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Abstract

While most of the literature on the determination of real exchange rates is focused on the role of standard macroeconomic variables, there exists however a few papers that are more concerned by the impact of factors which are usually considered to play a key role in the process of economic development, like demography or inequality. In the present paper, we extend this small branch of the literature by exploring the relationship between labor skills and real exchange rates over the long-run. Using panel regressions covering 22 countries over the period 1950-2010, we find that labor skills are indeed a structural determinant of real exchange rates, with a permanent increase of the skilled-unskilled labor ratio leading to a long-run appreciation of the real exchange rate. This findings is robust to the inclusion of several control variables, like those used in traditional analyses of real exchange rates.

Keywords: Real exchange rate, human capital, skills, Balassa-Samuelson effect.
JEL classification: C23, F31, F41, I25

1. Introduction

While the purchasing power parity (PPP) theory states that changes in real exchange rates are transitory, the empirical evidence shows on the contrary that movements of real exchange rates can persist very significantly. This stylized fact triggered a vast research aimed at discovering the fundamentals that are driving long run changes in real exchange rates (see Rogoff

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(1996) for a survey and Edwards and Savastano (1999) for a focus on developing countries). While this literature looked almost exclusively at the role played by standard macroeconomic variables, as for instance trade openness (Goldfajn and Valdes (1999)), productivity differential (MacDonald and Ricci (2005)), government consumption (Ostry (1994)), terms of trade (De Gregorio and Wolf (1994), Bodart, Candelon and Carpantier (2012)) and country size (Rose, Supaat and Braude (2009)), recent papers show alternatively that variables which are usually considered to play a key role in the process of economic development (population, fertility and inequality, for example)[1] also have an impact on the long-run deviations from PPP.

Among the very few studies that explore the role of these alternative factors, Rose et al. (2009) show that fertility matters for the determination of real exchange rates. In their study, they find that a decline in the fertility rate of one child per woman is associated with a depreciation of approximately 15% in the real effective exchange rate. Garcia (1999) shows that income inequality can also affect real exchange rates in the long-run and he finds, both theoretically and empirically, that the impact is ambiguous.

Our paper extends this new, and so far very limited, strand of literature by exploring the role of labor skills. Skills, which are defined in this paper as a certain level of education, have indeed largely risen over the last fifty years. In our sample of 22 countries, the share of population, aged 15 and over, holding a completed secondary school education level or more, has risen on average from 13% in 1950 to 54% in 2005, an increase of about 40 percentage points[2]. In some countries, such as the Netherlands, Germany or Norway, the increase over the same period was even higher, amounting to 56, 62 and 63 percentage points, respectively. At the same time, the real exchange rate of these countries appreciated relatively to most countries. Notwithstanding the role of other determinants, there are good reasons to believe that this correlation is not random.

Theory also supports our focus on skills. Standard theories of real exchange rate determination attribute structural variations in real exchange rates to either productivity difference between the non-tradable and the tradable sectors, either to difference in factor endowments between the same two sectors, or to changes in the relative demand of the non-tradable and the

[1]The role of these variables in the process of economic development has been emphasized by the unified growth theory. See Galor (2011) for a comprehensive review of this theory

[2]Similar trends are obtained with other education criteria.

tradable goods. The relative sectoral productivity theory is due to Balassa and Samuelson (Balassa (1964) and Samuelson (1964)), who have shown that a country will register an appreciation of its real exchange rate if it has a higher productivity in tradable goods relative to nontradable goods. The role of relative factor endowment in the determination of real exchange rates was originally proposed by Bhagwati (1984) who showed that, even without any difference in sectoral productivity, a country may have a higher real exchange rate if it has a higher aggregate capital-labor ratio and if the non-tradable good is labor intensive. Alternatively, the "demand-side" explanation, which was developed by Bergstrand (1991), emphasizes that if the income elasticity of the demand for non-tradable goods is above unity, increases in income per capita should push up the relative price of the non-tradable goods, and so generate an appreciation of the real exchange rate. All three explanations can potentially explain structural variation in real exchange rates, and the empirical literature has tried to identify the relative importance of each explanation. As shown in the next section, the role of skills is not related to one particular approach about what drives structural variations in real exchange rates but, instead, it spans the three approaches. We therefore believe that this feature makes skills a potentially fundamental determinant of real exchange rates in the long-run.

The objective of our paper is therefore to explore whether skills are actually a statistically and economically significant determinant of real exchange rates in the long-run. Our contribution is thus mainly empirical.

Regarding the methodology, we regress the bilateral real exchange rates of 22 countries on different measures of skills over the period 1950-2010 (using a quinquennial dataset). All variables are expressed in relative terms between two countries. To take all the available information into account, we fully exploit the dyadic ij dimensionality of the data. We thus consider all country pairs, contrary to many studies where only bilateral relationships with the US are used. By proceeding like that, we get results that are not conditional to a particular country of reference. As our sample includes 22 countries, we have 231 observations for each year. Several econometric strategies are implemented in order to minimize potential endogeneity biases.

To anticipate our results, we show that labor skills have indeed a long-run impact on real exchange rates. We find that when the skills ratio between two countries increases by 10%, there is about a 1% appreciation of the real exchange rate in favor of the country whose level of skills has increased (relatively to the other country). Various robustness checks tend to confirm the size and significance of the impact of skills on the real exchange rate.

The rest of the paper is organized as follows. Section 2 presents briefly the literature and the theoretical underpinnings of the analysis. Section 3 describes the empirical strategy. Section 4 presents the data. Section 5 discusses the results and presents robustness checks. Section 6 concludes.

2. Theoretical motivations

In this section, we provide several theoretical arguments that show why skills are potentially an important determinant of real exchange rates in the long-run. As it is standard in the literature on real exchange rate, we refer to the framework of a small open economy that produces tradable and nontradable goods, and so we define the real exchange rate as the ratio between the domestic prices of the nontradable and tradable goods[3]. According to that definition, a higher (smaller) ratio is equal to an appreciation (depreciation) of the real exchange rate.

First, in reference to the theory proposed by Bhagwati (1984), skills can affect real exchange rates because of induced changes in the relative factor supplies. For instance, as in Bhagwati (1984), let's consider that each good is produced with two factors of production. In our case, the two factors are unskilled labor and skilled labor (instead of labor and capital in the model of Bhagwati (1984)). Following Bhagwati (1984), it can then be shown that if the nontradable sector is using more intensively the unskilled labor than the tradable sector, then an increase in the skilled-unskilled labor ratio will lead to an appreciation of the real exchange rate. The explanation is as follows. With more skilled workers, firms in both sectors are able to produce more and, consequently, the aggregate demand for unskilled labor increases. Since the supply of unskilled labor is fixed by assumption, equilibrium on the market of unskilled labor requires that the wages paid to unskilled workers increase. Because of profit maximization by nontradable firms, the price of the domestic nontradable good will also rise. Since the price of the tradable good is pinned down by the international law of one price, the price of the nontradable relative to the tradable goods increases, that is the real exchange rate appreciates.

[3]The real exchange rate is more generally defined as the ratio between the domestic consumption-based price index and the foreign consumption-based price index expressed in the domestic currency. The definition that we use is obtained by assuming that the law of one price holds for the tradable good and that the prices of the foreign tradable and nontradable goods are given for the small economy.

