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JOINING THE EU: CAPITAL FLOWS, MIGRATION AND WAGES

Catia Batista

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Manor Road Building, Oxford OX1 3UQ

Joining the EU: Capital Flows, Migration and Wages

Cátia Batista[1]

Department of Economics - University of Oxford

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Abstract

What is the impact of joining the European Union on a small, less developed economy? This is the general question driving this research paper. In particular, the role of factor movements in explaining real wage behavior in Portugal after its entry in the European Union (EU) is quantitatively evaluated. For this purpose, we develop a simple theoretical model featuring a neoclassical aggregate production function a la Krusell et al (2000), which distinguishes between skilled and unskilled labor, as well as capital equipment and structures. Estimation of the implied aggregate elasticities of substitution is performed and used in simulating both types of wages and the skill premium. This constitutes an empirical test of the proposed technology, which finds an important role for capital-skill complementarity. Based on these results, counterfactual simulations are performed to measure the impact of foreign investment and emigration on skilled and unskilled wages between 1985 and 1999. We find a small role for labor movements, and a more important one for capital inflows. This should constitute a good starting point to think about the consequences of the Eastern enlargement of the EU and of other integration experiences that abolish barriers to factor mobility.

Keywords: International Migration, Capital Flows,Wages, Skill, Capital-Skill Complementarity, Economic Integration, European Union, Portugal

JEL Codes: F15; F2; J31; J61; O15; O33

Contents

1 Introduction

While the process of European integration is broadening and deepening at a fast pace, little attention has been devoted by the economics profession to explaining its real effects. This paper contributes to the literature by examining the impact of joining the European Union (EU) on a small, less developed economy.

We consider the case of Portugal, which joined the EU in 1986[1]. At this time, real wages and human capital in this country were significantly low relative to the average EU country. In particular, in 1985, Portuguese workers who had not graduated from college earned only 50% of corresponding French wages in PPP terms (where France may be regarded as the average EU country), and college graduates earned 72% (also in PPP terms), although these supplied about 2% of total hours worked. In the period from 1986 to 1999 several interesting phenomena occurred: in 1994, skilled and unskilled real wages had already converged to 93% and 67% of French wages, respectively; and by 1999 the levels of both skilled and unskilled wages had increased by about 55%, and educational attainment of the labor force also increased impressively to 7% of the labor input being supplied by college graduates.

Our purpose will be to analyze how free factor mobility (emigration and foreign capital inflows, in particular) contributed to the observed time pattern of real wages of skilled and unskilled workers in Portugal over the period 1986-1999. This is an important question on its own, but we believe that its examination can also lead to useful insights on the consequences of the Eastern enlargement of the EU which started in May 2004, as Eastern European countries are departing from initial conditions very similar to those of the Iberian countries in 1986.[2] More generally, this paper may contribute to a better understanding of other economic integration experiences involving free factor mobility, such as is expected to eventually happen in the North American Free Trade Agreement (NAFTA). Unlike trade liberalization, free factor mobility is a distinctive characteristic of the European integration process that has remained relatively unexplored.

Our theoretical framework consists of a small economy that opens to physical capital and labor flows, where a representative household optimally decides on human capital accumulation and migratory movements of its skilled and unskilled members. The setup of the model builds on the work of Stokey (1996), but includes costly migration flows since it is also our purpose to understand labor flows in the context of integration experiences. The technology used in the model allows equipment-specific technological change as studied by Greenwood et. al. (1997) and distinguishes between skilled and unskilled labor as in Krusell et. al. (2000). Following this line of research, the aggregate production function used here has four production factors (skilled and unskilled labor, capital equipment and structures), and does not display any type of externalities, but constant returns to scale instead.[3]

Empirically, the analysis proceeds by using the actual factor inputs in the data to estimate the parameters in the aggregate production function (and implied elasticities of substitution) for the Portuguese economy in the period 1985-1999. For this purpose, we use the two-step Simulated Pseudo Maximum Likelihood Estimation (SPMLE) procedure proposed and described in detail by Ohanian et. al. (2000). Our results are supportive of the aggregate technology displaying capital-skill complementarity, which is defined as capital equipment being more complementary with skilled than with unskilled labor.

The estimation results are used to simulate skilled and unskilled wage series, and to quantitatively evaluate the impact of the observed increases in emigration and foreign capital inflows due to Portugal's entry in the EU. The first step constitutes an empirical test to our theoretical framework, which performs well and proves the important role of capital-skill complementarity in explaining the behavior of real wages in Portugal between 1985 and 1999. In the second step in our simulations, emigration flows are found to be too small to have a significant impact on labor returns. Foreign capital inflows (especially unilateral transfers from the EU), however, seem to have a more important role, especially in accounting for the growth of skilled

[1] Portugal actually joined the European Economic Community (EEC) in 1986, which became the European Union (EU) only after 1993. For simplicity, the EU designation will be used throughout this paper.

[2] According to the Economist (2004), entering Eastern European countries and the Iberian countries (Portugal and Spain) at the time of integration in the EU both shared a fraction of about 20% of the EU population, and represented a 10% addition to the EU's GDP (in PPP terms). These Eastern countries depart, however, from a lower per capita GDP relatively to the EU average (46.5% vs. 62.2%, still in PPP terms). An additional difference is the higher educational attainment of the Eastern labor force.

[3] Human capital externalities of the type introduced by Lucas (1988) have been used to explain persisting wage differentials when labor mobility is allowed, as in Lucas (1990) and Giannetti (2003). However, this type of externalities have generally not been found empirically significant - see Acemoglu and Angrist (2000), for instance -, although there are some exceptions, as uncovered in local labor markets in Italy by Dalmazzo and de Blasio (2003).

workers' wages. In light of our results, this should be interpreted as a result of the strong complementarity between increased capital equipment stocks and skilled labor.

A final note should be made regarding other empirical studies that have addressed the real effects of economic integration processes. There is a large literature on the effects of trade on wages, but the role of free factor mobility, particularly that of migration, has not been emphasized. Gordon (2003) is an exception, which describes the behavior of Mexican wages after NAFTA and finds that Mexican regions with higher levels of Foreign Direct Investment (FDI) and higher rates of migration to the US seem to be associated with greater increases in wage levels and skill premium, which is qualitatively consistent with the results in our work.

The absence of literature empirically evaluating the wage impacts of factor flows is especially true regarding the integration experience of the European Union. More abundant related literature exists on per capita GDP convergence in Europe. This started with the work of Barro and Sala-i-Martin (1991), which, in addition to estimating the European speed of regional convergence, also discusses the small magnitude and role of migration in this process. It also includes the recent contribution by Caselli and Tenreyro (2004), who discuss the per worker GDP convergence experiences of the Western countries in the EU from 1950, and their potential extrapolation to the new Eastern EU members.

This paper is organized as follows. The next section presents the main stylized facts of the Portuguese economy relevant to our questions and to our theoretical modelling and empirical strategies to answer them. Section 3 describes the theoretical framework and its implications. This is followed by section 4, in which the parameters of the technology used in the model (mainly elasticities of substitution between capital equipment and the two types of labor) are estimated. In section 5 wage rates and the skill premium are simulated, and their behavior discussed in light of the capital-skill complementarity hypothesis. The following section quantitatively evaluates the impact of increases in factor flows due to entry in the EU on the behavior of real wages and the skill premium. The last section summarizes the main results of this study and presents directions for future research.

2 Brief Description of the Main Empirical Facts

This section presents the main facts of interest on the Portuguese labor market, and also on Portuguese investment flows and capital stocks that motivate our work. Additional details on data sources, data treatment and alternative indicators are provided in the Data Appendix.

2.1 The Labor Market

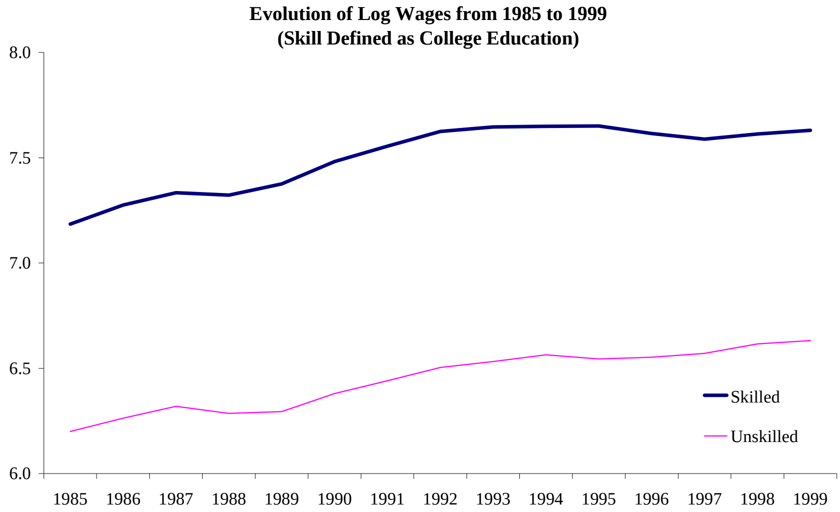
Labor market data are from the *Personnel Files* (PF) collected by the Portuguese Ministry of Labor and span the period 1985 to 1999, which includes the periods immediately before and after Portugal's entry in the EU.

Skilled workers are defined as having completed college. The percentage of the labor force attaining this level of education is rather small - about 7% in 1999. For this reason, one may think that a more meaningful definition of skill would be attainment of 12 years of schooling. We perform a sensitivity analysis of the labor market stylized facts presented in this section and of our empirical findings in the remaining of this work to this alternative definition of skill. Our results point to minor changes in our results and, hence, we choose to use the college definition to ease comparison with studies for other countries.

We begin by looking at the evolution of real wages.[4] These progressed quite rapidly, both for skilled and unskilled workers, especially in the period just after Portugal's integration in the EU and until 1992, when real wage growth started to stagnate for skilled workers, as shown in the following figure.[5]

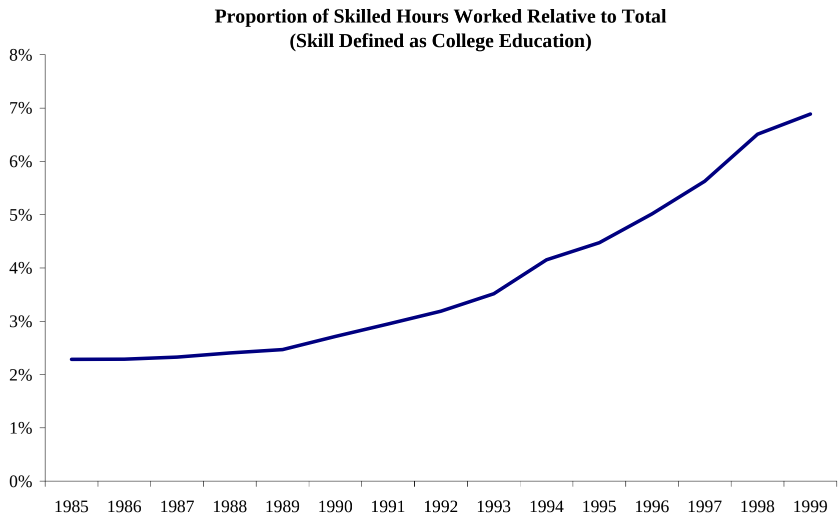
[4] Real wages were obtained by deflating nominal wages with a nondurable consumption price index, to avoid quality adjustment issues.

[5] This simultaneous increase of both skilled and unskilled real wages had already been documented for the 1980's and early 1990's by Gouveia and Albuquerque (1994) and Cardoso (1998).



Source: Own Calculations based on PF.

The labor quantities corresponding to this pattern of wage behavior emphasize a significant human capital accumulation process. There is a very substantial increase of the proportion of skilled (relatively to unskilled) hours worked: it went from a little more than 2% in 1985 to around 7% in 1999, as is displayed in the figure below. This pattern is mainly due to a significant growth in the supply of skilled labor, which averaged 10% per year in the period under analysis, while the supply of unskilled labor also increased but only by an average annual rate of 1.4%.

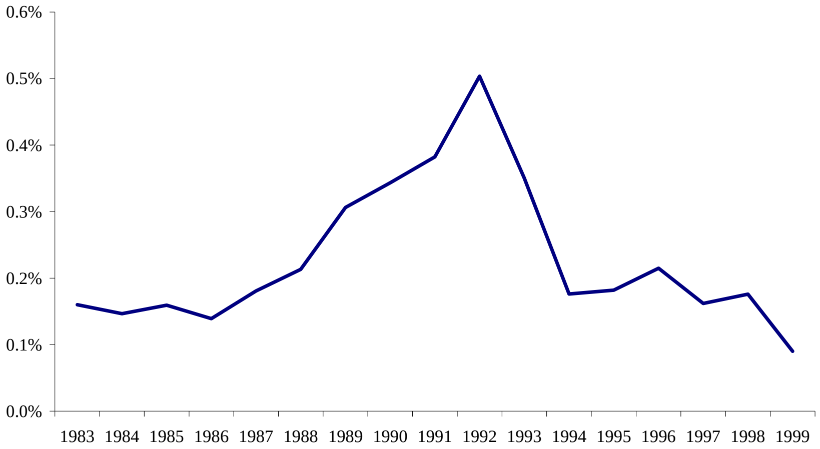


Source: Own calculations based on PF.

