Analyzing the link between real exchange rate and productivity

Diallo, Ibrahima Amadou

Centre D'études Et De Recherches Sur Le Développement International (CERDI)

13 November 2010

Analyzing the link between real exchange rate and productivity

DIALLO IBRAHIMA AMADOU[1]

November 13, 2010

Abstract :

This paper study, in panel data, the relationship between real exchange rate and total factor productivity on a sample of 68 developed and developing countries for the period 1960-1999. The theoretical part presents the arguments advanced to explain the effects of real exchange rate on productivity, technical efficiency and technological progress. The productivity is obtained as a *Solow* residual of an estimation of a *Cobb-Douglas* stochastic production function frontier. The results show that an exchange rate appreciation causes an increase of total factor productivity. The results also illustrates that this effect of real exchange rate on productivity is non linear: threshold effect. Below the threshold exchange rate reacts negatively on productivity while above the threshold it acts positively. Robustness analysis demonstrates that these results hold both in subsamples of developed and developing countries.

Keywords: Exchange rate, productivity, Appreciation, Depreciation.

JEL: O11, O16, O47

[1] *Contact:* zavren@gmail.com . CERDI (Centre D'études Et De Recherches Sur Le Développement International), University of Clermont-Ferrand 1, France.

Introduction :

The theoretical analysis of the relationship real exchange rate – productivity suggests a double direction link. On the one hand, real exchange rate acts on productivity and on the other hand productivity affects the real exchange rate.

In the first case, real exchange rate appreciation can act positively or negatively on productivity.

Many arguments have been proposed to explain how real exchange rate acts positively on productivity. First, real exchange rate appreciation reduces the relative price of imported capital, carrier of technological progress. Second, real appreciation increases the real remuneration of work which involve an increase of the productivity of this one *(Leibenstein (1966), Harris (2001))*. Third, by increasing foreign competition, real appreciation can push domestic firms to be more efficient *(Krugman (1989))*.

Real exchange rate appreciation can also be unfavourable to productivity. Initially, real exchange rate appreciation can slow down export expansion. This lowers commercial openness too vital to productivity. Then, real appreciation by slowing down foreign direct investments can slow down technical progress. In end, if production factors are not substitutable, the increase of wages caused by real appreciation involves a bad allowance of production factors.

In the second case, productivity acts on real exchange. This is known as the *Ballassa-Samuelson* theorem (*Balassa (1964)* and *Samuelson (1964)*). This theorem stipulates that the growth of the income of a country is accompanied by high productivity in the sector of tradable goods. It results an increase of the relative price of non tradable goods, i-e an appreciation of the real internal exchange rate.

This paper studies the effect of real exchange rate on total factor productivity on a sample of 68 developed and developing countries on the period 1960-1999. This relationship was studied for the Chinese provinces by *Sylvianne Guillaumont and Hua (2003).* The paper distinguishes itself from this previous work in three ways: first it is conducted on a panel of countries instead of provinces in one country, second the productivity variable is calculated using a Cobb-Douglas stochastic production function frontier instead of a Malmquist DEA index and third it takes account for the existence of a potential non linear effect between real exchange rate and total factor productivity.

The results show that an appreciation of real exchange rate results in an increase of total factor productivity. The results also illustrates that this effect of real exchange rate on productivity is non linear. Robustness analysis demonstrates that these results hold both in subsamples of developed and developing countries.

The paper is organized as follows: the first part expose the theoretical framework, the second part present the productivity calculation method, the third part provides an analysis of the econometrics models and methods used in the study, the fourth part analyzes the results and the last part is devoted to sensitivity analysis.

1. Theoretical Framework

The theoretical analysis of the relationship real exchange rate – productivity suggests a double direction link: one the hand, real exchange rate acts on productivity and on the other hand, productivity acts on real exchange rate.

1.1. Effects of real exchange rate on productivity

Real exchange rate appreciation can act positively or negatively on productivity according to the cases.

1.1.1. Positive effects of real exchange rate on productivity

Real exchange rate appreciation increase productivity *(Krugman (1989), Porter (1990)*). Many arguments have been proposed to explain this fact.

First, as real exchange rate appreciation is a result of an increase of the relative price of non tradable goods, real wages will increase insofar as they constitute an important part of the price of non tradable goods. Real exchange rate appreciation has hence a consequence of dropping the relative price of capital. This involves a reorganization of firms' production structure by an increase of capital intensity which in his turn increases technical efficiency. This drop of the relative price of capital also involves an increase of imported physical capital carrier of technological progress and increase of labor productivity.