In reference to the Balassa-Samuelson (Balassa (1964) and Samuelson (1964)) theory, skills can also generate variations in real exchange rates by leading to changes in the relative productivity of the two goods. This could notably be the case if human capital externalities exist. Let's consider for instance a Lucas type technological externality and assume that total factor productivity (TFP) is an increasing function of the quantity of skills of the domestic labor force. In this case, if it turns out that the intensity of human capital externalities differs across sectors, skills will have an impact on the relative price of nontradable goods other than the effect described previously. To show this very simply, let's assume that unskilled and skilled labor are used in the production of the two goods but that human capital externalities exist only in the tradable sector. Then, if the aggregate level of skills increase, TFP will increase in the tradable sector and, accordingly, higher wages will be paid to unskilled and skilled workers in that sector. If labor is perfectly mobile across sectors, as it is assumed in the standard Balassa-Samuelson framework, wages will also increase in the nontradable sector. As the TFP of nontradable firms is unchanged, the price of nontradable goods will also increase. Through this mechanism, other things being constant, increases in skills will therefore push the real exchange rate higher.

If demand enters into the determination of the relative price of tradable and nontradable goods, this introduces a third channel through which skills can affect the real exchange rate. This will be for instance the case if increases in skills lead to an increase in the aggregate income. As demonstrated by Bergstrand (1991), if the consumption of the nontradable good increases with total expenditure, increases in skills will also tend to change the relative price of nontradable goods through this channel. An interesting illustration of this channel is provided by Garcia (1999) in his study of the impact of income inequality on real exchange rates.

3. Methodology

To explore the role of skills in the determination of real exchange rates, we perform regression of bilateral real exchange rates on skills. As such regression raises traditional endogeneity issues (omitted variable bias, reverse causality), we overcome these problems by combining the following econometric strategies. First, we include traditional determinants of real exchange rates as additional independent variables in the regression equation (see equation (1)). Second, we control for omitted time-invariant country specific characteristics by including N fixed effects (where N is the number of countries). Third, while many studies use real exchange rates that are defined with respect to a single country (typically the US), we use instead all Q_{ijt} bilateral exchange rates between a country i and any j country of our sample [4]. We then include time-varying fixed effects specific to every reference country jt, which enables us to capture many various effects such as global macroeconomic factors (oil shocks for example) or country specific time-varying phenomena. This strategy replicates what is now commonly done in the empirical international trade and migration literature to tackle similar kinds of endogeneity issues (Ortega and Peri (2009), Anderson and Yotov (2012) among others).

The benchmark econometric specification is the following:

$$\begin{aligned} \log(Q)_{ijt} \quad = \quad & \beta_1 \log(SK)_{ijt} + \beta_2 GOV_{ijt} + \beta_3 \log(POP)_{ijt} + \beta_4 OPEN_{ijt} \\ & + \beta_5 INC_{ijt} + \beta_6 TT_{ijt} + \alpha_i + \alpha_{jt} + \epsilon_{ijt} \qquad (1) \end{aligned}$$

where the subscripts i and j stand for the two countries whose bilateral exchange rate is considered and t for the year, where Q stands for the real exchange rate, SK for the skill variable, GOV for government expenditures (ratio to GDP), POP for the country population, $OPEN$ for the degree of trade openness, INC for the GDP per capita and TT for the terms of trade.

The ij subscripts indicate that each variable is defined as a country i to country j relative measure. As a matter of interpretation, the parameters give the impact on the log bilateral real exchange rate between country i and country j of a unit increase of the difference between the X variable of country i and the corresponding X variable of country j. The parameters are to be interpreted as elasticities if the regressor of interest is in a logarithmic form (as it is the case for the skills variable). The Data section gives more details on the construction of X_{ijt} versions of the X_{it} variables. This econometric strategy allows us to obtain results that are not conditional to the reference country j, whereas most studies use the US as the sole country of reference.

The variable SK, which is the focus of our analysis, is a proxy for the skilled-unskilled labor ratio. It is measured by the share of the population, aged 15 and over, that holds at least a diploma of completed secondary school (alternative education measures are estimated for robustness tests). Data on skills are only available on a quinquennial basis (see Section 4).

[4] As an illustration, the real exchange rate of Italy will be defined bilaterally with respect to the US, but also with respect to the Netherlands, to Sweden, to France, etc. We thus get $T * N * (N-1)/2$ observations.

As a consequence, the dependent variable, Q, is defined as a 5-year forward average. The coefficient β_1 thus measures the average percent change of the real exchange rate over the years $t, t+1, t+2, t+3$ and $t+4$ resulting from a 1 percent change in the cross-country difference in the level of skills reported in year t.

To reduce the risk of bias due to omitted variables, we include in our econometric model several control variables, hereby following a common practice in empirical studies on real exchange rates, as for instance the recent study of Rose et al. (2009) looking at the impact of fertility on real exchange rates. As mentioned previously, the skills variable is only available on a quinquennial basis. We therefore use in our regression 5-year forward averages for each control variable.

The first control variable, GOV, is the GDP ratio of government expenditures. As government expenditures are usually biased towards nontradable goods, an increase of them tend to support an appreciation of the real exchange rate. We thus expect β_2 to be positive.

The variable POP is the population, in thousands. It is intended to capture a size effect, based on the grounds that smaller countries tend to pursue a more mercantilist exchange rate policy[5]. β_3 is thus expected to be positive.

The trade openness variable, $OPEN$, is proxied by the trade to GDP ratio. According to some studies (see for instance Rose et al. (2009)), trade liberalization is associated with a larger demand for imports and a potential decrease in the demand for nontradable goods, which gives rise to a depreciation of the real exchange rate. On the contrary, other studies stress that liberalization of uncertain duration can lead to a higher demand for nontradables and to a real exchange rate appreciation (Calvo and Drazen (1997)). Empirical studies also differ in their results about the sign of β_4.

The income variable, INC, is the real GDP per capita. This variable is strongly related to the Balassa-Samuelson effect, according to which richer countries tend to have a more productive tradable sector. Given perfect labor mobility across sectors, and since the productivity gains in the nontradable sector are usually lower compared to those in the tradable sector, increasing wages tend to push the prices of nontradable goods up and to support an appreciation of the real exchange rate. We therefore expect β_5 to be positive. From a demand side, if consumer demand is non homothetic

[5] See Aizenman and Lee (2010) for a discussion on the links between real exchange rates and mercantilism and Rose et al. (2009) for an application.

and the share of consumption devoted to nontradables increase with the income, the real exchange rate should also appreciate when the level of income increases. It must be noticed that if most of the effect of productivity on the real exchange rate is captured by the skills variable, as we expect, the impact of INC should mainly reflect the demand effect.

The terms of trade variable, TT, is measured as the ratio of export prices to import prices. It is included to capture foreign price shocks that may affect a particular country. Theory finds that the response of real exchange rates to terms of trade shocks is usually ambiguous as it depends on several effects that may be conflicting (see for instance Ostry (1988)). In particular, the ambiguity may come from the fact that the income effect of terms of trade shocks is opposite to the substitution effects[6]. Most empirical evidence, as for instance De Gregorio and Wolf (1994), Chen and Rogoff (2003), Bodart et al. (2012), find however that the β_6 is positive, namely that an improvement in the terms of trade induce an appreciation of the real exchange rate.