Because we would like to understand how factor flows caused by joining the EU have affected real wage behavior, one must naturally present the stylized facts that correspond to these flows.

Regarding emigration, we consider only permanent movements - defined by a migration period of no less than one year. This is to avoid dealing with short-term labor movements, which have increased sharply after Portugal's entry in the EU but are not necessarily related to typical migration decisions that we are interested in understanding.

Permanent Emigration as a Fraction of Total Workforce
(Permanent Defined as Emigration Period Longer than One Year)

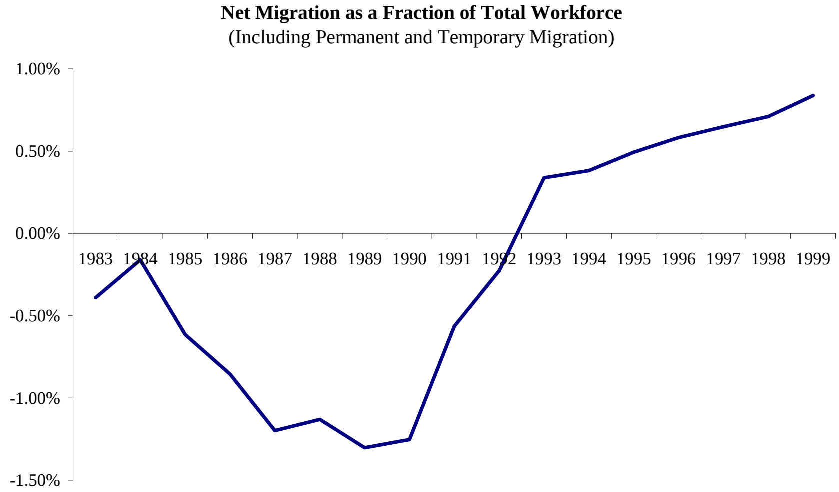


Source: Permanent Emigration Data from INE, and Estimates by Carrilho and Patricio (2003) for 1989-91; Workforce calculated from PWT 6.1.

A striking characteristic of these emigration flows is their small magnitude relative to the total workforce. And, indeed, as the figure illustrates, there was no strong and immediate jump in emigration after 1986. There was only a gradual increase until 1992, the year in which emigration attained a peak. This is probably related to the fact that legal barriers to labor mobility were not immediately abolished when the country entered the EU: indeed, Portugal joined in January 1st, 1986, but full labor mobility was only granted after a transition period, which ended in December 31st, 1991.[6] Note, however, that after this period, emigration flows fell sharply to about their pre-integration levels. This is according additional data from SourceOECD showing that the stock of Portuguese immigrants in EU countries fell from 18.8% to 18% of the total Portuguese workforce.

From the 90s, the most important migratory phenomenon in the Portuguese labor market has indeed been very sizable immigration, and no longer emigration. Even though this phenomenon was not directly created by Portugal's entry in the EU (since most immigrants came and are coming from outside the EU, and do not, therefore, benefit from the European open borders), this may be regarded as its indirect consequence. As is clear from the figure, over our period of interest immigration flows almost offset all emigration that occurs.

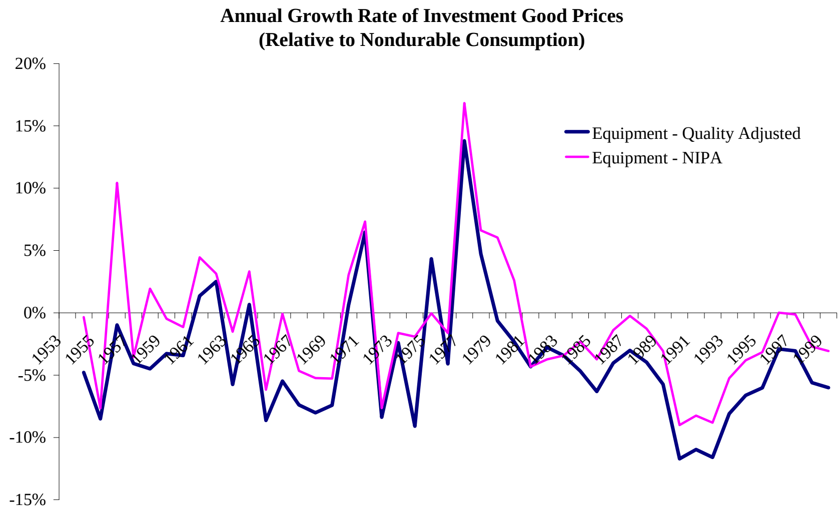
[6] For more details on the accession clauses the reader is referred to European Commission (2001, pp. 14-16).



Source: Net Migration Data from INE; Workforce calculated from PWT 6.1.

2.2 Investment Flows and Capital Stocks

We now pay attention to the evolution of capital stocks and associated investment costs. Following Krusell et. al. (2000), we distinguish between two types of capital: structures and equipment. The reason to do so is that, especially from around 1980, there have been enormous quality improvements in equipment capital, in simultaneous with considerable equipment price decreases. The true magnitude of these decreases can be captured by performing a quality change adjustment in the equipment price series, in the spirit of Gordon (1990). The impact of our quality adjustment can be appreciated in the following table and figure:

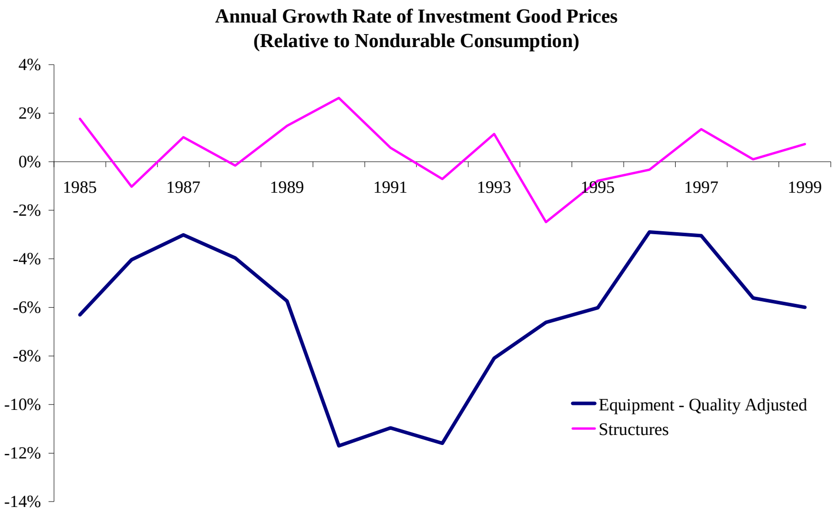


Source: Own calculations based on BoP, Long series for the Portuguese Economy, and INE, Quarterly National Accounts Bulletin 1995-1999.

Average Annual Change in Price of Equipment (Relative to Nondurable Consumption)	1954-99	1985-99
Quality Adjusted	-3.81%	-6.37%
NIPA	-1.11%	-3.59%

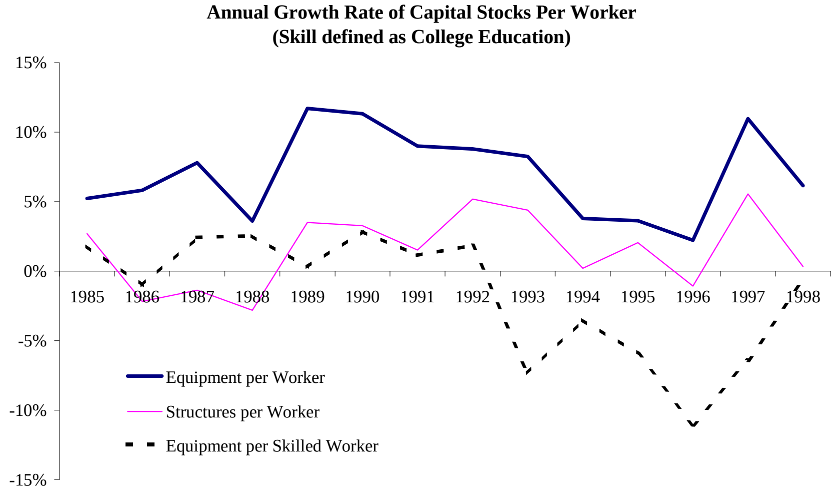
Source: Own calculations based on BoP, Long series for the Portuguese Economy, and INE, Quarterly National Accounts Bulletin 1995-1999.

By any measure, it is clear that the relative price of capital equipment has been declining over time, which is especially true between 1985 and 1992. This may be interpreted as technological change specific to the production of capital equipment, as investigated by Greenwood et. al. (1997), which is corroborated by the approximate constancy of the relative price of structures over our period of analysis, as the following figure makes clear.



Source: Own calculations based on BoP, Long series for the Portuguese Economy, and INE, Quarterly National Accounts Bulletin 1995-1999.

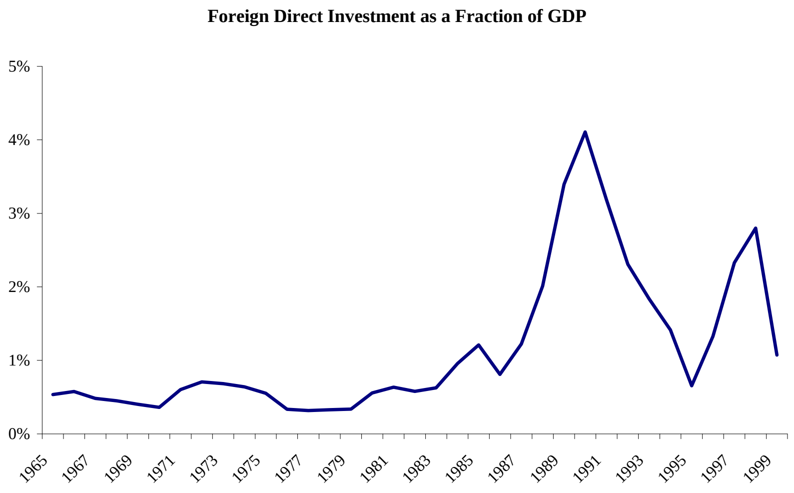
Another reason to distinguish between capital equipment and structures is the fact that equipment stocks have experienced impressive growth rates especially between 1986 and 1993, as is patent in the following figure, where both capital stocks are expressed in per worker terms, and equipment stock reflects adjustment for quality improvements.



Source: Own calculations based on PF, BoP - *Long series for the Portuguese Economy*, and INE - *Quarterly National Accounts Bulletin 1995-1999*.

This figure also displays the behavior of the equipment to skilled labor ratio. This was, on average, increasing from 1986 to 1993, but started to fall significantly from 1992. This piece of evidence seems to point in the direction of the capital-skill complementarity hypothesis (to be formally defined in the following section) as a good candidate to explaining the behavior of skilled wages, which also grew strongly until around 1992, but not thereafter.

We now turn to consider foreign capital inflows.[7] Foreign Direct Investment (FDI) displays a rather irregular pattern over time, as can be observed from the figure below. After an explosive increase, unprecedented in the Portuguese history, FDI fell sharply around 1992. According to Lopes (1999) this should be attributed to the recession that affected Europe at that time, as well as to the Portuguese escudo real appreciation.

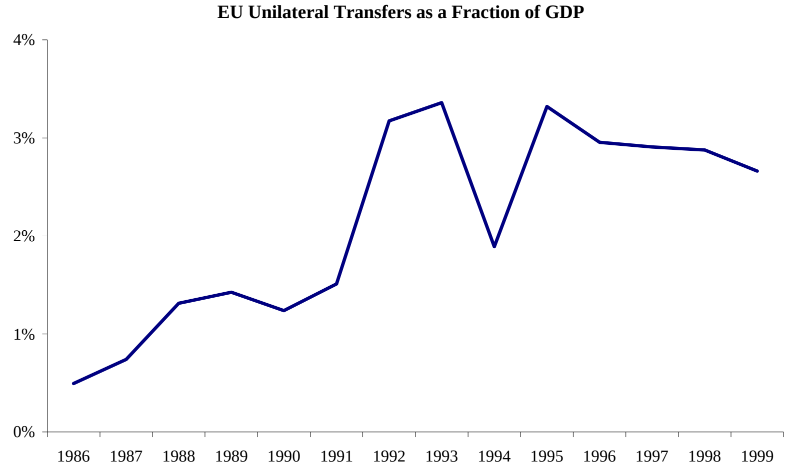


Source: Bank of Portugal: Long Series for the Portuguese Economy (1965-1995) and Balance of Payments Statistics.

Note that FDI likely underestimates foreign investment inflows, which may be included under foreign portfolio investment, for instance. These were, however, extremely volatile during our period of interest.

In addition to FDI, we consider unilateral transfers from the EU, which started in 1986 and steadily increased also until 1992. From this year, they remained relatively stable over time, as is depicted in the figure below.