Second, real exchange rate appreciation increases real remuneration of labor. According to the theory of wage efficiency, real wage conditions the effort provided to work, hence workers productivity.

In fact, the increase of workers real wage involves an increase of their income which allows them to better take care of themselves, to educate and increase their wellbeing in general. This acts in a positive way on the motivation of workers which in his turn exerts a positive influence on the effectiveness of the combination of productive factors by a reduction of X - inefficiency *(Leibenstein (1966), Harris (2001))*. The increase of real wage involved by real exchange rate appreciation also reduce the *the brain drain* because the skilled workers are incited to remain in their countries of origin. This results to an increase of workers productivity and a greater assimilation of the innovations.

Third, real exchange rate appreciation increasse foreign competition which pushes domestic firms to increase their effectiveness to remain in the market. Two effects are expected from foreign competition. On the one hand, foreign competition allows a redistribution of the resources from firms or sectors not very productive towards more productive firms or sectors. This is the phenomenon of creative destruction: the factors of production undergo a redistribution which leads to the increase in the total efficiency of the productive system so that the more efficient firms and sectors remain on the market whereas the less efficient firms and sectors disappear. On the other hand, foreign competition results in the introduction of a new non cooperative actor into the market which threatens the position of the national firms, which pushes them to be more efficient (Krugman (1989)). The explanation of Krugman (1989) is based on the theory of the contracts applied to the firms. In a company, the manager does not have the same motivation as the shareholder because he benefits only a part of the profit generated by the company. What interests the manager is the maximization of its utility function which has two variables: part of the profit and the effort he provides. Thus although the shareholder fixes the contract so that the preferences of the manager are the closest possible to his (incentive constraint), the manager always has a certain room which enables him to deviate from the principle of maximization of profit sought by the shareholder. The introduction of a new non cooperative actor (foreign) into the national market, transforms the effort provided by the managers into a strategic variable. The foreign firm can dominate the market by choosing a very high level of effort. The national firms conscious of this threat increase their level of effort to the risk of disappearing from the market. The shareholder of the national firm could also take the level of effort provided by the foreign managers as a scale. *Krugman (1989)* applied this reasoning to explain the effects of the overvaluation of the dollar and the pound at the beginning of the eighties respectively in the United States and in the United Kingdom. According to this explanation, the overvaluation of the real exchange rate of these two currencies during this period generated an increase in competition improving the marginal effect of effort which generated an increase in the effectiveness of management and an improvement of productivity.

1.1.2. Negative effects of real exchange rate on productivity

Real exchange rate appreciation can be unfavorable to productivity.

In the first place, real exchange rate appreciation exerts a negative impact on exports. However, according to *Feder (1983), Guillaumont (1994),* the tradable goods sector to which exports belong is more competitive than that of the non tradable goods since it faces international competition. A redistribution of production factors in direction of the tradable goods will have as a consequence an increase in productivity. Hence, real exchange rate appreciation involves a fall of technical efficiency insofar as it generates redistribution of production factors towards the non tradable goods to the detriment of the tradable goods.

In the second place, many work in particular *Findlay (1978), Wang (1990)* and *Boreinsztein et al. (1998)* showed that the foreign direct investments (FDI), by involving the adoption of new leading-edge technologies, the increase in the human capital and the adoption of effective methods of management, exert a positive effect on total factor productivity via their impact on technological progress. *Boreinsztein et al. (1998)* stress that the impact of the FDI on the economic growth is higher than that of the domestic investment in the countries having a sufficient level of human capital. Since real exchange rate appreciation reduces profitability in the sector of exports, it slows down the FDI and thus technological progress.

In the third place, if production factors are not substitutable, the real wage increase caused by the real exchange rate appreciation involves a bad allowance of production factors.

1.2. The effects of productivity on real exchange rate: Balassa-Samuelson theorem

Work completed in a separate way in 1964 by *Balassa* and *Samuelson*, showed that real exchange rate fluctuations can be explained by the "theory of real trade". This explanation was called thereafter theorem of *Balassa-Samuelson*. The idea of the theorem is that the growth of the income of a country is accompanied by a higher productivity in the sector of tradable goods. This results in an increase in the relative price of non tradable goods, i.e. an appreciation of the real internal exchange rate. The theorem thus explains why the countries with high growth rate tend to know an upward trend of their relative prices and consequently of the actual value of their currency in terms of foreign currencies. In other words, such countries often know a tendency to the real appreciation of their currency.