Notwithstanding the inclusion of these control variables, important country specific variables may be missing. For instance, because of country specific cultural, institutional and historical factors, the average duration of education can vary from country to country. To avoid the potential bias caused by the omission of time invariant country specific characteristics, we include country specific fixed effects α_i in the regression model. As it is well known that when there exists global factors that can potentially affect all, or some of, the variables over time, the omission of these factors can lead to spurious correlations, we also include time varying country j specific fixed effects α_{jt} in our panel framework. We adopt a very general specification where these time-varying effects are allowed to be specific to the reference country j. As the dimension of our panel is large enough, we include together all the fixed effects, so as to minimize the risk of omitting variables and to significantly lower the misspecification problem.

We estimate equation (1) by least squares (LSDV) on a set of 22 countries over the period 1950 to 2010 ($T = 12$). Since we cover a time frame of about 60 years and since the variables are defined in relative (country-to-country)

[6]Using a simple model of a small open economy, De Gregorio and Wolf (1994) show however that, when capital is immobile internationally, the relationship between the terms of trade and the real exchange rate is clearly positive, meaning that a country experiencing a deterioration of its terms of trade has to expect a depreciation of its exchange rate. More generally, if the income effect dominates the substitution effect, the real exchange rate should appreciate (depreciates) when the terms of trade improve (deteriorate).

terms, we treat the series as time stationary and restrict the analysis to the series in level[7].

4. Data

Data on real exchange rates, skills and the control variables are collected from three international sources: the IMF International Financial Statistics database, the Barro-Lee dataset on educational attainment and the Penn World Tables.

With the requirement that the data be available over a sufficiently long period, the final sample is restricted to 22 countries, as reported in Table 1.

Table 1: List of countries

Australia	Austria	Belgium
Canada	Denmark	Finland
France	Germany	Greece
Ireland	Italy	Japan
Netherlands	New Zealand	Norway
Portugal	South Africa	Spain
Sweden	Switzerland	United Kingdom
United States		

The bilateral real exchange rate Q_{ijt} between country i and country j is constructed by dividing the US dollar real exchange rate of country i by the US dollar real exchange rate of country j. The US dollar real exchange of country i is obtained by deflating the US nominal bilateral exchange rate of country i with the ratio between the US consumer price index and the consumer price index of country i. Real exchange rates are expressed as indices, with 2005=100. A higher value of the real exchange rate index corresponds to a real appreciation of the exchange rate of country i relative to country j. Primary data are taken from the IMF IFS database. The (bilateral) real exchange rates relative to US, Germany and Japan are presented in Figures 1, 2 and 3, respectively. The striking contrasts that appear between the figures (appreciations for most series against the US and depreciations for most series against the Japan) justify our dyadic approach,

[7] Like Rose et al. (2009), we do not find strong empirical evidence of non-stationarity.

which implies that our results do not depend on which reference country is taken for the calculation of the bilateral real exchange rate.

The skilled-unskilled labor ratio variable SK_{it} is built with data collected from the Barro-Lee data set (2011) on Educational Attainment for Total Population. This quinquennial dataset covers the period 1950-2010. The benchmark skills variable is the percentage of population aged 15 and over with completed secondary education as minimum education level attained (which is constructed by adding the series with mnemonics 'lsc' and 'lh'). The series are illustrated in Figure 4. One can observe that, as of 1950, the skilled-unskilled labor ratio has followed an upward trend in almost all countries. There are however some important differences among countries about the magnitude of the long-run increase of the skills ratio. We also use as robustness checks two alternative measures of relative labor skills: the percentage of population aged 15 and over with (not necessarily completed) secondary as minimum education level attained (constructed by adding the series with mnemonics 'ls' and 'lh') and the percentage of population aged 15 and over with tertiary as minimum education level attained (series with mnemonics 'lh'). Alternative databases to Barro-Lee are available but they are not properly suited for our study as they have either a shorter time window, such as de la Fuente and Domenech (2006) with quinquennial data over 1960-1995, or less frequent data, such as Cohen and Soto (2007) with decennial data. The relative country version of the skills variable, SK_{ijt}, is computed as the difference between SK_{it} and SK_{jt}.

The control variables $OPEN_{it}$, GOV_{it}, POP_{it} and INC_{it} come from the Penn World Tables (Heston, Summers and Aten (2011)). $OPEN_{it}$, the trade openness variable (mnemonic 'openk'), is equal to the ratio of the sum of exports and imports to GDP, with all the variables being measured in constant prices. GOV_{it} is equal to real government consumption divided by real GDP (mnemonic 'kg'). POP_{it} is the population in thousands (mnemonic 'p'). INC_{it} is the real GDP per capita (mnemonic 'rgdpl'). The relative country version of each control variable, denoted X_{ijt}, is equal to the difference between X_{it} and X_{jt}. The relative country version of the control variable, denoted $log(X)_{ijt}$, is equal to the difference between $log(X_{it})$ and $log(X_{jt})$.

The control variable TT_{it} is the terms of trade of country i. Using time series data from the International Financial Statistics database of the IMF, they are constructed by dividing the export price unit (in US$ terms, mnemonics 'xxY74..DF') of country i by the import price unit (in US$ terms, mnemonics 'xxY75..DF') of country i. The relative country version of the variable, TT_{ijt}, is computed as the difference between TT_{it} and TT_{jt}.