[7] These flows are all measured in net terms: this is especially important for the case of FDI, where it could be argued that the increase observed after integration was due to the world trend of capital movement liberalization.



Source: Bank of Portugal: Long Series for the Portuguese Economy (1965-1995) and Balance of Payments Statistics.

To summarize, we believe the stylized facts for Portugal to be quite interesting and distinct from those of other studied OECD economies, in terms of fast human capital accumulation, skill premium behavior[8], and physical capital accumulation.

We have unveiled two distinct periods, which are distinct not only in terms of skilled wage growth (first increasing, then stagnated), but also in terms of approximately contemporaneous comovements in stocks and prices of equipment, and skilled labor-equipment ratio. Note that the sharp growth of FDI and transfers from the EU until 1992 helps explaining why total investment growth was so fast in that period, since in addition to their direct effect, domestic investment (both private and public) likely increased to complement foreign investment.

3 Model of a Small Economy Open to Factor Flows

The model in this section describes the process of a small economy opening to capital inflows and labor outflows, as experienced by Portugal when entering the EU. It aims at reconciling the pieces of empirical evidence presented in the previous section in a one-country model economy in the spirit of section 2 in Stokey (1996), which opens to costly migration and capital flows.

The technology in this model displays capital-skill complementarity in the sense first formalized by Griliches (1969): skilled labor is more complementary with capital than unskilled labor.[9] This property of the aggregate production function is formalized in Stokey (1996), on which Krusell et. al. (2000) build to develop a more complex functional form that is empirically tested and found to have strong support in the US data. This is the functional form adopted in our model.

In particular, the aggregate production function distinguishes between the role of four different inputs, which agrees with the observed empirical facts The distinct evolution of both quantities and prices of capital structures and equipment motivated the inclusion of these two types of capital. The observed pattern of human capital growth and its associated pattern of skill premium lead us to differentiate between skilled and unskilled labor.

Stokey (1996) develops a fully specified general equilibrium model, under which attention is paid to three cases: a benchmark closed economy, capital inflows in a small open economy, and free trade of goods following

[8] Recall that Davis (1992) studied the skill premium behavior in the 1980s in nine OECD economies, and also in Brazil, Colombia, South Korea and Venezuela. He found increasing skill premia in seven of the OECD economies and in Brazil.

[9] For more details on how capital-skill complementarity has been modelled in the literature, in particular with attention to its role in explaining income inequality, the reader is referred to Batista (2002).

economic integration of the small open economy in a more developed area. This framework allows addressing the issue of the development of an economy evolving from autarchy to complete economic integration of the type allowed by NAFTA. However, because integration in the EU also involves abolishing barriers to labor mobility, this model needs to be extended to allow for labor movements.

In modelling labor flows, the empirical importance of migration costs[10] is matched by the introduction of a migration cost parameter, which should be interpreted as unofficial migration barriers, travelling and differential housing costs, psychological and other costs borne by emigrants related to the loss of local amenities.[11] For simplicity, these costs are assumed to be common for both skilled and unskilled workers.

The following sections set the model up in more detail.

3.1 Technology

In this economy, production of homogeneous output at date t, $Y(t)$, occurs according to a homogeneous of degree one aggregate production function with four production factors, as in Krusell et. al. (2000):

$$Y(t) = A(t).F\left[K_s(t), K_e(t), U(t), S(t)\right]$$

where $K_e(t)$ and $K_s(t)$ denote, respectively, the services of capital equipment and structures used in production[12]; $U(t)$ and $S(t)$ stand, respectively, for the unskilled and skilled labor inputs to production at date t [13]; and $A(t)$ is a country-specific Hicks neutral technological factor, which is introduced to account for the type of cross-country TFP level differences highlighted by Hall and Jones (1999) and Parente and Prescott (2000).

As noted by Greenwood et. al. (1997) and Krusell et. al. (1997), such an aggregate production function may be thought of as representing a two-sector economy, where one sector produces capital equipment goods, and the other produces capital structures and consumption goods. Assume that there is a common neutral technology factor $A(t)$ and a common production function F, but the equipment sector has a specific technology factor $q(t)$, which defines the relative price of equipment in terms of consumption goods $(1/q(t))$ Then, as long as F is homogeneous of degree one and factor markets are perfectly competitive, profit-maximizing firms will allocate the inputs so that input ratios will be equalized across sectors and the equilibrium relative price between consumption and equipment will be $q(t)$. The two sectors may under these conditions be aggregated, yielding

$$Y(t) = C(t) + X_s(t) + \frac{X_e(t)}{q(t)}$$

where $C(t)$ represents consumption good output, $X_e(t)$ stands for investment in capital structures, and $X_s(t)$ denotes output of the equipment sector

The choice of the functional form for the aggregate production function, F, pursues the objective of compatibility with the capital-skill complementarity hypothesis, i.e. the elasticity of substitution between capital and unskilled labor being larger than that between capital and skilled labor, as suggested by the data. We adopt the functional form used by Krusell et. al. (1997, 2000), which these authors verified to be

[10] This empirical role has been studied in the context of the small magnitude of internal migration within European countries. Namely, the fact that migration does not seem to respond to shocks (that cause, for instance, increased regional unemployment) seems to point to the presence of significant costs, which should be regarded as a lower bound to migration costs of international migration within Europe, given the language and cultural differences across countries. References are, for Italy, Attanasio and Padoa Schioppa (1991), Faini et. al. (1997), and Cannari et. al. (2000); and, for Spain, Bentolila (1997), Antolin and Bover (1997), and Bover and Velilla (1999).

[11] Note that these costs are distinct from "assimilation costs" derived from language and cultural differences that affect a worker's productivity in the host country, relative to nationals of that country. Sjaastad (1962) presents the seminal analysis of migration as a human capital investment decision, clearly discussing the role of different types of costs and benefits of migrating.

[12] The services of both types of capital are assumed to be proportional to the original capital stocks, measured in efficiency units.

[13] We assume that $U(t)$ and $S(t)$ add to L, the national workforce of the country, which is, for simplicity, taken as constant over time, i.e. number of retiring people equals number of workers entering the force. This implies that we are abstracting from the existence of unemployment in this economy.

consistent with available elasticity estimates and to fit well US data, and use the following specification:[14]

$$Y(t) = A(t).K_s(t)^{\alpha}.\tilde{Y}(t)^{1-\alpha}$$

where

$$\tilde{Y}(t) = \left[\mu.U(t)^{\theta} + (1-\mu)\left(\lambda.K_e(t)^{\rho} + (1-\lambda).S(t)^{\rho}\right)^{\frac{\theta}{\rho}}\right]^{\frac{1}{\theta}}$$

and

$$0 < \alpha,\ \mu,\ \lambda < 1 \text{ and } \theta,\ \rho < 1$$

This is just a Cobb-Douglas production function in capital structures K_s and the aggregate $\tilde{Y}$, which nests two Constant Elasticity of Substitution (CES) production functions. This nesting implies that the elasticity of substitution between unskilled labor and capital equipment is the same as that of unskilled labor and skilled labor, $1/(1-\theta)$, but this potentially differs from the elasticity of substitution between skilled labor and capital equipment, which is given by $1/(1-\rho)$. Capital-skill complementarity therefore translates in this model simply as $\theta > \rho$, meaning that capital is more complementary with skilled than with unskilled labor.

This function may be interpreted, in the spirit of Goldin and Katz (1998), as a two-stage production function: in a first phase, there is machine installation and maintenance (skilled workers adopt new technologies and ensure they work efficiently in the organization); then, there is the machine assembly and production stage (which has unskilled workers using the product of the skilled labor effort and equipment).

Rewriting the production function in per (national) worker terms, we obtain

$$y(t) = A(t).f\left[k_s(t), k_e(t), z(t)\right] = A(t).k_s(t)^{\alpha}.\left[\mu\left(1-z(t)\right)^{\theta} + (1-\mu)\left(\lambda k_e(t)^{\rho} + (1-\lambda)\, z(t)^{\rho}\right)^{\frac{\theta}{\rho}}\right]^{\frac{1}{\theta}}$$

where

$$y(t) \equiv \frac{Y(t)}{L};\ z(t) \equiv \frac{S(t)}{L};\ k_i(t) \equiv \frac{K_i(t)}{L},\ i = s, e$$

Competitive firms' profit maximizing choices determine the following interest rates and level of skill premium:

$$\begin{aligned} r_s(t) &= A(t).f_1\left[k_s(t), k_e(t), z(t)\right] \\ r_e(t) &= A(t).f_2\left[k_s(t), k_e(t), z(t)\right] \\ w_z(t) - w_u(t) &= A(t).f_3\left[k_s(t), k_e(t), z(t)\right] \end{aligned}$$

where $r_s(t)$ and $r_e(t)$ denote the rental rates of capital structures and equipment, respectively, and $w_z(t)$ and $w_u(t)$ stand for the wage rates paid to skilled and unskilled workers, respectively.

3.2 Introducing Migration

Recall that we are assuming that there are no restrictions to factor mobility in this country.

If (exogenous) foreign wages, $w_i^*(t)$, $i = z, u$, are initially high enough so that the representative household optimally chooses positive emigration, we can define $m_z(t)$ and $m_u(t)$ as the fractions of the labor force L that are (stocks of) skilled and unskilled emigrants, respectively. These are chosen by the representative household at each date. In their optimization problem, families must consider the cost ψ incurred when migrating. This cost can be thought of as cultural/psychic separation costs and transportation and other pecuniary costs. For simplicity, ψ is assumed to be the same regardless of skill level.

[14] One possible alternative was $Y = \Phi_1\left(K, \Phi_2\left(U, S\right)\right)$. However, this form does not give rise to capital-skill complementarity, but to the technology-skill complementarity modelled by Heckman, Lochner and Taber (1998), as noted by Greenwood and Jovanovic (1999).

One other possible alternative would be $Y = \Phi_1\left(S, \Phi_2\left(U, K\right)\right)$, as proposed by Stokey (1996). This implied, however, that the elasticities between skilled labor and equipment and between skilled and unskilled labor should be equal, which is contrary to the empirical observation that the former is smaller than the latter.

The possibility of emigration implies that production will be given by

$$\begin{aligned} y(t) &= A(t).f\left[k_s(t), k_e(t), z(t), m_z(t), m_u(t)\right] \\ &= A(t).k_s(t)^{\alpha}.\left[\mu\left(1 - z(t) - m_u(t)\right)^{\theta} + (1-\mu)\left(\lambda k_e(t)^{\rho} + (1-\lambda)\left[z(t) - m_z(t)\right]^{\rho}\right)^{\frac{\theta}{\rho}}\right]^{\frac{1}{\theta}} \end{aligned}$$

where $m_z(t)$ and $m_u(t)$ are taken as given.

This implies the same profit maximizing conditions for competitive firms as before:

$$\begin{aligned} r_s(t) &= A(t).f_1\left[k_s(t), k_e(t), z(t), m_z(t), m_u(t)\right] \\ r_e(t) &= A(t).f_2\left[k_s(t), k_e(t), z(t), m_z(t), m_u(t)\right] \\ w_z(t) - w_u(t) &= A(t).f_3\left[k_s(t), k_e(t), , z(t), m_z(t), m_u(t)\right] \end{aligned}$$

Given the homogeneity of degree 1 property of the aggregate production function in both countries, Euler theorem implies that domestic product per worker is equal to:

$$y(t) = w_z(t).\left[z(t) - m_z(t)\right] + w_u(t)\left[1 - z(t) - m_u(t)\right] + r(t).k(t)$$

3.3 Preferences

Households are assumed to supply labor inelastically and to privately finance all investment in human capital. Accumulation of human capital is subject to adjustment costs, contrary to physical capital accumulation. This is an unrealistic simplifying assumption, but it should not affect the pattern of transitions, only exaggerate its speed. Adjustment costs are introduced by the parameters $0 < \phi, B < 1$. Human capital depreciates at the rate $0 < \eta < 1$, which includes the effects of retirement. In addition to choosing optimal emigration paths, the representative households must determine consumption per worker $c(t)$, and investment in human capital $z(t)$.

Free capital mobility implies that the path of both types of physical capital will be a function of the households' choice for z, m_z, and m_u, in a way that their marginal productivity always exactly equals the corresponding depreciation rate (δ_s and δ_e, respectively) plus the world interest rate (ρ).

$$A.f_1\left[k_s\left(z, m_z, m_u\right), k_e\left(z, m_z, m_u\right), z, m_z, m_u\right] = \delta_s + \rho \tag{1}$$

$$A.f_2\left[k_s\left(z, m_z, m_u\right), k_e\left(z, m_z, m_u\right), z, m_z, m_u\right] = \delta_e + \rho \tag{2}$$

Because the representative household can borrow and lend at the world interest rate, its investment and consumption decisions can be thought of as separated. The investment problem therefore corresponds to the choice of the human capital and migration levels that maximize the discounted labor income stream net of migration and human capital investment costs:

$$\max_{\{I_z(t),\ m_z(t),\ m_u(t),\ t\ \geq 0\}} \int_0^{\infty} e^{-\rho t}\begin{bmatrix} w_z(t).\left[z(t) - m_z(t)\right] \\ +w_u(t).(1 - z(t) - m_u(t)) \\ +w_z^*(t).m_z(t) + w_u^*(t).m_u(t) \\ -I_z(t) - \psi.\left[m_z(t) + m_u(t)\right] \end{bmatrix} dt$$

$$s.t. \qquad \dot{z}(t) = BI_z(t)^{\phi} - \eta.z(t)$$

taking $z_0, \{w_z(t), w_u(t), w_z^*(t), w_u^*(t), t \geq 0\}$ as given.

