manufactures exports		0.11**		0.11**		0.49**		0.23*
(Change in PPP GDP share)		(0.05)		(0.05)		(0.23)		(0.12)
Logarithm of initial TFP					-0.07*	-0.08	0.04**	0.03**
					(0.04)	(0.05)	(0.02)	(0.01)
Constant	0.31***	0.29***	0.01**	0.004			-0.04	0.04
	(0.1)	(0.08)	(0.003)	(0.003)			(0.1)	(0.06)
Number of observations	310	260	247	195	247	195	310	260
Number of countries	58	55	58	54	58	54	58	55
Number of instruments					26	30	14	42
AR2 test p-value					0.20	0.84	0.44	0.19
Hansen J statistic (robust) p-value					0.39	0.29	0.20	0.22
R^2	0.18	0.18	0.27	0.25				
Estimation method	Country fixed effects		First differences		Difference GMM 1/		System GMM 2/	

**** indicates statistical significance at the 1%; ** at the 5%; and * at the 10% level. 1/ Arellano - Bond (1991) difference GMM; 2/ Blundell - Bond (1998) system GMM, two-step estimation using the Stata program xtabond2 written by Roodman (2006).*

Data sources: *See data sources and notes in the footnote to Table 1. The sample used in regressions 2.2 and 2.4 excludes Sierra Leone, for which there are no data on manufacturing exports, and two outliers, the Dominican Republic and Ghana. Regression 2.4 also excludes Tanzania, for which there are not enough observations on manufacturing exports for first differences estimation. Initial TFP is the TFP level in the first year of each five-year period. World manufactures exports as a share of GDP is used as an excluded exogenous instrument in regressions 2.6 and 2.8 and the US real interest rate is used in regressions 2.5-2.8.*

The GMM estimates confirm the fixed effects and first difference regressions. We cannot reject the hypothesis that causality runs from the RER to TFP growth and from manufacturing exports to TFP growth, in line with the model discussed in Section 3. Controlling for possible endogeneity, the positive impact of RER depreciation on TFP growth is even stronger: a 10% real depreciation leads to an increase in average TFP growth of 0.3% - 0.5% (Columns 2.5 and 2.7). Raising the share of manufactures exports in PPP GDP by 1% leads to an increase in the average TFP growth of 0.2% - 0.5%. As in Regressions 2.2 and 2.4, in the GMM regressions including manufactures exports the coefficient on the RER is not statistically significant (Columns 2.6 and 2.8).

The model predicts a gradual decline in the impact of a weaker RER on TFP growth to the point that more depreciation leads to slower economy-wide TFP growth and slower output growth. Table 3 reports the results of country fixed effects and first differences panel regressions of TFP growth and real per capita PPP GDP growth on the RER, the RER squared and the same control variables as above. The coefficient on the RER is statistically significant and positive in all regressions, whereas the coefficient on the squared term is significant and negative, thus confirming the pattern predicted in Figure 1 above.

The nonlinear effect of the RER on TFP growth suggests that there is some level of the RER at which TFP growth stops increasing. Using the estimates shown in Columns 3.1 and 3.2, economy-wide TFP growth is fastest when the level of the RER is at 180 - 205. Similarly, the estimates reported as Columns 3.3 and 3.4 show that the GDP growth rate is maximized when the RER index is in the range 185 - 265 (at base year 2000).

Following Rodrik (2008), there is some evidence that the effect of the RER on TFP growth operates (at least partially) through its impact on the sectoral composition of output. Rodrik regresses the shares of industry and agriculture in GDP and in employment, respectively,

Table 3: **TFP growth and the real exchange rate - tests for non-linear relationship, five-year averages (1975 - 2004)**