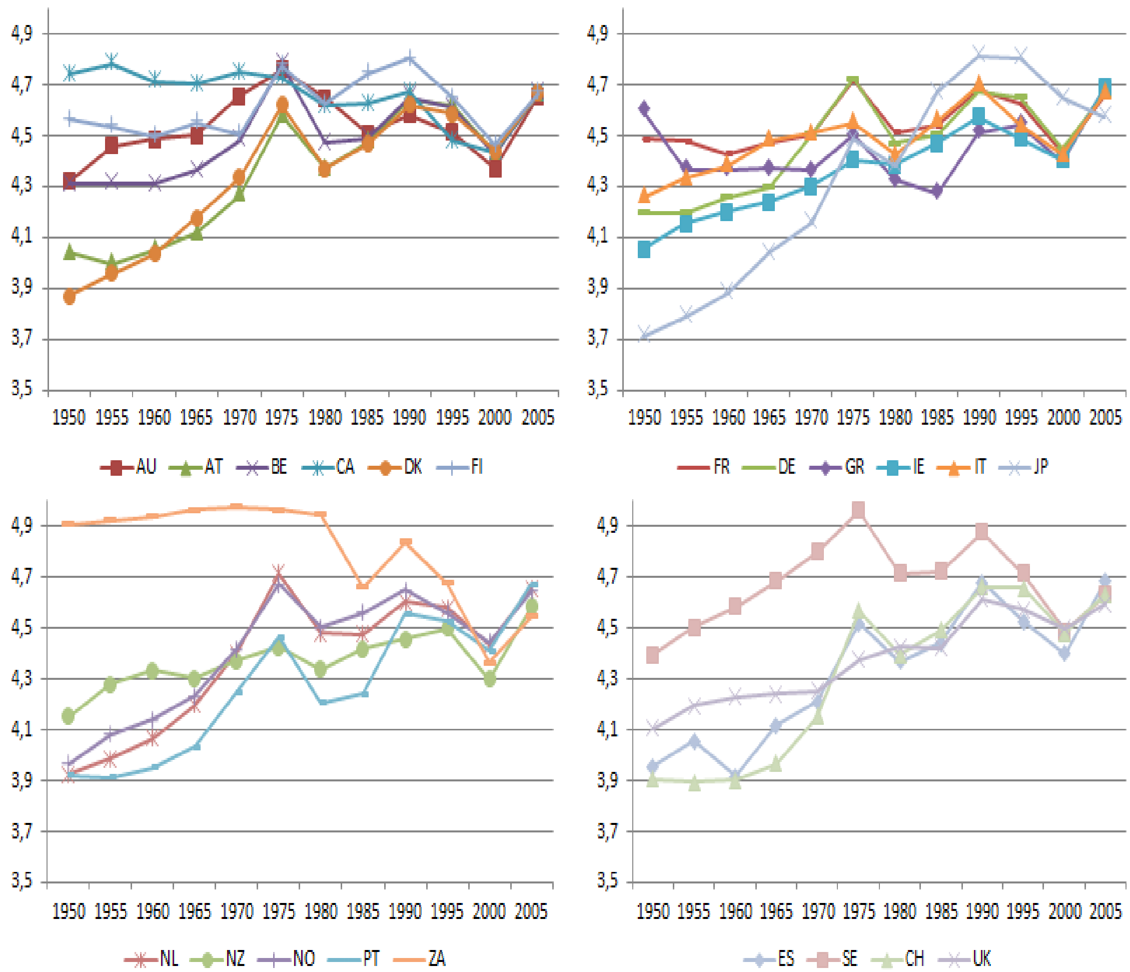

Figure 1: Evolution of the bilateral real exchange rate (relative to the United States)

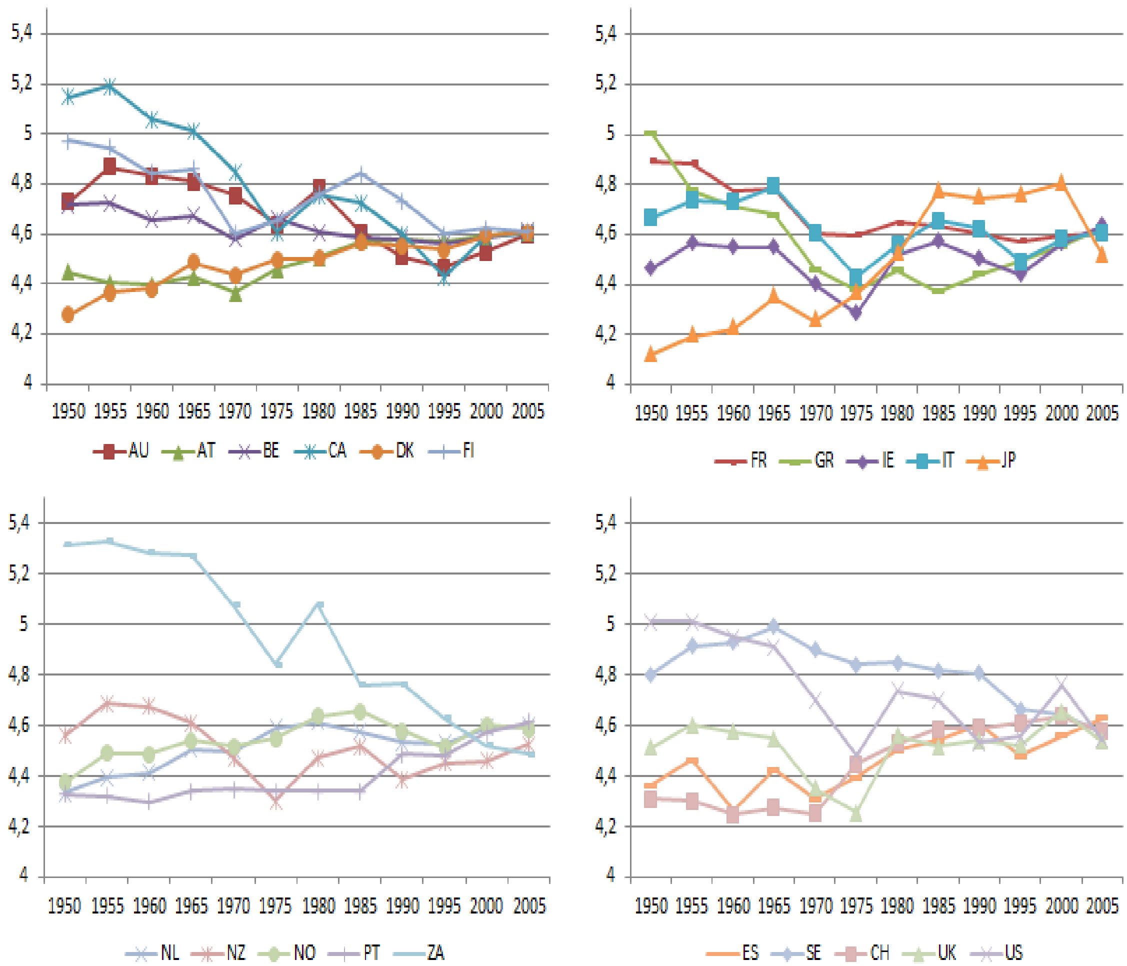

Figure 2: Evolution of the bilateral real exchange rate (relative to Germany)