Optimality requires the following conditions to hold:

$$w_z(t) = w_z^*(t) - \psi \qquad if \quad m_z(t) > 0 \tag{3}$$

$$w_u(t) = w_u^*(t) - \psi \qquad if \quad m_u(t) > 0 \tag{4}$$

$$\dot{z}(t) = B^{\frac{1}{1-\phi}}\left[\phi\mu(t)\right]^{\frac{\phi}{1-\phi}} - \eta.z(t) \tag{5}$$

$$\frac{\dot{\mu}(t)}{\mu(t)} = \eta + \rho - \frac{1}{\mu(t)}.A.f_3\left[k_s(z(t), m_z(t), m_u(t)), k_e(z(t), m_z(t), m_u(t)), z(t), m_z(t), m_u(t)\right] \tag{6}$$

where $\mu(t)$ is the co-state for $z(t)$.

The consumption problem solved by households is to maximize lifetime utility, subject to their lifetime earnings:

$$\max_{\{c(t),\ t\ \geq 0\}} \quad \int_0^\infty e^{-\rho t}\frac{c(t)^{1-\sigma}-1}{1-\sigma}dt$$

$$s.t. \quad \int_0^\infty e^{-\rho t}c(t)dt \leq \int_0^\infty e^{-\rho t}\left[\begin{array}{c} w_z(t).\left[z(t)-m_z(t)\right] \\ +w_u(t).(1-z(t)-m_u(t)) \\ +w_z^*(t).m_z(t)+w_u^*(t).m_u(t) \\ -I_z(t)-\psi.\left[m_z(t)+m_u(t)\right] \end{array}\right]dt+k_s\left(0\right)+k_e\left(0\right)$$

given $k_s\left(0\right), \ k_e\left(0\right).$

The solution to this problem is given by a constant stream of consumption ($\bar{c}$) which has a discounted value equal to the maximized value of the objective function of the investment problem, $V(z\left(0\right))$.

$$\frac{\bar{c}}{\rho}=V(z\left(0\right))+k_s\left(0\right)+k_e\left(0\right)$$

where $t=0$ corresponds to the date of opening the economy to factor flows.

The steady-state values for human and physical capital are the same as before the economy opened to factor flows, and are given by:

$$\begin{array}{rcl} A.f_1\left[\bar{k}_s,\bar{k}_e,\bar{z},\bar{m}_z,\bar{m}_u\right] & = & \delta_s+\rho \\ A.f_2\left[\bar{k}_s,\bar{k}_e,\bar{z},\bar{m}_z,\bar{m}_u\right] & = & \delta_e+\rho \\ A.f_3\left[\bar{k}_s,\bar{k}_e,\bar{z},\bar{m}_z,\bar{m}_u\right] & = & (\eta+\rho)\left(\phi^{-1}B^{-\frac{1}{\phi}}\left[\eta.\bar{z}\right]^{\frac{1-\phi}{\phi}}\right) \end{array}$$

where an upper bar denotes a steady-state value.

These steady-state levels are set so that the productivity of all types of capital exactly offsets depreciation and discount rates - adjusted for the impact of adjustment costs in the case of human capital.

The transitional dynamics for this economy are given by (5) and (6) for human capital and its co-state. The two types of physical capital adjust so that their rate of return keeps constant given household's choices for human capital and migration, as described by (1) and (2).

At this stage, the theoretical analysis performed qualitatively describes how opening economies to factor flows is enough to ensure cross-country wage convergence up to a wedge (created by migration costs ψ) in an initial stage of transition. This is the result of a decision of households to migrate immediately after this becomes allowed in order to equalize wages net of migration costs. During transition to the steady-state, however, as human capital accumulation leads national wage differentials to fall below ψ, there will be return migration.

Quantifying these effects is not straightforward provided that the parameters in the production function (and implied elasticities of substitution) have not been estimated for Portugal, and that there are no measures available in the literature for ψ. This dictates our next steps, beginning with the estimation of the technology parameters.

4 Estimating Aggregate Elasticities of Substitution

We estimate the parameter values of the aggregate production function using actual data for productive inputs, as well as the first order conditions of profit maximizing firms acting in competitive factor markets, in the tradition of Griliches (1969).[15] This empirical strategy builds on the work of Krusell et. al. (1997, 2000), Ohanian et. al. (2000), and Greenwood et. al. (1997).

[15] Griliches (1969) argued that substitution elasticities between different factors of production should be estimated using derived demand equations instead of the production function.

4.1 Econometric Model

We begin by specifying the stochastic nature of the production function.

Labor inputs in our model are defined in efficiency units - such that $S(t) \equiv \psi_s(t).h_s(t)$, and $U(t) \equiv \psi_u(t).h_u(t)$. The efficiency indices $\left(\psi_{s_t} \text{ and } \psi_{u_t}\right)$ are not observed by the econometrician, and Ohanian et. al. (2000) argue in favor of modelling $\varphi_t \equiv \begin{bmatrix} \ln \psi_s(t) \\ \ln \psi_u(t) \end{bmatrix}$ as a trend stationary process:

$$\varphi_t = \varphi_0 + \gamma.t + \varpi_t$$

where $\varpi_t \overset{i.i.d.}{\sim} N(0, \Omega)$, and $\gamma \equiv \begin{bmatrix} \gamma_s \\ \gamma_u \end{bmatrix}$ is the vector of constant growth rates of labor efficiency.[16]

Given this stochastic specification of the production function, we can now turn to detailing our econometric model. Our procedure will be to use restrictions implied by the theoretical model in order to achieve identification of its parameters, which may be implemented by using the following nonlinear state-space model:

$$\begin{aligned} Z_t &= g(X_t, \varphi_t; \phi) + e_t && \text{(Observation equations)} \\ \varphi_t &= \varphi_0 + \gamma.t + \varpi_t && \text{(State equations)} \end{aligned}$$

with observed variables $X_t \equiv \{K_{s_t}, K_{e_t}, h_{s_t}, h_{u_t}\}$, parameters $\phi \equiv \{\delta_s, \delta_e, \alpha, \mu, \lambda, \theta, \rho, \eta_e, \varphi_0, \gamma, \Omega\}$, and shocks $e_t \equiv \begin{bmatrix} 0 \\ 0 \\ \varepsilon_t \end{bmatrix}$, where $\varepsilon_t \overset{i.i.d.}{\sim} N(0, \eta_\varepsilon^2)$.

The observation equations summarize the model restrictions: Z_t displays the data counterparts to the expressions derived from the model, $g(X_t, \varphi_t, e_t; \phi)$. Since we have data on hours worked and on corresponding wages, we can use the representative firm's first-order conditions for skilled and unskilled labor to construct the theoretical counterparts to the labor share of income and to the wage-bill ratio - corresponding, respectively, to the first and second observation equations. We do not, however, possess reliable measures for the rental rates of capital structures and equipment goods. Therefore, the third observation equation will be a no arbitrage condition, imposed to ensure that the difference between the model counterparts to these unobserved rates is close to zero.

We will therefore have

$$Z_t \equiv \begin{bmatrix} shl_t \\ wbr_t \\ 0 \end{bmatrix} \tag{7}$$

and

$$g(X_t, \varphi_t, e_t; \phi) \equiv \begin{bmatrix} \left(w_{st}.h_{st} + w_{ut}.h_{ut}\right)/y_t \\ \left(w_{st}.h_{st}\right)/\left(w_{ut}.h_{ut}\right) \\ \left[r_{s\,t+1} + (1-\delta_s)\right] - \left[q_t\ r_{e\,t+1} + E_t\left[\frac{q_t}{q_{t+1}}\right](1-\delta_e)\right] \end{bmatrix} \tag{8}$$

where q_t is defined as the price of equipment relative to nondurables.

To simplify, we assume $E_t\left[\frac{q_t}{q_{t+1}}\right](1-\delta_e) = \frac{q_t}{q_{t+1}}(1-\delta_e) + \varepsilon_t$, where ε_t is the forecast error. Note that, since the relative price of equipment has been falling over time, $\frac{q_t}{q_{t+1}}(1-\delta_e) + \varepsilon_t$ corresponds to the expected capital loss on equipment after depreciation.[17]

An additional simplifying assumption will be to abstract from any time trend in the efficiency levels of skilled and unskilled labor. The state equations in our estimation will then be given by $\varphi_t = \varphi_0 + \varpi_t$.

[16] Ohanian et. al. (2000) discuss the details implied by using this trend stationary specification, as well as potential alternatives and their consequences.

[17] To express it in this form, we follow KORV and assume that A_{t+1} and φ_{t+1} are known when investment decisions are made, q_{t+1} being the only unknown at that date.

Moreover, we abstract from the potential existence of a risk premium (which enables us to ignore the covariance between consumption and capital returns), and take the tax treatment on structures and equipment investment to be identical.

4.2 Estimation Procedure

4.2.1 Preliminary Parameter Calibration

Since we only have 15 years of observations for all relevant variables, we must reduce the dimensionality of the parameter vector (15) before proceeding with the estimation. This is achieved by means of calibrating some parameters and of imposing additional restrictions (not derived from the model) based on available *a priori* information.

First, we use the Greenwood et. al. (1997) values for the depreciation rates, which we have already used to construct the capital stock series: $\delta_s = 0.056$ and $\delta_e = 0.124$.

We then need to calibrate η_ε. For this purpose, we performed some diagnostic tests (Phillip-Perron) and concluded that the hypothesis that $\frac{q_t}{q_{t+1}}$ was covariance stationary could not be rejected even at a 1% confidence level. After some more diagnostic checks (ACF and PACF), we concluded it would be best represented as an ARMA(1,2) model. From the estimation of this model, we obtained an estimate for the residuals' standard variation of $\hat{\sigma}_\varepsilon = 0.042$. Multiplying this standard deviation by $(1-\delta_e)$, we obtained our estimate for $\eta_\varepsilon = 0.0396$.[18]

Following Krusell et. al. (1997), one additional simplifying restriction that we impose is that the shocks to skilled and unskilled labor efficiency are uncorrelated and have common variance, which is very much in accordance with our results from estimating ARMA processes for both skilled and unskilled labor inputs. This implies that we can write $\Omega = \eta_{\varpi}^2 * I_2$, where η_{ϖ} is the common innovation standard deviation, which takes a value of 0.2.

One other restriction is necessary to set the scale of the model (which is not a model of levels of the variables). We could normalize μ, λ, φ_{s0} or φ_{u0}. Still following Krusell et. al. (2000), we choose to normalize the initial level of skilled labor efficiency, φ_{s0}, to zero.

Finally, we follow the procedure proposed by Lindquist (2004) to calibrate α, the average yearly share of national income for capital structures. For this purpose, we assume a common return for capital equipment and structures, $r = r_e = r_s$, which we take to be 6%, consistently with the findings reported by Citron and Walton (2002). This implies that

$$\alpha = \frac{1}{15}\sum_{t=1985}^{1999}\left[\frac{(r+\delta_s)\,k_{st}}{(r+\delta_s)\,k_{st}+(r+\delta_e)\,k_{et}}\,(1-shl_t)\right] = 0.28$$

In summary, we will consider the following calibrated values:

α	δ_s	δ_e	η_ε	η_w	φ_{s0}	γ_{st}	γ_{ut}
0.28	0.056	0.124	0.04	0.2	0	0	0

In this manner, we have managed to use our *a priori* information to reduced the dimension of our parameter vector to five (μ, λ, θ, ρ andφ_{u0}). Although this calibration of parameters naturally adds uncertainty to the overall empirical exercise, which we do not take into account when evaluating our estimation results, we believe it to be advantageous because of the degrees of freedom it also brings.

4.2.2 Simulated Pseudo Maximum Likelihood Estimation (SPMLE)

Ohanian et. al. (2000) show that, when unobserved variables are multivariate Gaussian trend stationary processes, Simulated Pseudo Maximum Likelihood Estimation (SPMLE) of our non-linear latent variable model, based on an approximated likelihood function constructed from the first and second moments of the dependent variables, produces parameter estimates with negligible bias in small samples, with computational efficiency. Following their work, we decided to also perform a two-stage version of SPMLE.[19]

[18] Note that, in order to increase the accuracy of the estimation procedure, we used at this stage our equipment relative price measure (adjusted for changes in quality) for the longer period 1953-1999.

[19] The SPMLE method is due to Laroque and Salanie (1989). Its basic idea is that instead of using an intractable original likelihood, one may simulate the associated empirical moments necessary to construct a simpler function.