Dependent Variable:	TFP growth		Real per capita GDP growth	
(Robust standard errors in parentheses)	3.1	3.2	3.3	3.4
Log of RER	0.24***	0.102**	0.29***	0.103**
	(0.08)	(0.048)	(0.1)	(0.041)
Log of RER Squared	-0.02***	-0.01*	-0.03***	-0.01*
	(0.01)	(0.006)	(0.01)	(0.005)
Openness	0.017***	-0.001	0.031***	0.015*
	(0.006)	(0.008)	(0.008)	(0.009)
Government consumption (share of GDP)	-0.19***	-0.39***	-0.24***	-0.38***
	(0.07)	(0.08)	(0.08)	(0.08)
Secondary school enrollment	0.03*	-0.04	0.027	-0.06**
	(0.02)	(0.03)	(0.019)	(0.03)
Log of initial real PPP GDP per capita	-0.046***		-0.054***	
	(0.013)		(0.012)	
Constant	-0.21	0.0	-0.23	0.002
	(0.21)	(0.003)	(0.26)	(0.003)
Number of observations	304	249	304	248
Number of countries	57	58	57	58
R^2	0.19	0.12	0.23	0.14
Estimation method1/	FE	FD	FE	FD
Growth maximizing RER	182	206	184	265

**** indicates statistical significance at the 1%; ** at the 5%; and * at the 10% level. 1/ FE is country fixed effects and FD are first differences that eliminate country fixed effects.*
Data sources: *See data sources in the footnote to Table 1. Log of initial real PPP GDP per capita is dropped from regressions 2.2 and 2.4 as a robustness test, becasue when differenced it becomes too similar to GDP growth.*

reporting four regressions on the RER and other independent variables. Table 4 reports four country fixed effects panel regressions in which the dependent variables are the value added of manufacturing, industry, agriculture or services in percent of GDP. The data are from the WDI and are averaged over five years. The explanatory variables are the RER and real PPP GDP per capita, the latter serving as a proxy for convergence. RER depreciation is associated with an increase in the manufacturing and industry shares of GDP[11] and a decrease (albeit not statistically significant in the latter case) in the agriculture and services shares of GDP. As expected given Engel's law, higher GDP per capita is associated with larger industrial and services sectors and smaller agricultural sector.

Table 4: **Sectoral shares of GDP and the real exchange rate, five-year averages (1975 - 2004)**

	Shares of GDP			
Dependent Variable:	Manufacturing	Industry	Agriculture	Services
(Robust standard errors in parentheses)	4.1	4.2	4.3	4.4
Log of RER	0.03***	0.06***	-0.03*	-0.03
	(0.01)	(0.01)	(0.02)	(0.02)
Log of real PPP GDP per capita	0.01	0.03*	-0.14***	0.10***
	(0.02)	(0.02)	(0.01)	(0.02)
Constant	-0.1	-0.24*	1.43***	-0.19
	(0.16)	(0.14)	(0.14)	(0.16)
Number of observations	295	298	298	298
Number of countries	55	55	55	55
R^2	0.08	0.19	0.47	0.21
Estimation method	Country fixed effects			

**** indicates statistical significance at the 1%; ** at the 5%; and * at the 10% level.*
Data sources: *See data sources in the footnote to Table 1.*

The results in Table 4 are similar to Rodrik's (2008): a weaker RER is associated with an increase in the share of industry and a smaller agricultural sector (columns 4.2 and 4.3).

[11]Manufacturing is a subset of the industrial sector.

Since both industrial and agricultural goods are tradable goods, the negative impact of the RER on agriculture is unexpected, as Rodrik notes as well. However, to the extent that the RER and TFP growth raise per capita income, Engel's law may dominate the effects of productivity growth in agriculture, leading to an overall decline in agriculture's GDP share despite productivity growth in that sector. Trade in agricultural commodities is also managed with extensive quotas and tariffs, so that trade barriers may thwart the opportunity for expanded exports driven by a more competitive exchange rate. Indeed, this is the argument of many less developed countries in the Doha Round.

Following Rodrik (2008), we also run a two-stage least squares regression of TFP growth on the manufacturing share of GDP and the logarithm of real per capital PPP GDP, in the first stage of which the manufacturing share of GDP is regressed on the logarithm of the RER.[12] The coefficient on the manufacturing share of GDP is significant at the 1% level and is equal to 0.7, indicating that the variation in the manufacturing share of GDP directly caused by the RER, controlling for real per capita GDP, is associated positively with TFP growth. This result shows that depreciation leads to manufacturing sector growth, which in turns leads to higher productivity growth.