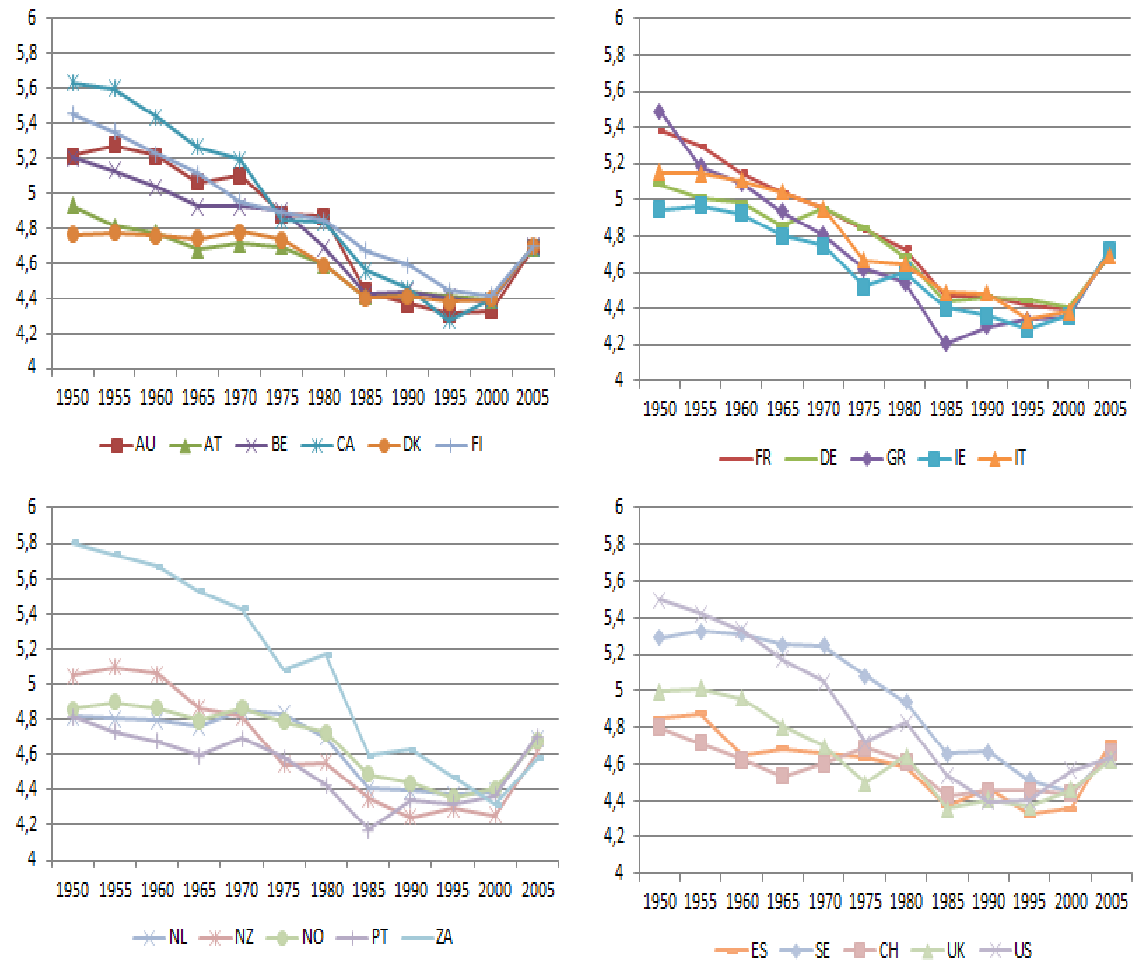

Figure 3: Evolution of the bilateral real exchange rate (relative to Japan)

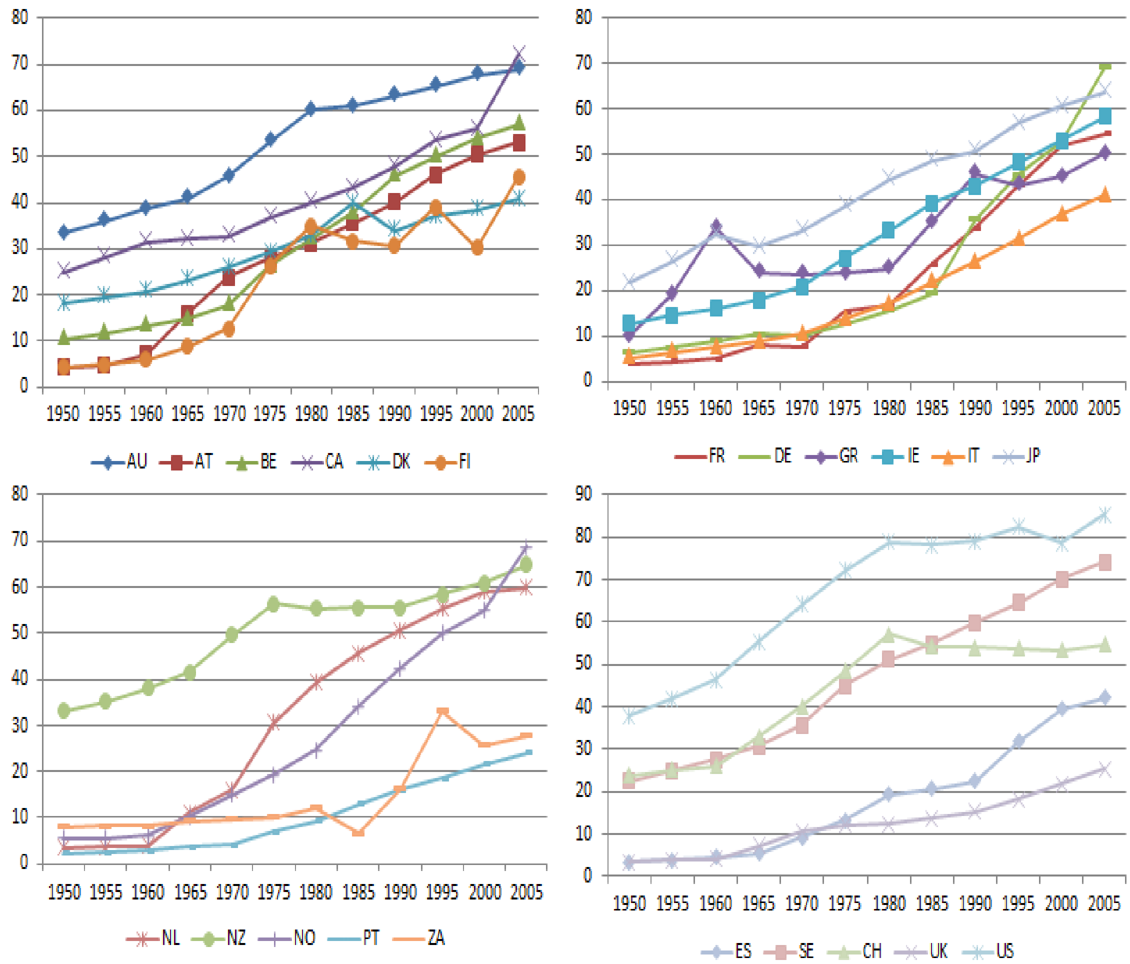

Figure 4: Evolution of the percent of the population aged 15 and over with completed secondary school as minimum education level attained

Since the skills variable is available on a quinquennial basis, the time dimension has 12 periods (1950-2010) at most, depending on the availability of the control variables. Therefore, we have a maximum of 2772 observations ($\frac{N(N-1)T}{2}$) per variable.

Some country-based and year-based descriptive statistics are reported in Tables 10 and 11 of the Appendix. We note that most series exhibit a positive time trend, which justifies the inclusion of yearly fixed effects α_{jt}. In particular, on can observe that the US bilateral real exchange rate of the countries in our sample has appreciated by about 40% between 1950 and 2010 and the US relative skills by 170%.

5. Results and interpretation

Six alternative specifications of the benchmark case are reported in Table 2. Skills have a positive and highly significant impact on the real exchange rate in each specification. The coefficient ranges from 0.08 to 0.11. Since both skills and real exchange rates are expressed in logarithmic form, the results reported in Table 2 show that, on average, the elasticity is close to 10%. In other words, a 10% increase of the difference in the level of skills between two countries leads to a 1% appreciation of the real exchange rate in favor of the country whose level of skills has increased in relative terms.

In the specification (1), all controls are included. All are significant, trade openness excepted. The coefficient of GOV, POP and INC have the expected sign, meaning that government consumption has a positive impact on the real exchange rates, that smaller countries tend to have a lower real exchange rate and that the GDP per capita is positively related to the real exchange rate. The terms of trade have a negative sign. Therefore, contrary to most studies that find a positive sign, our result indicates that the real exchange rate depreciates (appreciates) when the terms of trade improve (deteriorate). Specification (2) is our preferred specification, where the trade openness variable, which was not significant in the full specification, is excluded. Given that the GDP per capita is often used to capture the Balassa-Samuelson productivity differential effect and that our skills variable partially captures this effect, specifications (3) and (4) explore the case where the variable INC is excluded from the regressors . We find that the exclusion of INC increases the magnitude of the skills effect and that the R^2 measures fall only slightly from 0.84 to 0.82. Specification (6) shows that the elasticity of the real exchange rate with respect to skills further increases when the skills variable is the sole regressor (with the fixed effects).