The two-step version of SPMLE introduced by White (1994), Ch.7, takes into account potential endogeneity of the labor inputs (which may respond to contemporaneous shocks in technology and/or labor quality). We assume capital stocks of both equipment and structures to be predetermined in this sense, given their large magnitude and small volatility relative to investment (which makes them less likely to respond sizably to i.i.d. shocks).

A more detailed explanation of the estimation procedures is provided in appendix. We next present a brief summary.

In the first step, we pay attention to the issue of potential endogeneity of the labor inputs by predicting skilled and unskilled hours worked based on a simple regression on current and lagged stocks of equipment and structures, lagged relative price of equipment, a business cycle indicator and a time trend:

$$\begin{aligned} h_{i_t} &= \beta_1+\beta_2K_{e_t}+\beta_3K_{e_{t-1}}+\beta_4K_{s_t}+\beta_5K_{s_{t-1}}+\beta_6q_{t-1}+\beta_7t+\beta_8BC_{t-1}+v_t\ , \\ \text{for } i &= s_t,\ u_t,\ t=1,\ ...,\ 15 \end{aligned} \tag{9}$$

From these estimations we obtained the fitted labor inputs, which will be used in the second step, instead of the original labor inputs.

In this second step, we implement SPMLE. We start by performing 500 simulated draws for ε_t and ϖ_t from their assumed distributions, for each date t.[20] We construct φ_t^i for $i = 1$ ...500, $t = 1$ ...15, which allows us to compute $f(X_t, \varphi_t^i, ei; \phi)$ for $i = 1$ ... 500, $t = 1$ ...15. We then use this computation to calculate the first and second sample moments of the model's counterparts to Z_t, which are given by:[21]

$$m_{500}\left(Xt;\phi\right) = \frac{1}{500}\sum_{i=1}^{500} f(X_t,\varphi_t^i,e_t^i;\phi) \text{ for } t=1 \text{ ...15} \tag{10}$$

$$V_{500}\left(Xt;\phi\right) = \frac{1}{499}\sum_{i=1}^{500}\left[Zt-f(X_t,\varphi_t^i,e_t^i;\phi)\right]\left[Zt-f(X_t,\varphi_t^i,e_t^i;\phi)\right]' \text{ for } t=1 \text{ ...15} \tag{11}$$

This allows us to write the log-likelihood function for Z_t, using the additive separability and normality assumed for ε_t. It is given by

$$\begin{aligned} L_{500}(Z;\phi) &= \frac{1}{30}\sum_{t=1}^{15}\left[Z_t-m_{500}(X_t;\phi)\right]'\cdot\left(V_{500}\left(Xt;\phi\right)\right)^{-1}\cdot\left[Z_t-m_{500}(X_t;\phi\right]+ \\ &\quad +\frac{1}{30}\sum_{t=1}^{15}\ln\left(\det\left[V_{500}\left(Xt;\phi\right)\right]\right) \end{aligned} \tag{12}$$

Our estimator $\hat{\phi}_{500,15}^{PSML}$ is then obtained by maximization of this likelihood function.[22]

The two-step SPML parameter vector estimate and its standard errors are the following: [23]

[20] The number of simulations we performed is the same used by Krusell et al. (2000). Its choice was determined by the study conducted in Ohanian et al.(2000), which asserted that 50 simulations were enough to ensure that the mean bias was "essentially zero in our model for the key curvature parameters θ and ρ", and also by the fact that from this number of simulations on the estimated parameters suffered a negligible change due to simulation uncertainty.

[21] As noted by KORV, these simulated values must be kept throughout our whole exercise, so that the likelihood function does not become itself a random object.

[22] According to the results presented in Ohanian et al.(2000), our estimator has no approximation bias and is consistent and asymptotically normal, so that as $S \to \infty$, $T \to \infty$ and $\frac{\sqrt{T}}{S} \to 0$,

$$\sqrt{T}\left(\hat{\phi}_{ST}-\phi_0\right) \to N\left(0, J_0^{-1}\cdot I_0\cdot J_0^{-1}\right)$$

where $I = E\left[\frac{\partial L(Z_t;X_t,\phi_0)}{\partial\phi}\cdot\frac{\partial L(Z_t;X_t,\phi_0)}{\partial\phi'}\right]$ and $J = E\left[-\frac{\partial^2 L(Z_t;X_t,\phi_0)}{\partial\phi\partial\phi'}\right]$.

Also, the simulation bias is extremely small already at S=20.

[23] Standard errors calculation is based on the asymptotic covariance matrix $\frac{1}{T}\left(J_0^{-1}\cdot I_0\cdot J_0^{-1}\right)$, where the sam-

Parameter	ρ	θ	μ	λ	φ_{u0}
Estimate	-0.9015	0.1675	0.2136	0.0897	-13.22
(White Std Error)	0.4510	0.1671	0.0393	0.5554	0.0048

The estimated values are consistent with the capital-skill complementarity hypothesis, given that the estimated value for θ is significantly larger than ρ. In addition, the elasticity estimates implied by our estimates are all sensible in light of the values reviewed by Hamermesh (1993) and Krusell et. al. (1997).[24]

Indeed, our estimates are not dramatically different from the ones estimated by Krusell et. al. (2000) for the US economy, although our values imply lower elasticities of substitution between equipment and both skilled labor and unskilled labor, which means there is a lower degree of capital-skill complementarity. The values we obtain are, however, close to those estimated by Lindquist (2004) for another European country, Sweden.

Implied Elasticity between Equipment and Labor *Country − Source*	*Skilled* $\left(\frac{1}{1-\rho}\right)$	*Unskilled* $\left(\frac{1}{1-\theta}\right)$
Portugal - own results	0.53	1.20
US - Krusell et. al. (2000)	0.67	1.67
Sweden - Lindquist (2004)	0.52	1.40

The degree of substitutability between equipment and unskilled labor (which is restricted to be the same as that between skilled and unskilled labor, given the functional form adopted for the production function) is especially lower than that estimated for the US and Sweden, which may reflect the poor quality of the Portuguese unskilled labor force.

5 Simulation of Wage Rates and of the Skill Premium

The objective of this section is to empirically evaluate the technology we proposed by testing its ability to predict real wage and skill premium behavior. For this purpose, we simulate these variables using actual input data, the parameters estimated in the previous section, and our calculations for the TFP series, $\{A_t\}_{t=1985}^{1999}$.

We will abstract from relative efficiency issues by assuming that unobservable efficiency levels of labor $\left(\psi_{s_t} \text{ and } \psi_{u_t}\right)$ remained constant over our period of analysis. This assumption allows us to focus on the extent to which observable variables only can explain the behavior of our variables of interest.

Since we want to abstract from changes in the (unobservable) efficiency levels of labor, we normalize ψ_{s_t}

ple counterparts to I and J are given by: $\hat{I}_{500,15} = \frac{1}{15}\sum_{t=1}^{15}\left[\frac{\partial L(Z_t;X_t,\hat{\phi}_{500,15})}{\partial\phi}\cdot\frac{\partial L(Z_t;X_t,\hat{\phi}_{500,15})}{\partial\phi'}\right]$ and $\hat{J}_{500,15} = \frac{1}{15}\sum_{t=1}^{15}\left[-\frac{\partial^2 L(Z_t;X_t,\hat{\phi}_{500,15})}{\partial\phi\partial\phi'}\right]$.

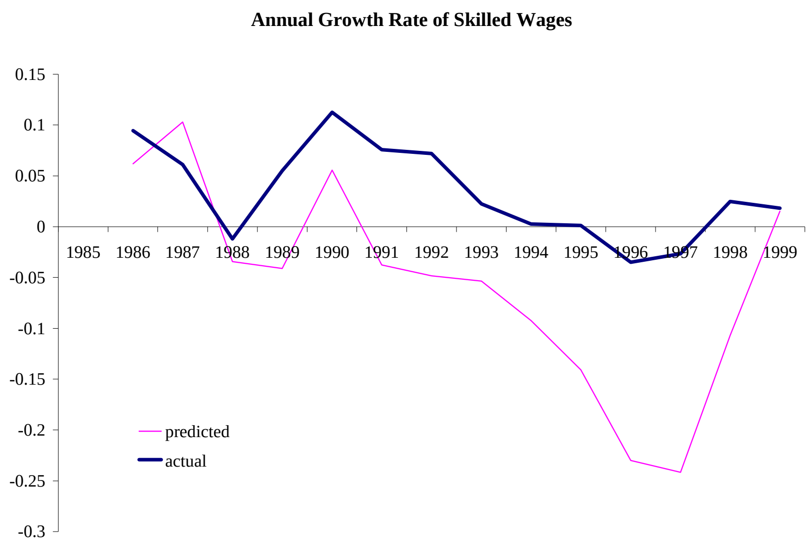
[24] Evidence referred by Krusell et. al. (1997) puts most estimates for the elasticity of substitution between unskilled labor and equipment capital ranges from 0.5 to 3 (implying $\theta \in [-1, 0.67]$), whereas those for the elasticity of substitution between skilled labor and equipment vary between near zero and 1.2 (implying $\rho \in [-\infty, 0.15]$).

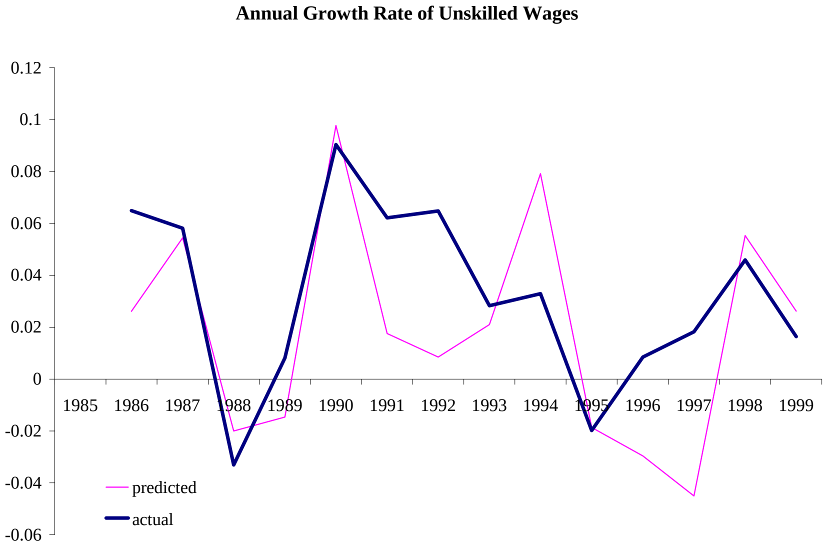
and ψ_{u_t} to 1 at all periods of time. Under this normalization, our variables of interest may be written as:

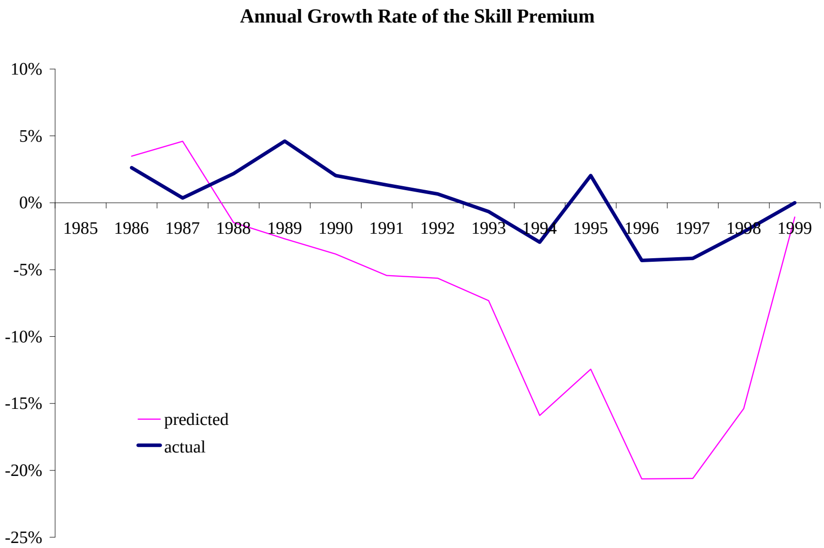
$$\begin{aligned}
w_z(t) &= A(t).(1-\mu)(1-\alpha)(1-\lambda).k_s^{\alpha}(t).z(t)^{\rho-1}\left[\lambda\left(\frac{k_e(t)}{z(t)}\right)^{\rho}+(1-\lambda)\right]^{\frac{\theta-\rho}{\rho}} && (13)\\
&\quad .\left(\mu.\,(1-z(t))^{\theta}+(1-\mu)\left[\lambda\left(\frac{k_e(t)}{z(t)}\right)^{\rho}+(1-\lambda)\right]^{\frac{\theta}{\rho}}\right)^{\frac{1-\alpha-\theta}{\theta}} \\
w_u(t) &= A(t).\mu(1-\alpha).k_s^{\alpha}(t).\,(1-z(t))^{\theta-1}\,. && (14)\\
&\quad \left(\mu.\,(1-z(t))^{\theta}+(1-\mu)\left[\lambda\left(\frac{k_e(t)}{z(t)}\right)^{\rho}+(1-\lambda)\right]^{\frac{\theta}{\rho}}\right)^{\frac{1-\alpha-\theta}{\theta}} \\
\frac{w_z(t)}{w_u(t)} &= \frac{1-\mu}{\mu}.\,(1-\lambda)\,.\left[\lambda.\left(\frac{k_e(t)}{z(t)}\right)^{\rho}+(1-\lambda)\right]^{\frac{\theta-\rho}{\rho}}.\left(\frac{z(t)}{1-z(t)}\right)^{\theta-1} && (15)
\end{aligned}$$

As pointed by Krusell et. al. (2000), the expression for the skill premium highlights two effects driving the skill premium behavior in this economy: on the one hand, we have a capital-skill complementarity effect (increasing the stock of capital equipment per skilled worker tends to increase the skill premium as long as $\theta > \rho$, i.e., there is capital-skill complementarity); on the other hand, there is a quantity effect (an increase in the proportion of skilled labor should decrease the skill premium for the parameter values we are considering). Note that this does not depend on a country's TFP level.