2. Calculation of total factor productivity

Total factor productivity is calculated from a stochastic production frontier using the method of *Battese and Coelli (1992),* on quinquennial data for all countries of the sample of study. Before going further on this method, let us explain the concept of technical inefficiency in output for a firm. We say that a firm is technically inefficient when it does not manage to position its production on its frontier production possibilities. In other words, the firm potentially produces less than what it should produce because of existence of the technical inefficiency.

In the method of *Battese and Coelli (1992),* the technical inefficiency is modeled as a truncated normal random variable multiplied by a specific function of time. This implies that for a panel of countries we have:

$$\ln(Y_{it}) = f\left[\ln(X_{it}), \beta\right] - u_{it} + v_{it}; \quad u_{it} \geq 0 \qquad (1)$$

$\ln(Y_{it})$ et $\ln(X_{it})$ are respectively log of output and inputs for country i at time t.

$u_{it} = \exp\left\{-\eta(t - T_i)\right\} u_i$ is the technical inefficiency.

T_i is the last period of the i^{th} country,

η is a parameter , $u_i \overset{iid}{\sim} N^{+}(\mu, \sigma_{\mu}^{2})$;

$v_{it} \overset{iid}{\sim} N(0, \sigma_{v}^{2})$;

u_i et v_{it} are independently distributed one and the other and the regressors

This method is used to estimate a Cobb-Douglas production function (constant returns to scale and nonconstant returns to scale)[2]

[2] We specify here the general form without constant returns. To obtain the constant returns the equation (2) is estimated while imposing $\beta_3 = 0$, which correspond to $\alpha+\beta-1=0$

$Y_t = A_t K_t^{\alpha} L_t^{\beta}$. By deviding the two sides by L_t, we have:

$y_t = A_t k_t^{\alpha} L_t^{\alpha+\beta-1}$

By taking the log of the two sides we get:

$\ln(y_t) = \ln(A_t) + \alpha \ln(k_t) + (\alpha+\beta-1)\ln(L_t)$.

The estimated equation can be written as:

$$\ln(y_{it}) = \beta_1 + \beta_2 \ln(k_{it}) + \beta_3 \ln(L_{it}) - u_{it} + v_{it} \qquad (2)$$

with:

y_{it} output per worker , k_{it} capital per worker,

L_{it} The number of workers

i countries, t time

u_{it} and v_{it} are as defined precedently.

Total factor productivity (tfp_{it}) is then:

$$tfp_{it} = \exp\left\{\ln(y_{it}) - \left[\beta_2 \ln(k_{it}) + \beta_3 \ln(L_{it})\right]\right\} \qquad (3)$$

The results of estimates of production functions that are used to calculate the various total factor productivities are provided in table A.1. in the appendix.

3. Econometrics models and estimations methods

In this section we successively present the GMM estimation and the *Hansen (1999)* methods

3.1. The GMM estimation method

To estimate the impact of real exchange rate on productivity, the method of system GMM is used. The estimated equation is:

$$y_{i,t} - y_{i,t-1} = (\alpha-1) y_{i,t-1} + \beta' X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \qquad (4)$$

Where $y_{i,t}$ is the log of total factor productivity, in this case $y_{i,t} - y_{i,t-1}$ represent total factor productivity growth. $X_{i,t}$ represent the regressors. μ_i country fixed effects. λ_t time fixed effects. ε_{it} idiosyncratic errors. *i* indicate countries and *t* the time.

Equation (4) can be equivalently rewriting as:

$$y_{i,t} = \alpha y_{i,t-1} + \beta' X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \qquad (5)$$

The standards methods of estimation cannot be used to estimate equation (5) because of the presence of the lagged dependent variable. Two methods are available to estimate this equation: the estimator of *Arellano and Bond (1991)* or difference GMM and the system GMM estimator.

We use the system GMM estimator because *Blundell and Bond (1997)* showed using Monte Carlo simulations that the system GMM estimator is more efficient than the difference GMM estimator. The system GMM method consists in simultaneously estimating by the method of generalized moments the following two equations:

$$y_{i,t} = \alpha y_{i,t-1} + \beta' X_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \qquad (6)$$

$$y_{i,t} - y_{i,t-1} = \alpha(y_{i,t} - y_{i,t-1}) + \beta'(X_{i,t} - X_{i,t-1}) + (\lambda_t - \lambda_{t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \qquad (7)$$

Equation (7) is called equation of first differences and equation (6) equation in level. The equation in level is instrumented by the variables in first differences whereas the equation in first differences is instrumented by the lagged values of the variables in level. The instruments[3] are generated using the following moment conditions:

- *For the equation in first difference (equation 7)*

$$E\left[y_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1} \right) \right] = 0 \text{ for } s \geq 2; t = 3,\ldots,T \qquad (8)$$

$$E\left[X_{i,t-s} \cdot \left(\varepsilon_{i,t} - \varepsilon_{i,t-1} \right) \right] = 0, \text{ for } s \geq 2; t = 3,\ldots,T \qquad (9)$$

- *For the equation in level (equation 6)*

$$E\left[\left(y_{i,t-s} - y_{i,t-s-1} \right) \cdot \left(\mu_i + \varepsilon_{i,t} \right) \right] = 0 \text{ , for } s = 1 \qquad (10)$$

$$E\left[\left(X_{i,t-s} - X_{i,t-s-1} \right) \cdot \left(\mu_i + \varepsilon_{i,t} \right) \right] = 0, \text{ for } s = 1 \qquad (11)$$

The conditions (8) to (11) combined with the generalized method of moments allow estimating the coefficients of the model. We use the system GMM estimator since, first we will have the lagged dependent variable as a regressor, second the endogeneity of the link real exchange rate-productivity and third the use of macroeconomics data which are highly endogenous. Hence the System GMM in addition to account for inobserved heterogeneity of countries and omitted variables, it allows to solve the endogeneity of real exchange rate and other control variables including the measurement error on variables problem. Moreover it is more efficiente than the *Arellano and Bond (1991)* and the non dynamic panel data fixed effect estimators.

---

[3] To test the validity of the lagged variables as instruments, *Arellano and Bond (1991)*, *Arellano and Bover (1995), Blundell and Bond (1997)* suggest the test of overidentification of Sargan and the test of autocorrelation of second order.

3.2. The Hansen (1999) estimation method

In the theoretical part, we stated that exchange rate could act positively or negatively on productivity. This suggests than the effect of exchange rate on productivity is non linear. We use the *Hansen (1999)* method of determination of endogenous thresholds to test this assumption.

The estimated equation is written as

$$tfp_{it} = \beta_1 reer_{it} I(reer_{it} \leq \gamma) + \beta_2 reer_{it} I(reer_{it} > \gamma) + \delta^{'} X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \qquad (12)$$

Where:

$I(.)$ is an index function according to whether real effective exchange rate ($reer_{it}$) is lower or higher than the endogenous threshold γ.

tfp_{it}, $reer_{it}$, X_{it}, μ_i, λ_t and ε_{it} are defined and calculated in the same way as in equation (4).

The method of Hansen (1999) consists in estimating equation (12) by fixed effects in two stages:

- Find the endogenous optimal threshold $\hat{\gamma}$ which minimizes the sum of squared residuals (S_1) of equation (12) estimated by fixed effects:

$$\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}}\, S_1(\gamma)$$

- Test the significativity of the threshold $\hat{\gamma}$. The null assumption of absence of threshold effect is written: $H_0 : \beta_1 = \beta_2$. This assumption is tested by the statistics $F_1 = \frac{\left(S_0 - S_1(\hat{\gamma})\right)}{\hat{\sigma}^2}$ where S_0, S_1 and $\hat{\sigma}^2$ are respectively the sum of squared residuals under H_0, the sum of squared residuals under H_A and the estimated variance of the residuals. The problem to carry out this test is that under H_0 the non identification of the threshold implies that F_1 does not follow the standards statistical distributions. To cure it, *Hansen (1999)* proposes to carry out a bootstrap in order to derive a distribution of the statistic F_1. For the needs for inferences on the significativity of the endogenous threshold, he proposes to build, for all $\hat{\gamma}$ a confidence interval on the basis of the likelihood ratio according to $LR_1(\gamma) = \frac{\left(S_1(\gamma) - S_1(\hat{\gamma})\right)}{\hat{\sigma}^2}$.

4. Data and Variables

The sample of study includes 68 countries: (22) developed and (46) developing countries over the period 1960-1999[4]. In order to eliminate cyclical fluctuations and to focus on middle and long term relationships, the averages over five years were calculated. Consequently, the temporal depth was reduced to eight sub-periods: 1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999. The data mainly come from *Summers and Heston (2004) (Penn World*

---

[4] This sample size is given according to the availability of the data. Table A.2. gives the list of countries.

Tables 6.1), the World Bank (World Development Indicators, 2004), Barro and Lee (2000), Easterly (2001) and CERDI (2000).