Table 2: Impact of skills on the real exchange rate

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.08004***	0.08187***	0.08984***	0.08998***	0.08525***	0.10667***
	[8.495]	[8.632]	[9.378]	[9.382]	[9.086]	[11.652]
$GOV5_{ijt}$	0.01155***	0.01197***	0.00093			
	[3.561]	[3.678]	[0.269]			
$\log(POP5)_{ijt}$	-0.45111***	-0.46616***	-0.67161***	-0.67075***	-0.48223***	
	[13.914]	[13.835]	[18.088]	[18.094]	[13.960]	
$OPEN5_{ijt}$	0.0004		0.00111***	0.00112***		
	[1.570]		[3.817]	[3.790]		
$INC5_{ijt}$	0.00002***	0.00002***			0.00002***	
	[16.663]	[17.799]			[15.673]	
$TT5_{ijt}$	-0.16322***	-0.16509***	-0.14986***	-0.14782***	-0.14027***	
	[6.887]	[7.116]	[5.424]	[5.095]	[5.849]	
Observations	2009	2009	2009	2009	2009	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.840	0.840	0.819	0.819	0.838	0.757

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

To assess the robustness of the results, the estimates are reiterated with several variants of the model. First, we check whether our previous results are modified when alternative measures of the skills are used. Table 3 reports the estimates that are obtained with a less restrictive measure of skills. In this variant, skills are defined as the percentage of population aged 15 and over with secondary (or more) as education level attained. In the benchmark case, secondary had to be at minimum completed, which is not the case in this variant. We note in Table 3 that the impact of skills on the real exchange rate is increased compared to the results of Table 2, with elasticities ranging from 9% to 14%. The significance and sign of the control variables do not change.

Table 3: Variant 1. Skills are defined as secondary education or more

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.09581***	0.09782***	0.11295***	0.11158***	0.10585***	0.14073***
	[8.728]	[8.852]	[10.467]	[10.397]	[9.756]	[15.298]
$GOV5_{ijt}$	0.00895***	0.00927***	-0.0019			
	[2.752]	[2.841]	[0.551]			
$\log(POP5)_{ijt}$	-0.46088***	-0.47449***	-0.67426***	-0.67645***	-0.48426***	
	[14.178]	[14.126]	[18.560]	[18.644]	[14.189]	
$OPEN5_{ijt}$	0.00036		0.00102***	0.00101***		
	[1.406]		[3.476]	[3.378]		
$INC5_{ijt}$	0.00002***	0.00002***			0.00002***	
	[16.071]	[17.074]			[15.283]	
$TT5_{ijt}$	-0.14613***	-0.14747***	-0.13303***	-0.13679***	-0.12996***	
	[6.201]	[6.370]	[4.845]	[4.733]	[5.416]	
Observations	2009	2009	2009	2009	2009	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.841	0.841	0.821	0.821	0.84	0.763

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

As a second check to the robustness of the results, we now take, contrary to the precedent check, a stricter definition of the skills, which are now defined as the percentage of population aged 15 and over with tertiary as education level attained. The results are reported in Table 4. The skills effect remains significant, but is smaller in magnitude, with elasticities ranging from 4% to 8%. The controls keep their significance and signs as in the precedent variants, with the exception of trade openness which becomes now significant at 10% (but not at 5%).

Table 4: Variant 2. Skills are defined as tertiary education or more

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.04259***	0.04467***	0.04133***	0.04157***	0.04809***	0.08064***
	[4.326]	[4.510]	[3.850]	[3.865]	[4.880]	[7.740]
$GOV5_{ijt}$	0.01189***	0.01243***	0.001			
	[3.565]	[3.722]	[0.280]			
$\log(POP5)_{ijt}$	-0.46725***	-0.48691***	-0.70300***	-0.70203***	-0.50321***	
	[13.917]	[14.026]	[19.439]	[19.533]	[14.127]	
$OPEN5_{ijt}$	0.00052*		0.00130***	0.00131***		
	[1.959]		[4.414]	[4.391]		
$INC5_{ijt}$	0.00002***	0.00002***			0.00002***	
	[17.629]	[18.974]			[16.731]	
$TT5_{ijt}$	-0.10647***	-0.10708***	-0.08653***	-0.08421***	-0.07856***	
	[4.587]	[4.673]	[3.138]	[2.905]	[3.293]	
Observations	2009	2009	2009	2009	2009	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.837	0.836	0.814	0.814	0.834	0.753

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

Looking together at Tables 2 to 4, we note that the lower the level of education, the larger the impact of skills on the real exchange rates.

As a third check, we explore further whether our results are biased because of endogeneity problems by estimating a difference-GMM dynamic panel with robust standard errors. Results are reported in Table 5. They show that the impact of skills on the real exchange rate is even larger than in the previous estimates, with a long-run elasticity value of around 15%[8].

Table 5: Variant 3. Difference-GMM approach

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\log(SK)_{ijt}$	0.10804***	0.10804***	0.10515***	0.10457***	0.10443***	0.10503***	0.07458***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.010)
$GOV5_{ijt}$	0.00021		-0.00073	-0.00608			
	(0.005)		(0.005)	(0.005)			
$\log(POP5)_{ijt}$	-0.26611***	-0.26518***	-0.20602**	-0.22082**	-0.24153**	-0.20751**	
	(0.093)	(0.089)	(0.087)	(0.098)	(0.097)	(0.084)	
$OPEN5_{ijt}$	-0.00108***	-0.00107***		-0.00017	-0.00020		
	(0.000)	(0.000)		(0.000)	(0.000)		
$INC5_{ijt}$	0.00001***	0.00001***	0.00001***			0.00001***	
	(0.000)	(0.000)	(0.000)			(0.000)	
$TT5_{ijt}$	0.07744***	0.07752***	0.09236***	0.10717***	0.10429***	0.09054***	
	(0.021)	(0.021)	(0.022)	(0.022)	(0.021)	(0.021)	
$L.\log(Q5)$	0.17423***	0.17473***	0.19668***	0.21819***	0.20286***	0.19427***	0.26670***
	(0.043)	(0.039)	(0.044)	(0.039)	(0.036)	(0.040)	(0.032)
$L2.\log(Q5)$	0.11074***	0.11114***	0.11511***	0.14727***	0.13872***	0.11392***	0.16246***
	(0.031)	(0.028)	(0.032)	(0.034)	(0.030)	(0.028)	(0.027)
Observations	1560	1560	1560	1560	1560	1560	2079
AR(1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AR(2)	0.21	0.21	0.12	0.01	0.01	0.12	0.00

AR(1) and AR(2) stand for first- and second-order autocorrelation tests.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

In the fourth robustness check, all control variables are defined as point estimates, instead of 5-year averages. More precisely, all the independent variables are defined in such a way that X_t is the variable X in year t, and no longer the 5-year forward average of X over $t, t+1, t+2, t+3$ and $t+4$.