The results from our simulation are presented in the following figures.







The growth in skilled wages is systematically underpredicted during our period of study, whereas unskilled wage growth is, on average, rather well forecasted. This pattern results in a simulated behavior of the skill premium that also systematically underpredicted. Note that the forecast pattern is basically following the growth pattern of capital equipment per skilled worker, which falls dramatically especially from 1992, as predicted by capital-skill complementarity. Indeed, this technological characteristic seems to play an important role in explaining the behavior of the annual growth rates of our variables of interest, especially their turning points.

Despite these positive findings, our results show persistent gaps between actual and simulated growth rates. This should indicate that there is either a problem with our specification/estimation or that there is an important role for factors other than the observable-driven capital-skill complementarity and quantity effects.

In terms of the specifics of our analysis, an explanation would be to attribute these gaps to the definition of "skill" used in our exercise: defining skilled workers as those who completed 12 years of schooling, instead of those who completed college could prove more meaningful for the concept of capital-skill complementarity in an economy where, in 1999, only 7% of the labor input corresponded to college graduates, whereas around 25% had completed 12 years of schooling. It could be that the definition of skill as attaining a college degree does not capture the significant capital-skill complementarity effect, since the proportion of college graduates in the labor force is so small. We explore this hypothesis in the Appendix, but do not find evidence supportive of it.

In addition, simple experimentation of alternative parameter values did not prove useful in diminishing these gaps, although a more formal test could be performed by adapting our state-space model to match the skill premium, skilled and unskilled wages, instead of the three macroeconomic features we used following Krusell et. al. (1997, 2000).

Alternative factors could be related to factors such as institutional labor market characteristics that are not well captured by our framework, but could be part of the "unobservable trend" identified by Katz and Murphy (1992), and that are likely more relevant in European markets.

In addition, it should be noted that a substantial increase in trade flows has occurred in the period we are analyzing (the degree of openness[25] of the Portuguese economy more than doubled to about 60% in this period), and that the pattern of specialization in labor intensive, low technology content exports seems to have deepened, according to evidence presented by Lopes (1999). This should have strongly contributed to an increase in real wages (especially unskilled) higher than what the model predicts. Despite the resulting fall in the skill premium (particularly sharp in the last years of our sample), this variable and the level of labor earnings (especially unskilled) do not yet seem close to have been equalized in Northern and Southern EU countries. This will be the object of further discussion in section 7 of the paper.

6 A Counterfactual Exercise: Measuring the Impact of International Factor Flows on Wage Rates

This section aims at evaluating how much of the real wage and skill premium behavior after Portugal's entry in the EU can be quantitatively explained by the international factor flows occurred at this time. Recall that the basic features of these flows are described in detail in section 2.

6.1 The Effects of Emigration

There is only a limited amount of data on the educational composition of the Portuguese permanent emigration flows: survey data from INE[26] for 1997 point to the proportion of skilled workers in emigration flows being approximately the same as that in the labor force; the same survey for 2001 seems, however, to indicate that only 1.23% of emigrants were college graduates. These pieces of evidence are consistent with the observed fact that the skill premium is higher in Portugal than in European host countries[27], but do not provide us with reliable information that can be used to simulate the effects of emigration flows on the behavior of real wages in Portugal.

It is, nevertheless, possible to use this information to establish two benchmarks: (1) if the proportion of skilled workers who emigrate is the same as that in the overall labor force, then the small magnitude of emigration flows implies that emigration flows will not change the fraction of skilled workers employed in production and technology therefore implying that wages and the skill premium should remain basically unchanged; (2) if, on the contrary, emigration is essentially unskilled, then effects on wages and the skill premium should be expected.

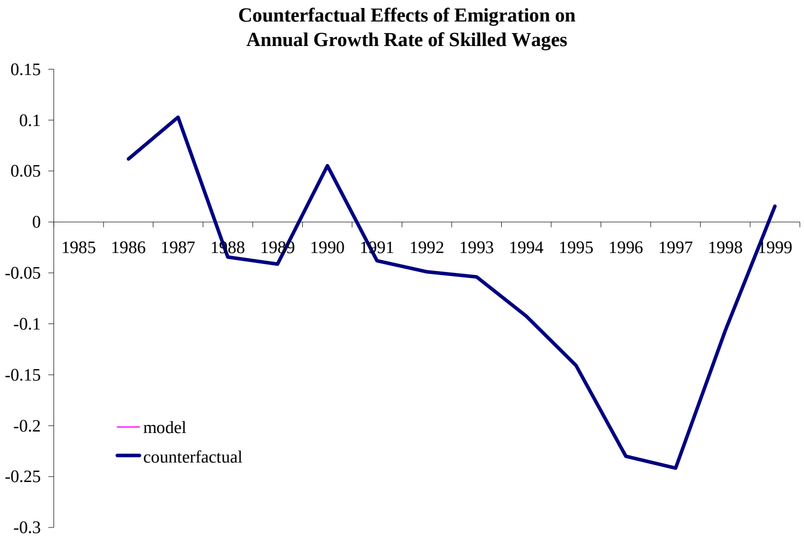
We proceed by considering these two benchmark cases: the first provides a lower bound to the effects of emigration (insignificant); the second provides an upper bound, which is calculated by simulating the effects on wage rates of totally unskilled emigration. For this purpose, the counterfactual of no migration above the average level of emigration in 1983-85 is used. The choice of this threshold level of emigration is intended

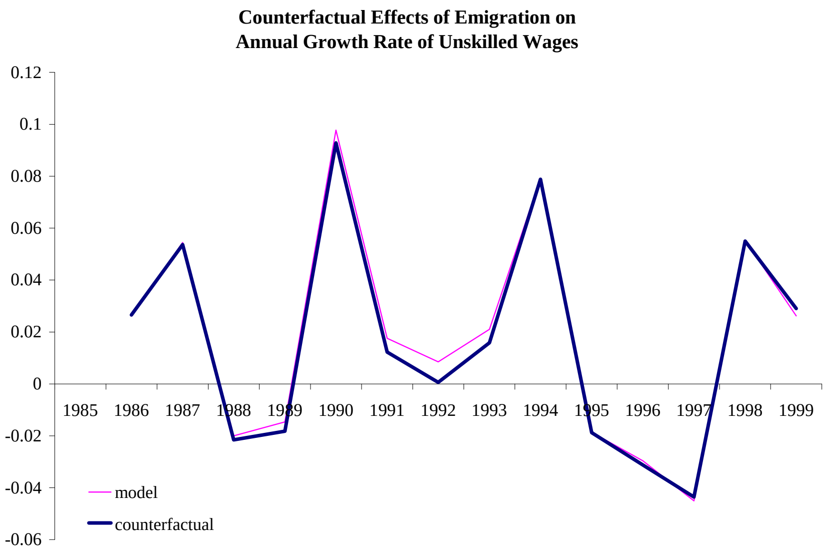
[25] Measured as the fraction of average exports and imports in GDP.

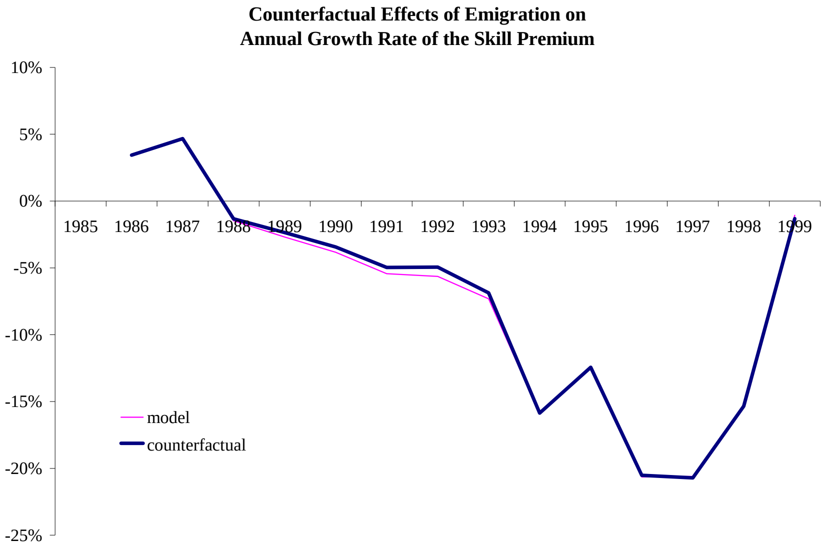
[26] *Inquérito aos Movimentos Migratórios de Saída* (IMMS). INE. Lisboa. 1993-2002.

[27] This type of selection argument in migration was introduced by Borjas (1987), based on the Roy (1950) model.

to filter out migratory movements that would occur regardless of Portugal's entry in the EU. The results of the simulations performed are displayed in the following figures.







As expected as consequence of a pure quantity effect, a pattern of essentially unskilled emigration creates upwards pressures in unskilled relative to skilled wages. Quantitatively, these effects are however pretty small: cumulative effects over the period 1986-1999 on unskilled wages are of a magnitude of 3.3% on unskilled wages, but of less than 1% on skilled wages and the skill premium. These are displayed in the following table:

	Impact of Emigration	
	Av. Annual Growth Rate	Cumulative Effects
Skilled Wages	0.01%	0.07%
Unskilled Wages	0.19%	3.30%
Skill Premium	-0.16%	-0.79%

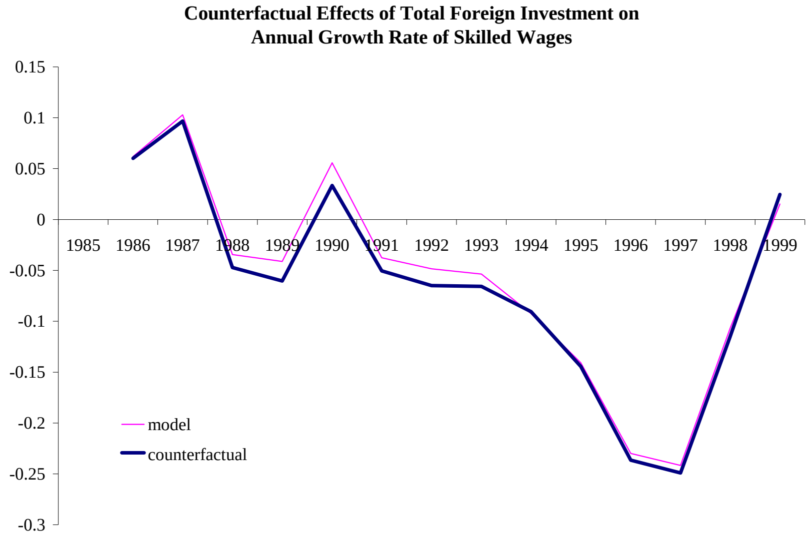
6.2 The Effects of Foreign Investment

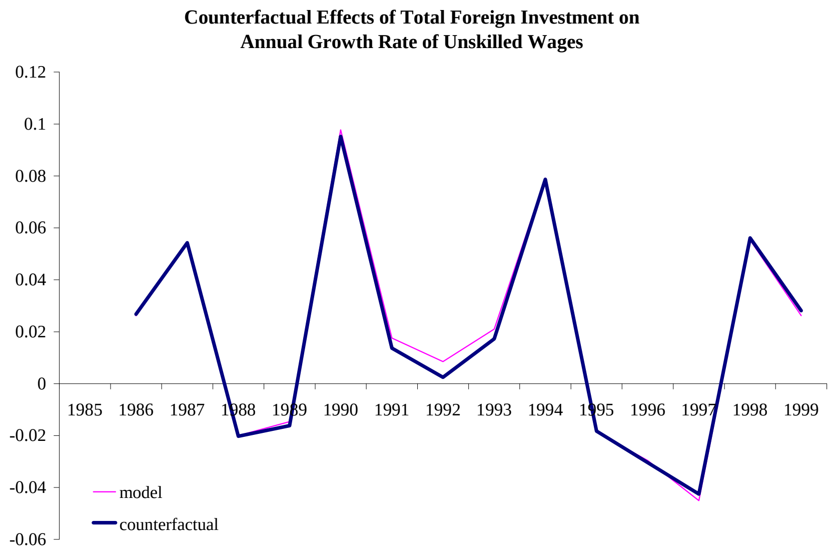
In order to assess the impact of foreign capital inflows caused by joining the EU, it is necessary to distinguish what fraction of this investment represents an increase caused by the integration process. Our approach is a very simple one: consider the difference between post-1986 FDI and the average FDI level during 1983-85, and consider all EU transfers (since these only started from 1986 and are a direct result of integration).