The literature on real exchange equilibrium and real exchange rate misalignment states that some of our control variables like openness, government consumption, inflation and the terms of trade are potential determinants of real exchange. To address this issue, we regress, using System GMM, each of these control variables on real exchange rate and put the resulting residues on the main estimations of the impact of real exchange rate on productivity in tables A.5, A.6, A.7 and A.8[5]. Hence we are estimating the total effect of real exchange rate on productivity since we have taken account the effect that these control variables have on real exchange rate.

Tables A.3 and A.4 respectively provide the details of calculation of all the variables and the descriptive statistics.

5. Results

In this section, we will successively presents the results in system GMM and the *Hansen (1999)* method results.

5.1. System GMM estimate results

The System GMM estimates results are presented in Table A.5. The statistics of the test of Sargan show that we cannot reject the null assumption of validity of lagged variables as instruments. In the same way, the statistics AR(2) show that we

[5] The regression results of each of these control variables on real exchange rate are available upon request.

cannot reject the null assumption of absence of autocorrelation of second order of the errors. This implies that the estimate of the relationship real exchange rate-productivity of our sample by the system GMM is applicable. All the regressions are carried out with robust standard-errors obtained by the procedure of estimate of system GMM in one stage. These standard deviations are efficient for the presence of any form of heterocedasticity and autocorrelation in the panel.

The coefficient of the real effective exchange rate is significant and has a positive sign. This means that an appreciation of the real effective exchange rate increases the productivity. The use of instrumental variables makes it possible to say that the positive relation between the real effective exchange rate and the productivity seems to go from the real effective exchange rate towards the productivity and not the reverse. The impact of real effective exchange rate on productivity is very high. While being based to regression (4), and by supposing a variation expressed in percentage of real effective exchange rate of 35%, the corresponding rise of total factor productivity is 4%.

The minus coefficient of the logarithm of lagged total factor productivity indicates a conditional convergence compared to the productivity. This convergence is conditional in what it shows a growth from the total factor productivity is higher as the former productivity is low, only if the other explanatory variables are maintained constant. The coefficient indicates that conditional convergence is very high because it is carried out at a rate of 18%.

The GDP per capita is significant at 1% and positive in all equations. The positive sign of the initial GDP per capita means that convergence compared to total factor productivity is larger as the initial GDP per capita is high.

The human capital is significant and has the expected sign in all regressions. The magnitude of the human capital coefficient is higher than that of all the other variables in all regressions. This suggests that the human capital exerts a significant positive impact on total factor productivity.

The other controls variables are only marginally significant.

5.2. Hansen (1999) estimate results

The *Hansen (1999)* estimates results are presented in Table A.6. The temporal specific effects were taken into account. The robust standard errors are between brackets. The endogenous threshold is equal to -0.2525. The real exchange rate corresponding to this threshold is equal to 0.7769. The statistics of the likelihood ratio indicates that the endogenous threshold is significant to 5%. This suggests that the effect of real exchange rate on total factor productivity is nonlinear. Under the threshold, real exchange rate acts negatively on productivity while above the threshold real exchange rate has a positive effect on productivity.

6. Robustness Analysis

Table A.7 shows that the impact of real exchange rate on total factor productivity is robust if we use an alternative measurement of total factor productivity

Table A.8 shows that the impact of real effective exchange rate on total factor productivity is robust with the estimate on the subsamples of developing countries and non developing countries.

Conclusion

This article explored the relation between the real effective exchange rate and the total factor productivity in the medium and long term. The results show that an appreciation of the real effective exchange rate increases the productivity. The impact of real effective exchange rate on productivity is very high. By supposing a variation expressed in percentage rate of real effective exchange of 35%, the corresponding rise of the total factor productivity is 4%. The results also illustrates that this effects of real exchange rate on productivity is non linear. Under the threshold, real exchange rate acts negatively on productivity while above the threshold real exchange rate has a positive effect on productivity.

Bibliography

Arellano, M. et Bond, S.,1991. "Some Tests of specification for panel data: Monte Carlo Evidence and application to employment Equations". *Review of Economic studies* 58:277-297.

Arellano, M. et Bover, O., 1995. "Another look at the instrumental- variable Estimation of error-components Models". *Journal of Econometrics* 68(1):29-52.

Balassa, B., 1964. "The Purschasing Power Parity Doctrine: A reappraisal". *Journal Political Economy*, 2(3):584-596.

Battese, G.E et Coelli ,T.J., 1992. "Frontier production functions technical efficiency and data: with applications to paddy farmers in India". *Journal of productivity Analysis* 3: 153-169.

Blundell, R et Bond, S., 1997. "Initial Conditions and Moment restrictions in dynamic Panel Data Models". University College London Discussion Paper 97(7).