[8]This elasticity value is obtained by multiplying the short-tun elasticity estimate of around 0.10 by $\frac{1}{1-0.17-0.11}$ to account for the dynamic components of the real exchange rate

Since, in this specification, all control variables and $\log(SK)$ are defined as beginning-of-period values, and that the dependent variable remains defined as a 5-year average, potential simultaneity biases are strongly reduced. Indeed, future values of the real exchange rate (in $t+1, t+2, t+3$ and $t+4$) are not expected to influence the values in t of the regressors. The results are reported in Table 6. It appears that the elasticity of the real exchange rate with respect to skills remains around 8%, what suggests that our previous results are only slightly affected by potential bias due to endogeneity. Regarding the control variables, we note that government consumption is no longer significant.

Table 6: Variant 4. Control variables are year-t measured (instead of five-year forward averages)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.07706***	0.08099***	0.08256***	0.08180***	0.08042***	0.10667***
	[8.043]	[8.333]	[8.451]	[8.143]	[8.155]	[11.652]
GOV_{ijt}	-0.00415	-0.00357	-0.01347***			
	[1.284]	[1.107]	[4.191]			
$\log(POP)_{ijt}$	-0.43381***	-0.46666***	-0.64098***	-0.65969***	-0.46298***	
	[13.481]	[13.978]	[18.441]	[18.469]	[13.737]	
$OPEN_{ijt}$	0.00080***		0.00141***	0.00132***		
	[3.209]		[5.057]	[4.502]		
INC_{ijt}	0.00002***	0.00002***			0.00002***	
	[15.613]	[16.567]			[16.297]	
TT_{ijt}	-0.13934***	-0.14350***	-0.13063***	-0.16097***	-0.15101***	
	[6.468]	[6.868]	[5.173]	[6.277]	[7.180]	
Observations	1944	1944	1944	1944	1944	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.842	0.841	0.823	0.819	0.841	0.757

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

As additional robustness check (see Table 7), we now replace the variable INC by its logarithmic version. We also redefine the variable $TT5_{ijt}$ as the ratio of TT_{it} and TT_{jt} (instead of a difference)(see Table 8). In both cases, on can observe that the elasticity of the real exchange rate with respect to skills remains highly significant.

Table 7: Variant 5. Income is expressed in logarithmic terms

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.04428***	0.04515***	0.08984***	0.08998***	0.04874***	0.10667***
	[3.916]	[3.923]	[9.378]	[9.382]	[4.554]	[11.652]
$GOV5_{ijt}$	0.00949***	0.00969***	0.00093			
	[3.872]	[4.055]	[0.269]			
$\log(POP5)_{ijt}$	-0.45351***	-0.46282***	-0.67161***	-0.67075***	-0.46703***	
	[13.366]	[13.590]	[18.088]	[18.094]	[13.994]	
$OPEN5_{ijt}$	0.00023		0.00111***	0.00112***		
	[0.839]		[3.817]	[3.790]		
$\log(INC5)_{ijt}$	0.46239***	0.46532***			0.44982***	
	[18.762]	[20.124]			[21.001]	
$TT5_{ijt}$	-0.03934*	-0.03962*	-0.14986***	-0.14782***	-0.02314	
	[1.713]	[1.733]	[5.424]	[5.095]	[1.001]	
Observations	2009	2009	2009	2009	2009	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.855	0.855	0.819	0.819	0.853	0.757

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

As final robustness check, we now replace the α_i and α_{jt} fixed effect dummies by a set of α_i, α_j and α_t fixed effects. The results are reported in Table 9 where we note that the skills elasticity of the real exchange rate remains significant around 8%.

As a conclusion to these robustness checks, it first appears that skills play a significant role in the determination of the real exchange rate. Their impact on the real exchange rate remains highly significant when alternative measures of the skills ratio are used. Only the size of the impact is altered, with an elasticity ranging from a minimum of 4% to a maximum of 14% and with a median estimate of 9%. The impact is also the largest when a wide

Table 8: Variant 6. The relative country version of Terms of Trade is computed using a ratio (rather than a difference

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.07396***	0.07592***	0.08460***	0.08464***	0.07946***	0.10667***
	[7.820]	[7.931]	[8.810]	[8.761]	[8.376]	[11.652]
$GOV5_{ijt}$	0.01052***	0.01097***	0.00019			
	[3.124]	[3.249]	[0.052]			
$\log(POP5)_{ijt}$	-0.45449***	-0.47110***	-0.67235***	-0.67217***	-0.48538***	
	[13.883]	[13.873]	[17.945]	[17.941]	[13.961]	
$OPEN5_{ijt}$	0.00044*		0.00114***	0.00114***		
	[1.698]		[3.887]	[3.828]		
$INC5_{ijt}$	0.00002***	0.00002***			0.00002***	
	[16.078]	[17.150]			[15.235]	
$TT5_{ijt}$	-0.12873***	-0.13047***	-0.12145***	-0.12107***	-0.10952***	
	[5.386]	[5.556]	[4.440]	[4.286]	[4.654]	
Observations	2009	2009	2009	2009	2009	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.839	0.838	0.818	0.818	0.837	0.757

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

Table 9: Variant 7. Alternative set of fixed effects

Variables	(1)	(2)	(3)	(4)	(5)	(6)
$\log(SK)_{ijt}$	0.07252***	0.07244***	0.08070***	0.08117***	0.07204***	0.09447***
	[7.365]	[7.356]	[7.864]	[7.882]	[7.372]	[10.688]
$GOV5_{ijt}$	0.00643**	0.00642**	-0.00312			
	[2.033]	[2.024]	[0.964]			
$\log(POP5)_{ijt}$	-0.54973***	-0.54881***	-0.68645***	-0.68769***	-0.55427***	
	[15.550]	[16.491]	[17.618]	[17.605]	[16.550]	
$OPEN5_{ijt}$	-0.00002		0.00053*	0.00053*		
	[0.080]		[1.892]	[1.873]		
$INC5_{ijt}$	0.00002***	0.00002***			0.00002***	
	[16.189]	[16.533]			[15.657]	
$TT5_{ijt}$	-0.22193***	-0.22195***	-0.23071***	-0.23601***	-0.21211***	
	[12.221]	[12.213]	[11.356]	[11.181]	[11.473]	
Observations	2009	2009	2009	2009	2009	2772
i dummies	Yes	Yes	Yes	Yes	Yes	Yes
jt dummies	No	No	No	No	No	No
j dummies	Yes	Yes	Yes	Yes	Yes	Yes
t dummies	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.683	0.683	0.644	0.644	0.682	0.536

Robust t statistics in brackets.

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

The dependent variable is the five-year forward average real exchange rate, ie $\log(Q5)_{ijt}$.

The suffix "5" appended to the name of the variables stands for 5-year forward averages.

measure of skills is used. We then note that the inclusion of the controls and of the various fixed effects leads to relatively high R^2 values (above 0.80). We also find that the skills variable remains highly significant when we include GDP per capita on the regressions, which suggests that skills and GDP per capita affect the real exchange rate through separate channels.