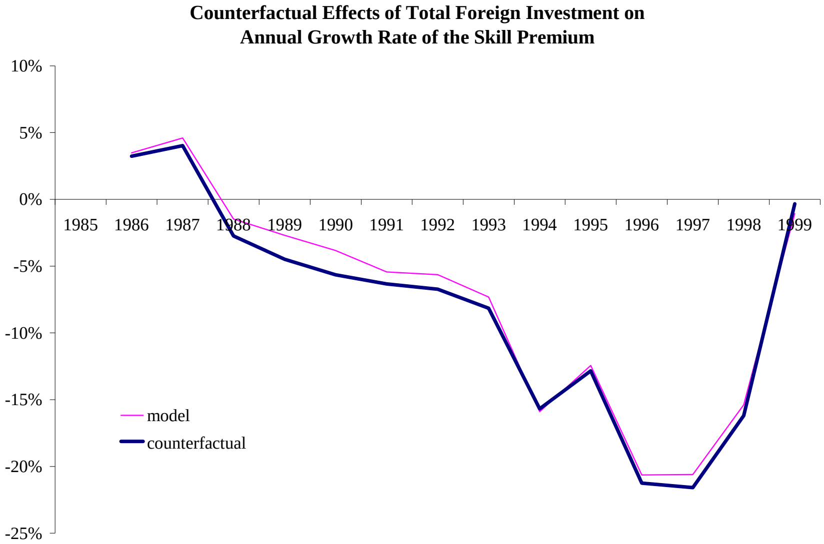
An additional simplifying assumption is made regarding the contribution of FDI and EU transfers to capital equipment and structures, since there is no data available on this partition. We take each year's proportion of total investment into equipment and structures and assume it to apply to both FDI and EU transfers as well.

The counterfactual simulation is performed by subtracting the increase in foreign investment attributed to joining the EU from the original investment series used to construct capital stocks. This means that the counterfactual effects of no increase foreign investment are accumulated in the process of capital stock formation.

We begin by considering the effects of total foreign investment (defined as the sum of relevant FDI and EU transfers), which are displayed in the figures below.


Counterfactual Effects of Total Foreign Investment on
Annual Growth Rate of Skilled Wages
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
model
counterfactual


Counterfactual Effects of Total Foreign Investment on
Annual Growth Rate of Unskilled Wages
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
model
counterfactual



Increased foreign investment seems to have significantly contributed to an increase in wages, especially those of more educated workers, which may be attributed to considerable rises in capital equipment under capital-skill complementarity. This increase in skilled wages resulted in a sizeable increase in the skill premium. The order of magnitudes involved is made clear in the table below.

	Impact of Total Foreign Investment	
	Av. Annual Growth Rate	Cumulative Effects
Skilled Wages	0.84%	4.85%
Unskilled Wages	0.09%	1.63%
Skill Premium	0.74%	3.43%

Given the quantitative importance of the effects uncovered, an interesting question is that of distinguishing between the relative importance of FDI and EU transfers in this exercise. This comparison may be performed by comparing the two tables that follow, which show that most effects on skilled wages are due to the impact of EU transfers, whereas FDI seems to have had a stronger effect on the behavior of the wages of less educated workers.

	Impact of Foreign Direct Investment	
	Av. Annual Growth Rate	Cumulative Effects
Skilled Wages	0.23%	1.31%
Unskilled Wages	0.17%	2.89%
Skill Premium	0.07%	0.30%

	Impact of Unilateral Transfers from EU	
	Av. Annual Growth Rate	Cumulative Effects
Skilled Wages	0.60%	3.58%
Unskilled Wages	0.12%	2.10%
Skill Premium	0.48%	2.32%

6.3 Summary and Implications

The counterfactual exercises in this section indicate that in the Portuguese experience of integration in the EU labor flows are quantitatively less important than capital flows in determining the behavior of real wages.

In particular, depending on the educational composition of the migration flows, the effects of observed emigration can range from no effects at all (if emigrants are not less skilled than the labor force in general), to mild cumulative growth effects, up to 3%, over the period 1986-99 if emigrants are substantially less educated than workers in general. In addition, if one were to account also for immigration flows (making the reasonable assumption that their educational composition is likely to be the same as that of emigration flows), even these small effects on wages would likely vanish away given our previous discussion on the characteristics of the labor market. Indeed, the approximate magnitudes of these flows over our period of interest, make them likely to cause offsetting effects over our period of interest.

This small contribution to the evolution of real wages can be related to evidence summarized by Barro and Sala-i-Martin (1999) that labor flows seem to contribute little to regional convergence of per capita income generally, but especially in European regions. A possible cause for this phenomenon is the small response of migration to persistent real wage differentials, as those existing between Northern and Southern European countries - which translates in our case as a small number of emigrants leaving Portugal after its entry in the EU. This issue deserves further consideration in the next section of the paper.

Regarding the impact of foreign investment on the behavior of real wages, this seems to be quantitatively more relevant in explaining the behavior of skilled wages (with an effect of almost 5% over the period 1986-99), which may be attributed to the technological property of capital-skill complementarity - which should cause skilled wages and the skilled premium to increase in the presence of a growing capital equipment to skilled labor ratio.

The results we obtain concerning the effects of foreign investment deserve some qualification. In particular, some authors, as Lopes (1999), have argued that not all of these transfers effectively translated into investment. In contrast, it should be noted that increases in FDI may not fully translate direct foreign investment in Portugal since other types of foreign financial flows (as portfolio investment) are also likely to have contributed to this effort. More importantly, it should be emphasized that we are only measuring the direct effect of foreign capital inflows, and these are in many instances complementary to domestic investment. This leads us to believe that the EU integration has probably had a more sizable effect on real investment and, therefore, in real wages to which we can only provide a lower bound.

7 Concluding Remarks and Directions for Further Research

What was the effect of international factor flows caused by the Portuguese integration in the EU on the behavior of real wages? Our work answers this question by showing that emigration played only a small role, whereas foreign capital inflows had a larger contribution, even if we only take their direct effects into account.

The small impact of migratory movements on wage behavior is related to the small magnitude of emigration flows after 1986, despite the existing real wage differentials between Portugal and countries already in the EU. If immigration flows are also considered, the wage effects of labor movements over our period of interest are indeed likely to be insignificant.

The effect of foreign capital inflows associated with EU membership was especially strong on the growth rates of skilled wages. We interpreted this effect as result of capital-skill complementarity, a characteristic of our technology that arises from our estimation of the elasticities of substitution between capital equipment and skilled labor, and between capital equipment and unskilled labor.

A note should be paid to the fact that the effects of FDI only should be thought of as a lower bound to the effects of foreign investments in Portugal after the European integration. This is because foreign portfolio investments, for instance, are also likely to contribute to increased investment. In addition, the effects of unilateral transfers from the EU are most likely underestimated since these are associated to complementary increases in domestic investment (both public and private). As a result we should emphasize that we only measured the direct effect of foreign capital inflows, which leads us to believe that the EU integration had probably a more sizable effect on real investment and, therefore, on real wages to which we can only provide a lower bound.

Nevertheless, our results point to direct effects of factor flows on real wage growth that are quantitatively not large. This leads us to believe that other aspects of the European integration process may play an important role in explaining real wage behavior. Namely, as argued in section 5, increased trade flows with a pattern of specialization in labor intensive, low-technology content exports may have contributed significantly to indirect factor flows with important effects on real wages.

In addition, one may argue that important institutional arrangements take place when a country joins the EU, such as an increased degree of legal uniformity. This type of effect could be reflected in converging total factor productivity, which could also have a significant role in explaining the behavior of skilled and unskilled wages.

Further investigating the effects of intensified trade and converging total factor productivity on real wages should constitute an interesting avenue for future research.

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8 Appendices

8.1 Labor Market Data

Labor market data are from the "*Personnel Files*" (PF) collected by the Portuguese Ministry of Labor and span the period 1985 to 1999. They were collected in October of each year from 1994 (March in the previous years), and include full-time wage earners on the payroll in that month. All firms employing paid labor in Portugal are legally obliged to report this information, which includes age, highest completed level of education, tenure with the current firm, and gender.

We used three variables from this data base, each already classified into education levels: average number of hours worked per year, per worker; number of workers; and workers' hourly wages.

Regarding average hourly wages, we chose to use the "actual gain" measure of wages that includes all money and/or goods paid to workers on a regular basis - which includes not only the basic wage, but also food and housing subsidies, as well as productivity supplements. From the available measures, this seemed the most accurate manner to measure workers' reward for their productivity.

No data were available for any variable for the year 1990 due to an incorrect sampling experiment performed in that year by the Department of Statistics of the Ministry. We chose to predict the values corresponding to 1990 by means of simple linear interpolations, believing that we should use all pieces of available information to compensate for the data scarceness we face.

The education level taxonomy was changed after 1993. This allowed a more comprehensive and rigorous classification, at the cost of considering less education levels. Again, the short span of data available made us opt by using all the data available, including those for the period between 1985 and 1993. Because of this decision, we had to make the two taxonomies consistent. For this purpose, we took the latter classification as a basis and attempted to fit the previous categories into these latter in a manner as rigorous as possible. These final categories are:

- No elementary schooling completed (mainly older people who are not able to read or are able to read without formal education);
- Elementary schooling completed (4 years of schooling, compulsory from 1956 for boys and from 1960 for both boys and girls);
- Secondary schooling - 1st cycle (6 years of schooling, compulsory from 1964);
- Secondary schooling - 2nd cycle (9 years of schooling, compulsory from after the mid-1980s);
- Secondary schooling - 3rd cycle (12 years of schooling, has recently been announced compulsory from 2010);
- Bachelor's degree (15 years of schooling);
- Licentiate degree (most common College degree, averages 17 years of schooling).

Portugal has a very low level of workers' education in the European context.[28] In 1985, only 2.5% of the labor force had a college degree (either Bachelor's or Licentiate) and 65% had 4 years of schooling or less. These statistics have significantly (given the restrictions inherent to human capital investment) improved in the period under analysis to 7% and 38.5%, respectively.

Finally a note regarding our decision to ignore some information. The category "*Others*" incorporated all workers who could not be fitted into the initial conventional taxonomy. It ceased to exist from 1994. In the original data provided by the Ministry, there were also some censored observations. What we did was to sum all the observations in the category "Others" with those originally ignored and then compute a corrected density for the number of workers, so that we would not distort the construction of the indicators we needed for our empirical analysis - mainly averages weighted by this density.

[28] For more details, the reader is referred to Hartog et al. (2001).

8.2 Investment Data

The Gross Fixed Capital Formation annual time series between 1953 and 1995 were obtained from the Bank of Portugal (BoP)'s study "Long Series for the Portuguese Economy". For the years 1996-99, this information was provided by the National Statistics Institute (INE), "Quarterly National Accounts Bulletin".

We distinguish two categories of investment goods: structures and equipment. Equipment goods include the original categories "Machinery and Equipment" and "Transportation Materials". Structures include "Construction" and "Others".

The NIPA series for Gross Fixed Capital Formation flows and their deflators were not adjusted for increases in the quality of equipment over time. We decided to use Gordon (1990)'s equipment quality adjustment index to derive the adjusted equipment price index, which we used to adjust the equipment investment series, as described in the next subsection.

Even though there are very substantial differences between the economies of the United States and Portugal, we believe this usage to be reasonable given nowadays very rapid technology globalization. Our hypothesis is however most unlikely to hold in the earlier periods of investment considered. Nevertheless, these flows have little impact on the stocks of capital from 1985, which is likely to make the impact of this assumption negligible.

Gordon (1990)'s index was unfortunately only available until 1983. The strategy followed for the quality adjustment after that date was used by Greenwood, Hercowitz and Krusell (1997) and suggested to them by Robert Gordon: a fixed deduction from the growth rate of equipment prices. An adequate (and conservative) value for this deduction was computed to be 3%, the average quality adjustment between 54-83. This is consistent with the quality adjustment computed by KORV.

8.2.1 Computation of Capital Stock Series

Both the structures and (quality adjusted) equipment price indices were deflated by a non-durable goods and services price index.[29] These series are what we designate by relative (to the price of non-durable consumption) capital price indices.

Capital price indices were then used to deflate the corresponding investment series, which yielded investment time series in efficiency units.

The capital stocks were then computed following the Perpetual Inventory Method. This basically solves the following difference equation

$$K_t = (1-\delta) K_{t-1} + I_t = \begin{array}{ll} (1-\delta)^t K_0 + \sum_{j=0}^{t} (1-\delta)^t I_{t-j} & \text{if } t \leq L_{\max} \\ \sum_{j=0}^{L_{\max}} (1-\delta)^t I_{t-j} & \text{if } t > L_{\max} \end{array}$$

This solution allows us to estimate capital from the investment series only - at the cost of losing the L_{max} initial observations, which is not a problem for us given that our data scarcity was driven by the labor data.