Boreinsztein, E., De Gregorio, J. et Lee, J.,W., 1998. "How does foreign direct investment affect economic growth". *Journal of International Economics* 45 :15–135.

Feder, G., 1983. "On Exports and Economic Growth". *Journal of Development Economics,* 12 (1-2):59-73.

Findlay, R., 1978. "Relative backwardness, direct foreign investment, and the transfer of technology: a simple dynamic model". *Quarterly Journal of Economics* 92:1–16.

Guillaumont Jeanneney S. et Hua P., 2003."Taux de change réel et productivité en chine". *CERDI, Etudes et Documents*, EC.2003.29

Guillaumont, P., 1994. "Politique d'ouverture et croissance économique: les effets de la croissance et de l'instabilité des exportations " *Revue d'économie du développement* 1: 91-114.

Hansen, Bruce, 1999. "Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference". *Journal of Econometrics* 93(2):345–68.

Harris, R., G., 2001. "Is there a Case for Exchange Rate Induced Productivity Changes" m*imeo* Department of Economics, Simon Fraser University, Canadian Institute for Advanced Research

Krugman, P., 1989. "Surévaluation et accélération des productivités : un modèle spéculatif" in Laussel D. et Montet C. *Commerce international et concurrence parfaite,* Paris, Economica, 121-135.

Leibenstein, H., 1966. "Allocative Efficiency versus X-Efficiency" *American Economic Review,* 392-415.

Porter, M., E., 1990. "The Competitive advantage of Nations". Cambridge, Mass, *Harvard University Press.*

Samuelson, P., 1964. "Theoretical Notes on Trade Problems". Review of Economics and Statistics 46:145-154.

Wang, J., Y., 1990. "Growth, technology transfer, and the long-run theory of international capital movements". Journal of International Economics 29:255–271.

Appendix

Table A.1: Results of the regressions of the production functions used for calculation of the total factor productivity

Production Function Cobb-Douglas. *Battese et Coelli (1992)* Method		
Dependent variable : ln(y)		
Regressors	Non constant returns to scale	Constant returns to scale
ln(k)	0.4719***	0.4762***
	(0.0160)	(0.0143)
ln(L)	0.0092	
	(0.0152)	
Constant	2.8199***	2.8983***
	(0.2626)	(0.2314)
Time varying decay model	yes	yes
Observations	544	544
Nomber of countries	68	68
Test of constant returns to scale	0.5443	

Note : Robust standard errors are between brackets. For the test of constant returns to scale, it is the p-value that is reported.
* significant at 10%; ** significant at 5%; *** significant at 1%

<u>Table A.2:</u> List of Countries

Nº	Country codes (WB)	Country Name	Nº	Country codes (WB)	Country Name
1	ARG	Argentina	35	KEN	Kenya
2	AUS	Australia	36	KOR	Korea, Rep.
3	AUT	Austria	37	LKA	Sri Lanka
4	BEL	Belgium	38	LSO	Lesotho
5	BOL	Bolivia	39	MEX	Mexico
6	BRA	Brazil	40	MUS	Mauritius
7	CAN	Canada	41	MWI	Malawi
8	CHE	Switzerland	42	MYS	Malaysia
9	CHL	Chile	43	NER	Niger
10	CMR	Cameroon	44	NIC	Nicaragua
11	COL	Colombia	45	NLD	Netherlands
12	CRI	Costa Rica	46	NOR	Norway
13	CYP	Cyprus	47	NZL	New Zealand
14	DNK	Denmark	48	PAK	Pakistan
15	DOM	Dominican Republic	49	PAN	Panama
16	ECU	Ecuador	50	PER	Peru
17	EGY	Egypt, Arab Rep.	51	PHL	Philippines
18	ESP	Spain	52	PNG	Papua New Guinea
19	FIN	Finland	53	PRT	Portugal
20	FRA	France	54	PRY	Paraguay
21	GBR	United Kingdom	55	RWA	Rwanda
22	GHA	Ghana	56	SEN	Senegal
23	GMB	Gambia, The	57	SLV	El Salvador
24	GRC	Greece	58	SWE	Sweden
25	GTM	Guatemala	59	SYR	Syrian Arab Republic
26	HND	Honduras	60	TGO	Togo
27	IDN	Indonesia	61	THA	Thailand
28	IND	India	62	TTO	Trinidad and Tobago
29	IRL	Ireland	63	URY	Uruguay
30	IRN	Iran, Islamic Rep.	64	USA	United States
31	ISR	Israel	65	VEN	Venezuela, RB
32	ITA	Italy	66	ZAF	South Africa
33	JAM	Jamaica	67	ZAR	Congo, Dem. Rep.
34	JPN	Japan	68	ZWE	Zimbabwe