6. Conclusions

Beside the traditional literature on the determination of real exchange rates in the long run, which looks mainly at the role of standard macroeconomic variables, a few papers have investigated the role of factors that are usually considered to play a key role in the process of economic development, like inequality, population or fertility. The objective of this paper is to explore how skills, which are one of these factors, affect real exchange rates in the long run. We investigate empirically the relationship between cross-country differences in the level of labor skills and bilateral real exchange rates. To do that, we used panel quinquennial data for 22 countries over the period 1950-2010. By relying on a dyadic approach that allows to get results that do not depend on which country of reference is used for the calculation of the bilateral exchange rates, we find a significant relationship between labor skills and real exchange rates. We also find that this relationship was robust to the inclusion of several control variables, like the standard macroeconomic variables used in traditional analyses of real exchange rates, and to alternative measures of labor skills. Through the many different specification variants that we have estimated, we usually found that a 10% increase of the difference in the level of skills between two countries leads to a 1% appreciation of the real exchange rate in favor of the country whose level of skills has increased in relative terms.

We believe that this finding sheds new light on what drives structural variations in real exchange rates. It suggests that labor skills should be an important variable of any model concerned with the determination of real exchange rates in the long-run. This comes as a complement to recent papers illustrating the role and importance of skills in the export sector. For instance, Matsuyama (2007) notes that "international trade inherently requires more intensive use of skilled labor with expertise in areas such as international business, language skills, and maritime insurance", what he calls the skill-biased globalization. Similarly, Verhoogen (2008) and Maurin, Thesmar and Thoenig (2002) illustrate the role and need of skills in the tradable sector, but with a focus on export to high income countries.

Brambilla, Lederman and Porto (2012) integrate both mechanisms into a unified theory of export destinations and skills. Evidence that globalization has increased the concentration of skills in the tradable sector suggests that the importance of skills in the determination of real exchange rates has increased with globalization.

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Appendix: Complementary Descriptive Statistics

Table 10: Country-based descriptive statistics

	Benchmark variables (time)							Additional variables (averages)			
Country	logQ5	loglsclh	GOV5	logPOP5	OPEN5	INC5	TT5	loglslh	loglh	logINC5	pop5
Australia	4.54	3.94	9.64	9.56	26.00	22,795	1.17	4.37	3.07	9.96	14,192
Austria	4.36	3.06	10.24	8.93	54.60	21,505	-	3.46	1.35	9.85	7,535
Belgium	4.49	3.26	11.27	9.18	92.74	20,664	1.01	3.90	2.23	9.84	9,664
Canada	4.66	3.68	9.58	10.07	45.41	23,043	0.87	4.27	2.84	9.98	23,738
Denmark	4.35	3.36	10.27	8.51	50.39	21,872	0.98	3.81	2.45	9.91	4,951
Finland	4.62	2.85	10.22	8.47	42.92	18,369	1.03	3.38	2.13	9.71	4,727
France	4.55	2.72	10.66	10.90	28.72	19,721	0.99	3.31	1.79	9.80	53,544
Germany	4.47	2.88	12.02	11.26	46.51	25,313	0.95	3.51	1.80	10.12	77,066
Greece	4.44	3.37	9.36	9.14	28.72	14,969	1.20	3.69	1.78	9.48	9,302
Ireland	4.37	3.34	7.18	8.11	69.65	16,250	1.08	3.86	2.13	9.53	3,317
Italy	4.49	2.72	10.21	10.91	33.39	18,542	0.98	3.54	1.23	9.71	54,267
Japan	4.33	3.69	10.96	11.62	13.97	19,310	1.53	4.04	2.49	9.66	110,268
Netherlands	4.38	3.02	16.49	9.52	66.85	23,728	0.96	3.79	1.88	9.99	13,557
NewZealand	4.37	3.90	9.51	8.02	36.82	18,429	0.98	4.20	2.85	9.79	3,034
Norway	4.41	2.99	8.20	8.30	57.80	26,911	0.59	3.65	2.00	10.07	3,984
Portugal	4.26	2.02	4.60	9.17	38.74	10,936	0.96	2.68	1.13	9.12	9,527
SouthAfrica	4.81	2.53	5.47	10.25	51.34	5,217	0.99	3.61	1.16	8.54	29,299
Spain	4.32	2.55	7.35	10.49	24.43	15,660	0.97	3.11	1.68	9.51	35,747
Sweden	4.67	3.77	11.21	9.01	50.10	22,126	1.21	3.98	2.39	9.94	8,150
Switzerland	4.31	3.73	4.77	8.75	52.10	27,982	0.92	3.92	2.46	10.20	6,279
UK	4.38	2.32	10.32	10.93	33.11	20,630	0.98	3.81	1.87	9.87	55,657
USA	4.61	4.17	9.74	12.32	14.06	26,422	1.15	4.40	3.30	10.12	222,894
Total	4.46	3.18	9.47	9.70	43.52	19,936	1.03	3.74	2.09	9.75	34,577

logQ5: log of US bilateral real exchange rate (five-year forward averages). loglsclh: log of percent of population 15 and over with a completed secondary education level (or more). GOV5: percent of public expenses in terms of GDP (five-year forward averages). POP5: Population in thousands (five-year forward averages). OPEN5: Trade openness to GDP (five-year forward averages). INC5: GDP per capita (five-year forward averages). TT5: Terms of trade (five-year forward averages). loglslh: log of percent of population 15 and over with a secondary education level (or more). loglh: log of percent of population 15 and over with a tertiary education level (or more).

Table 11: Year-based descriptive statistics

	Benchmark variables							Additional variables			
Country	logQ5	loglsclh	GOV5	logPOP5	OPEN5	INC5	TT5	loglslh	loglh	logINC5	POP5
1950	4.23	2.25	10.36	9.46	21.16	8,355	1.13	2.98	1.11	8.93	26,271
1955	4.26	2.38	9.68	9.52	23.76	9,564	1.04	3.11	1.21	9.08	27,835
1960	4.29	2.52	9.23	9.57	26.82	11,389	1.05	3.23	1.30	9.27	29,488
1965	4.35	2.76	9.04	9.62	30.71	13,776	1.13	3.45	1.58	9.47	31,245
1970	4.45	2.94	9.00	9.67	35.18	16,707	1.12	3.61	1.76	9.68	32,768
1975	4.63	3.21	9.57	9.71	36.92	18,673	1.03	3.78	2.07	9.79	34,295
1980	4.48	3.37	9.93	9.74	39.61	20,322	0.96	3.90	2.20	9.87	35,585
1985	4.52	3.48	9.80	9.76	44.29	22,666	0.93	3.99	2.42	9.97	36,766
1990	4.66	3.63	9.71	9.80	50.68	24,606	1.00	4.09	2.62	10.06	38,066
1995	4.59	3.78	9.24	9.83	61.52	27,304	1.00	4.19	2.84	10.16	39,558
2000	4.44	3.84	9.07	9.86	71.02	30,726	0.98	4.24	2.92	10.28	40,861
2005	4.65	3.95	9.08	9.89	77.30	33,483	1.00	4.31	3.06	10.37	42,189
Total	4.46	3.18	9.47	9.70	43.25	19,798	1.03	3.74	2.09	9.74	34,577

logQ5: log of US bilateral real exchange rate (five-year forward averages). loglsclh: log of percent of population 15 and over with a completed secondary education level (or more). GOV5: percent of public expenses in terms of GDP (five-year forward averages). POP5: Population in thousands (five-year forward averages). OPEN5: Trade openness to GDP (five-year forward averages). INC5: GDP per capita (five-year forward averages). TT5: Terms of trade (five-year forward averages). loglslh: log of percent of population 15 and over with a secondary education level (or more). loglh: log of percent of population 15 and over with a tertiary education level (or more).

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