The depreciation parameters were chosen following Greenwood, Hercowitz and Krusell (1997). They were assumed constant across vintages and set at $\delta_e = 0.124$ and $\delta_s = 0.056$.

We also imposed a maximum length of usage for equipment of $L^e_{max} = 15$ and for structures of $L^s_{max} = 32$. This latter was chosen so that investment data would not become scarce and the former was chosen to be a date at which the remaining percentage value of equipment was the same than that of structures at $L^s_{max} = 32$.

These seem sensible numbers according to the study by Böhm et. al. (1998), which surveyed literature on these estimation procedures in OECD countries.

[29] This is done in order to avoid further problems related to quality adjustment issues.

8.3 National Income and Product Accounts (NIPA) Data

Our main source of information regarding the Portuguese NIPA was again the Long Series for the Portuguese Economy, provided by the Bank of Portugal (BoP). However, since these only present data until 1995, we again had to make use of information provided by the (Portuguese) National Institute of Statistics (INE) and also by the BoP Annual Reports of 1996 through 1999.

In particular, we used the BoP Long Series for data on labor earnings and GDP (used to calculate *labor income share*) until 1995 and the BoP Annual Reports from then on.

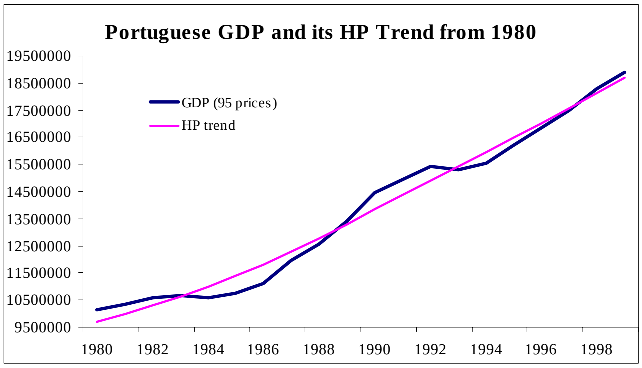
The GDP series (at 1995 constant prices, in millions of Escudos) used to construct the *business cycle indicator* necessary for the first step of the SPML estimation was also obtained from the BoP Long Series until 1995, but after this year we took INE's information.

Finally, the series on private consumption used to calculate the *nondurable goods and services deflator* were also made available by the BoP Long Series until 1995 and by INE from that year on.

8.4 Auxiliary Estimation Procedures

8.4.1 First Step of SPMLE

Because SPMLE of the parameters in the production function requires strict exogeneity of labor and capital inputs, in the first step of SPMLE we pay attention to the issue of potential endogeneity of the labor inputs. To address this concern, we began by using the Hodrick-Prescott filter (with smoothing parameter 100, given the annual frequency of the data) to detrend the Portuguese GDP series (at 1995 prices - please see Data Appendix for more details). This procedure, as graphed in the figure below, provided us with a Business Cycle (BC) indicator



This BC indicator, in addition to a constant term, current and lagged stocks of equipment and structures, lagged relative price of equipment and a time trend were then used as regressors to predict skilled and unskilled hours worked, to prevent potential endogeneity problems:

$$\begin{aligned} h_{i_t} &= \beta_1 + \beta_2 K_{e_t} + \beta_3 K_{e_{t-1}} + \beta_4 K_{s_t} + \beta_5 K_{s_{t-1}} + \beta_6 q_{t-1} + \beta_7 t + \beta_8 BC_{t-1} + v_t \ , \\ \text{for } i &= s_t,\ u_t,\ t = 1,\ ...,\ 15 \end{aligned}$$

From these estimations we obtained the fitted labor inputs, which are used in the second step instead of the actual inputs.

8.4.2 Second Step of SPMLE Implementation

The econometric estimation described in section 4 was implemented using Matlab 6.0.

A more detailed remark is deserved by our SPMLE procedure. Initially the function "fminunc" of Matlab 6.0 was used to perform the likelihood maximization of the second step of the SPMLE, with options set to use the "Medium Scale Optimization". This uses the numerical gradient BFGS quasi-Newton method, described in Judd (1998), pp.113-15, with a mixed quadratic and cubic line search procedure. Unfortunately, it was not capable of achieving convergence, which may be attributed to the highly non-linear nature of the likelihood function. Therefore, we had to switch to another numerical optimization method.

The function used to achieve our estimates is “fminsearch” of Matlab 6.0. "optim" toolbox. This uses the simplex search method of Lagarias et. al. (1998), a direct search method that does not use numerical or analytic gradients. Numerical gradients and hessians were then computed using the "Hessian" routine by James P. LeSage, available from www4.ncsu.edu/~pfackler.

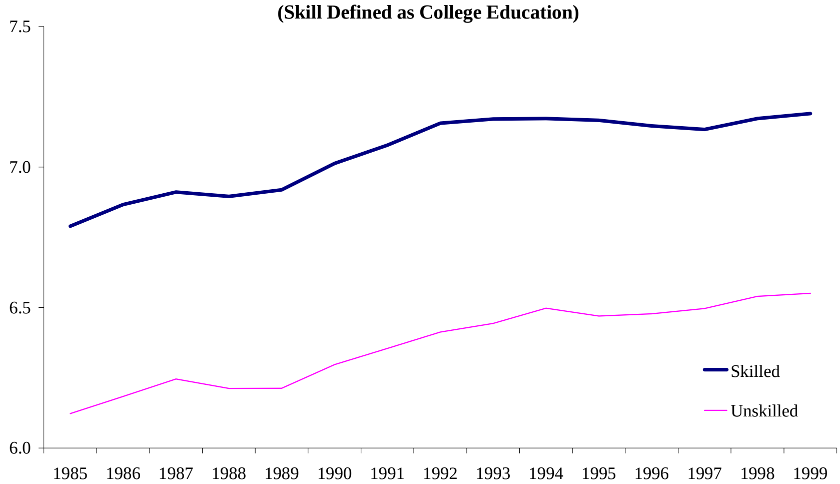
8.5 Sensitivity Analysis to the Definition of “Skill”

Our classification of data according to “skilled” and “unskilled” categories took the “*college completion*” classification used for most studies on the United States labor market. However, only 7% of the full-time working population in 1999 had attended college. Such small share of college graduates in the workforce could potentially lead to a biased picture of the Portuguese skilled workforce that is relevant for the capital-skill complementarity hypothesis. Therefore, we decided to perform a sensitivity analysis to our definition of skill of the labor market facts presented in section 2.

For this purpose, let us now define “skill” as completion of secondary school (12 years of schooling), since this corresponds to approximately 25% of the labor input in 1999, which is about the same proportion of the US labor force completing college.

We obtain that our stylized results would basically remain unchanged: real wage growth progressed quite rapidly, both for skilled and unskilled workers, especially in the period immediately after Portugal’s integration in the EEC, as shown in the following figure.

Evolution of Log Wages from 1985 to 1999
(Skill Defined as College Education)

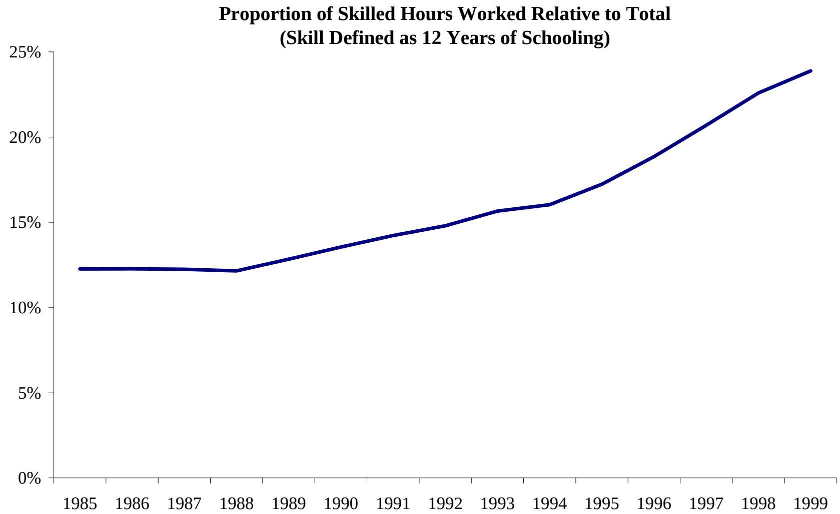


Source: Own Calculations based on PF.

Regarding labor quantities, we observe, as expected, a substantial increase of the proportion of skilled (relatively to unskilled) hours worked, as is displayed in the next figure.[30] This pattern is mainly due to a significant growth in the supply of skilled labor, which averaged 6.7% in the period under analysis, while the supply of unskilled labor remained roughly constant.

[30] The decline from 1993 to 1994 may be due to changes in the statistical classification of workers’ education level, which we attempted to make consistent over time, as described in more detail in the Data Appendix.

The evolution of the labor force’s skill level basically exhibited the same pattern as that of hours worked per level of skill, the same happening to the relative proportion of skilled vs. unskilled quantities.



Source: Own calculations based on PF.

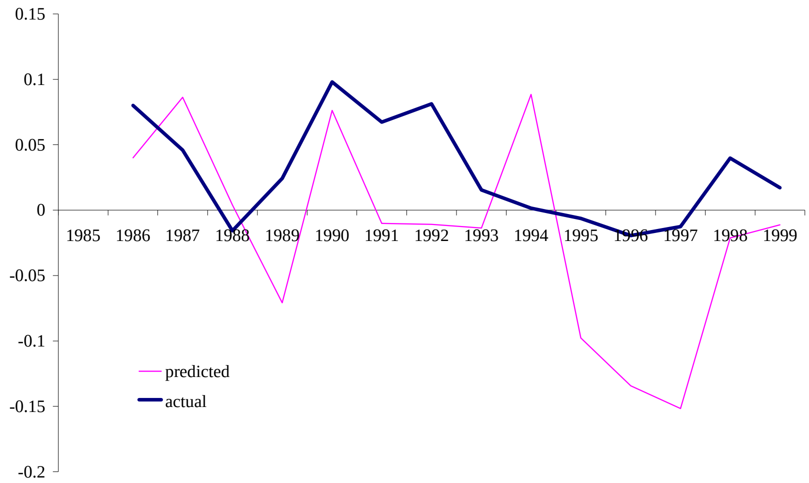
Using this definition of skill, the two-step SPML parameter vector estimate and its standard errors are the following:

$Parameter$	ρ	θ	μ	λ	φ_{u0}
$Estimate$	-0.8441	0.2211	0.1500	0.0021	-20.85
$(White\ Std\ Error)$	0.4998	0.1608	0.0094	0.0637	0.0067

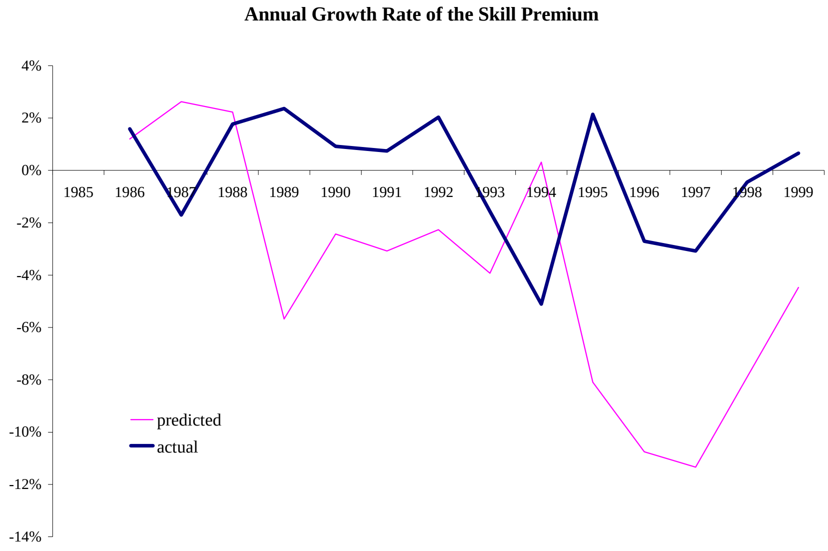
The estimated values are very close to those obtained using the "college definition" of skill. They are also consistent with the capital-skill complementarity hypothesis, and imply sensible elasticity estimates.

The use of these estimates in simulating the behavior of skilled and unskilled real wages, as well as of the skill premium shows, however, that the systematic downward gap in predicting annual growth rates disappears, but no improvements are achieved in terms of the ability to predict turning points in the behavior of these growth rates. This is clear from the following figures.

Annual Growth Rate of Skilled Wages



Annual Growth Rate of Unskilled Wages



The overall analysis of the effects of the alternative definition of skill as completing 12 years of schooling leads us to believe that no significant changes or improvements should occur in terms of the stylized facts and technological characteristics studied. In particular, it does not seem to be the case that this equating skill to 12 years of schooling would deepen or make more significant the concept of capital-skill complementarity. Therefore, we opted to keep the definition of skill as "college completion", also as a way to ease comparison of this study with others in the literature.