<u>Table A.3:</u> Definitions and methods of calculation of the variables

Variables	Definitions	Expected Sign	Sources of data
Real effective exchange rate	Weighted average of the bilateral exchange rates according to the trade partners. Base 100=1995. An increase is an appreciation.	Positive ou Negative	*CERDI database (2000)*
Initial GDP per capita	GDP per capita (1996 constant dollars) beginning of period.		*Penn World Table 6.1*
Human Capital	The human capital is calculated at the beginning of period as the sum of the average number of years of studies in the secondary of the men, the average number of years of studies in the secondary of the women, the average number of years of studies in the tertiary sector of the men and the average number of years of studies in the tertiary sector of the women balanced by their respective coefficients in a regression including the growth rate of total factor productivity, the initial GDP per capita, the residue of openness, the residue of government consumption and the residue of inflation.	Positive	*Barro et Lee (2000)*
Residue of openness*	Residue of the regression of the logarithm of the Openness = (Exports +Imports)/GDP on the logarithm of the real effective exchange rate.	Positive	*World Bank, World Development Indicators, 2004*
Residue of government consumption*	Residue of the regression of the logarithm of the Government consumption = Government Consumption /GDP on the logarithm of real effective exchange rate.	Négative	
Residue of inflation*	Residue of the regression of ln(1+inflation) on the logarithm of real effective exchange rate.	Négative	
Residue of the growth of the terms of trade*	Residue of the regression of the Growth rate of the terms of trade on the logarithm of real effective exchange rate.	Positive	*Easterly, 2001*

*This method of calculation of the controls variables is similar to that used by Sylvianne *Guillaumont and Hua, 2003*. The idea is to be able to calculate the total impact of the real exchange rate on productivity.

<u>Table A.4:</u> Descriptive statistics on variables

Variables	Observations	Means	Standard deviations	Minimum	Maximum
lpgfcx*	544	2.5009	0.3648	1.0606	3.1842
lpgfnx**	544	2.4233	0.3691	0.9541	3.1238
Real effective exchange rate	529	1.4153	0.9339	0.2598	11.3760
Initial GDP per capita	544	6869.9260	6212.5730	321.7051	28409.6200
Human Capital	541	-0.0485	0.0741	-0.3345	0.1327
Residue of openness	453	2.23E-10	0.1880122	-0.8063945	0.8506406
Residue of government consumption	448	2.87E-10	0.1764319	-0.8675174	0.8297289
Residue of inflation	455	-2.02E-10	0.3107403	-0.705259	3.469315
Residue of the growth of the terms of trade	439	-6.80E-12	0.077388	-0.3542168	0.2589573

* lpgfcx: logarithm of total factor productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)*

** lpgfnx: logarithm of total factor productivity, Cobb-Douglas function with nonconstant returns, method of *Battese and Coelli (1992*

Table A.5: System GMM estimate results

Dependent variable: logarithm of total factor productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)*				
Regressors	(1)	(2)	(3)	(4)
ln (productivity), t-1	-0.2251**	-0.1621*	-0.2019**	-0.1456
	(0.0907)	(0.0955)	(0.0882)	(0.1052)
ln(Real effective exchange rate), t	0.0869**	0.0831*	0.0785*	0.1196**
	(0.0431)	(0.0422)	(0.0436)	(0.0513)
ln(Initial GDP per capita)	0.1602***	0.1385***	0.1503***	0.1588***
	(0.0407)	(0.0373)	(0.0405)	(0.0454)
Initial human capital	0.8018**	0.5965*	0.6975**	0.8925**
	(0.3641)	(0.3426)	(0.3175)	(0.3656)
Residue of openness, t	0.1144		0.1304	0.2034*
	(0.0973)		(0.1051)	(0.1215)
Residue of inflation, t	-0.0380*		-0.0171	-0.0053
	(0.0209)		(0.0192)	(0.0207)
Residue of government consumption, t	0.1564*			
	(0.0790)			
Residue of the growth of the terms of trade				0.1621
				(0.1305)
Constant	-0.7547***	-0.7389***	-0.7276***	-0.9505***
	(0.2328)	(0.2507)	(0.2311)	(0.2740)
Observations	425	471	435	417
Nomber of countries	68	68	68	67
Sargan test	0.414	0.617	0.464	0.721
AR(2)	0.847	0.217	0.702	0.522
Nomber of instruments	43	28	38	43

Note: The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. For the test of Sargan and the test of autocorrelation of second order {AR(2)}, the probabilities are shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).