Finally, we address the concern of Aizenman and Lee (2008) that a weak real exchange rate might slow productivity growth by reducing investment, via the higher cost of imported machinery and equipment. Table 5 reports Arellano-Bond difference and system GMM regressions, in which the dependent variable is the GDP share of domestic investment. In

[12]This regression was performed using the xtivreg2 program in Stata written by Schaffer (2007). The equation is exactly identified. The Angrist-Pischke (AP) first-stage chi-squared Wald statistic rejects the null hypothesis that the endogenous regressor, the manufacturing share in GDP, is unidentified. The first-stage F statistic (15.32) exceeds the rule of thumb, suggested by Staiger and Stock (1997), that the F statistic be larger than 10, which means that the IV specification does not suffer from weak identification. In addition, the Stock and Yogo (2005) weak identification test indicates that the maximum size distortion of a 5% Wald test is 15%.

addition to the logarithm of the RER, the regressions include a lagged dependent variable and three standard control variables: lagged real GDP growth, to capture the conventional accelerator effect; the change in the GDP share of domestic credit to the private sector, which is a proxy for the availability of capital; and a measure of uncertainty computed as the one-step ahead absolute forecast error of real GDP growth from a univariate autoregressive model of order one (AR1), estimated recursively for each country and averaged over the current and previous two years, as in Serven (1998). Lagged investment and domestic credit are treated as predetermined and endogenous, respectively, and are instrumented by up to three available lags of their levels in the difference GMM and of their levels and first differences in the system GMM, again limiting the instrument count.

The coefficient on the lagged dependent variable is positive, statistically significant and large in all regressions, pointing to considerable persistence in domestic investment. According to the results presented in Column 5.1, the real exchange rate is positively associated with domestic investment. In Column 5.2 the coefficients on domestic credit and lagged growth have the expected positive signs, whereas the coefficient on uncertainty is not statistically significant. The system GMM estimates are similar, although the coefficient on the real exchange rate is statistically significant only in the regression with control variables. Overall, the regression results reported in Table 5 suggest that, if anything, the relationship between real depreciation and domestic investment is positive.[13]

[13]Using the same dataset, Mileva (2011) provides some evidence that, for the countries with relatively underdeveloped financial markets, higher real exchange rate volatility reduces investment, as firms have limited access to instruments hedging against currency risk. The author concludes that both RER depreciation and, to a lesser extent, lower RER volatility can be associated with higher domestic investment in developing countries.

Table 5: **The real exchange rate and investment, five-year averages (1975 - 2004)**

Dependent Variable:	Domestic investment (share of GDP)			
(Robust standard errors in parentheses)	5.1	5.2	5.3	5.4
Log of RER	0.028**	0.028**	0.009	0.015*
	(0.013)	(0.014)	(0.008)	(0.009)
Uncertainty		0.22		0.06
		(0.22)		(0.13)
Domestic credit to private sector		0.09**		0.07**
(Change in GDP share)		(0.04)		(0.04)
Lagged real GDP growth		0.26**		0.22**
		(0.12)		(0.11)
Lagged domestic investment	0.85***	0.45***	0.84***	0.60***
(share of GDP)	(0.16)	(0.14)	(0.13)	(0.19)
Constant			0.01	-0.01
			(0.04)	(0.04)
Number of observations	209	205	266	263
Number of countries	56	56	57	57
Number of instruments	7	25	9	14
AR2 test p-value	0.18	0.65	0.15	0.92
Hansen J statistic (robust) p-value	0.69	0.20	0.90	0.89
Estimation method	Difference GMM 1/		System GMM 2/	

***** *indicates statistical significance at the 1%; ** at the 5%; and * at the 10% level. 1/ Arellano - Bond (1991) difference GMM; 2/ Blundell - Bond (1998) system GMM, two-step estimation using the Stata program xtabond2 written by Roodman (2006).*