* significant at 10%; ** significant at 5%; *** significant at 1%

<u>Table A.6:</u> Hansen (1999) estimate results

Dependent variable: logarithm of total factor productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)*	
Estimated endogenous thresold	$\hat{\gamma}$ = -0.2525[a]
Confidence region at 5%	[-0.4212 ; 0.5627]
$\text{Reer}_{it} I(\text{Reer}_{it} \leq \gamma)$	-0.1217*** (0.0259)
$\text{Reer}_{it} I(\text{Reer}_{it} > \gamma)$	0.0773*** (0.0250)
Initial human capital	0.1668 (0.1549)
ln(Initial GDP per capita)	0.4826*** (0.0402)
Residue of government consumption, t	-0.0625* (0.0356)
Sum of Squared Errors under H_0	1.6099
Sum of Squared Errors under H_A	1.5073
Test of significativity of the endogenous threshold	$F_1 = 0$
F_1	21.4417
p-value (simulation)	0.0340
(Critical values à 10% ; 5% ; 1%)	(14.8787 ; 18.7998; 27.4565)
Nomber of simulations	2000

Note : The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).
* significant at 10%; ** significant at 5%; *** significant at 1%
[a] The real exchange rate corresponding to this threshold is (0.7769)

Table A.7: Robustness of the estimates according to the various measurements of total factor productivity

Regressors \ Dependent variables	logarithm of total factor productivity, Cobb-Douglas function with nonconstant returns, method of *Battese and Coelli (1992).*	logarithm of total factor productivity, Cobb-Douglas function with constant returns, method of Battese and Coelli (1992).
Real effective exchange rate	0.1206** (0.0511) N=417; S=0.707 AR(2)=0.528	0.1196** (0.0513) N=417; S=0.721 AR(2)=0.522

Note : The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. For the test of Sargan and the test of autocorrelation of second order {AR(2)}, the probabilities are shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).

The coefficients corresponding to the other explanatory variables are not reported. These other explanatory variables are those included in the regression (4) of table A.5. It is: ln(Initial GDP per cpaita); Human capital, beginning of period; Residue openness, t; Residue inflation, t; Residue of growth rate of the terms of trade. The time specific effects also were taken into account but their coefficients are not reported.

** significant at 5%

Table A.8. Estimates on the subsamples of Developing countries and non Developing countries

Dependent variable: logarithm of total factor productivity, Cobb-Douglas function with constant returns, method of *Battese and Coelli (1992)*				
Regressors	Developing countries			Non developing countries
	(1)	(2)	(3)	(1)
ln (productivity), t-1	-0.2090	-0.2250**	-0.1405	-0.2974
	(0.1253)	(0.0956)	(0.1118)	(0.1738)
ln(Real effective exchange rate), t	0.1253**	0.0699*	0.0800**	0.1091*
	(0.0622)	(0.0412)	(0.0333)	(0.0569)
ln(Initial GDP per capita)	0.2052***	0.1775***	0.1573***	0.0509
	(0.0565)	(0.0482)	(0.0535)	(0.0557)
Initial human capital	0.9040*	0.7370*	0.8053**	-0.1549
	(0.4516)	(0.3799)	(0.3600)	(0.1958)
Residue of openness, t		-0.0364	0.0208	
		(0.0997)	(0.0910)	
Residue of inflation, t		-0.0442*	-0.0313*	
		(0.0223)	(0.0186)	
Residue of the growth of the terms of trade			-0.0445	
			(0.1701)	
Constante	-1.1653***	-0.8756***	-0.9392***	0.3497
	(0.3680)	(0.3022)	(0.2691)	(0.5064)
Time specific effects	yes	yes	yes	**no**
Observations	317	287	273	154
Nomber of countries	46	46	46	22
Sargan test	0.138	0.106	0.080	0.000
AR(2)	0.140	0.310	0.792	0.894
Nomber of instruments	28	38	43	22

Note The robust standard-errors are between brackets. The coefficients of the corresponding time specific effects are not shown. For the test of Sargan and the test of autocorrelation of second order {AR(2)}, the probabilities are shown. The period of study 1960-1999 is subdivided in 8 sub-periods of 5 years (1960-1964, 1965-1969, 1970-1974, 1975-1979, 1980-1984, 1985-1989, 1990-1994, 1995-1999).

* significant at 10%; ** significant at 5%; *** significant at 1%