Data sources: *See data sources in the footnote to Table 1. Uncertainty is computed as the one-step ahead absolute forecast error of real GDP growth from a univariate autoregressive model of order one (AR1), estimated recursively for each country and averaged over the current and previous two years, as in Serven (1998). The sample excludes Haiti, for which there are no data on investment.*

5 Conclusions

Using the well-known TFP estimates of Bosworth and Collin (2003, 2008) and real exchange rate estimates consistent with a traded-non-traded goods variation of Matsuyama's (1992) growth model, we find a robust and causal relationship between a weak real exchange rate and faster TFP growth. This relationship is nonlinear as suggested by our two sector model with diminishing returns: the acceleration of TFP growth created by a weak real exchange rate diminishes as the trade good sector dominates GDP. There is also some evidence that the traded goods sector, as represented by manufacturing exports, is a key TFP transmission mechanism.

These estimates suggest that the growth impact of an undervalued exchange rate can be substantial. If China's real exchange rate is undervalued by 20-30%, as some recent estimates suggest[14], our results show that 20% and perhaps as much as a third of China's 3% TFP growth may be attributable to its exchange rate policy. Rapid expansion of the traded goods sector has two effects on overall productivity growth: one is the movement of workers from low- to higher-productivity growth sectors, the other is faster "learning by doing" productivity growth in the traded goods sector. Early on, these two effects can combine to create an impressive, if not miraculous, surge in per capita growth.

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[14] See Table 1 of Siregar and Rajan (2006) for a number of estimates of exchange rate misalignment in China.

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Appendix Trade-weighted real exchange rates

The World Bank and the IMF provide trade-weighted real effective exchange rates, or REERs, for about half of the countries in the Bosworth and Collins (2006) TFP sample. Both sets of real exchange rates follow the PPP tradition of having the CPI in both the numerator and the denominator. To get closer to the traded - non-traded goods view of the real exchange rate developed in this paper, and to fill in the missing REER series, we computed trade-weighted real exchange rates with producer or wholesale prices in the numerator. Trade weights for 1985, 1995 and 2005 were computed using trade flows from the IMF Direction of Trade Statistics database:

$$\omega_i = \frac{(X+M)_{i,j}}{\sum_{j=1}^{n}(X+M)_{i,j}},$$

in which the numerator reflects the amount of trade country i has with trading partner j, and the denominator reflects the total value of trade of country i with its 56 largest trading partners. These weights were used to compute a weighted-average of dollar wholesale prices for trading partners[15]:

$$P^*_{i,t} = \textstyle\sum_{i=1}^{n} \omega_i P^w_{i,t}.$$

These weighted-average dollar WPI, or traded goods prices, were used to compute the real exchange rates:

[15] Wholesale price indices, obtained from the IMF's International Financial Statistics (IFS) database, were used to quantify general price levels in each of these countries. Consumer prices were obtained mainly from IFS and the WDI. Where no wholesale price series were available, GDP price deflators were used. The details and sources of these price data are available from the authors upon request. Price data from the World Bank and the IMF were indexed to the year 2000, while price data from the United Nations (from the database on national accounts) were indexed to 1990. All price indices were rebased to 2000. International prices were expressed in terms of an index in US dollars. The official average annual exchange rates (local currency units to US dollars) from 1970 to 2006 were obtained from the WDI and indexed to the year 2000. For the euro area countries, the entire exchange rate series in euros were back-casted using the growth rates of the old local currency unit series.

$$q^*_{i,t} = \frac{e_{i,t} P^*_{i,t}}{P_{i,t}},$$

in which $e_{i,t}$ is the nominal (rf) exchange rate, and $P_{i,t}$ is the local consumer price index.[16]

[16] We also tried geometric averages, $\ln q_{i,t} = \ln P^*_{i,t} + \ln e_{i,t} - \ln P_{i,t}$, in which $\ln P^*_{i,t} = \omega_i \ln P^w_{i,t}$, but the arithmetic averages seemed to be closest to the WDI and IMF series, which we also tested as discussed in the paper.