Barriers to Technological Adoption in Spain and Portugal

Steven P. Cassou · Emanuel Xavier de Oliveira

Abstract: Since 1945, both Spain and Portugal have experienced significant market transformations. These countries were both led by dictators for many years until the mid 1970s when each moved toward more democratic governments and more open markets. As a result, each experienced significant changes in output with Spain's becoming a model for proper market based transformations. Although Portugal's transformation has been less impressive it experienced improvements too. This paper uses a Parente and Prescott (1994, 2000) type model to investigate the recent transformations in each of these countries and quantify the extent to which barriers to technological adoption may have played for these two development experiences. Our results indicate that from 1945 to 2003 these barriers have fallen considerably but remain high, and are somewhat higher in Portugal than in Spain.

Keywords: Technology barriers · Economic Development · Spain · Portugal

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1. Introduction

The foundations for economic growth and development have long been a major area of inquiry for economists. In 1956, Solow (1956) took on the challenge and contributed significantly to our understanding. Even though the Solow growth model still left open questions and anomalies, it became a baseline framework from which new theories can be extended and compared. One recent theory has been presented by Parente and Prescott (1994, 2000, 2005) which modifies the Solow model to include a technological capital stock. Their theory suggests that countries may reach differing steady states because of barriers to technological adoption.[1] This paper builds on the Parente and Prescott (2000) structure by modifying the model to include adjustment costs in capital investment. This addition results in a model in which closed form solutions can be obtained. More importantly, it results in an improved simulation structure where no attention to negative investment levels is needed. We apply this model to recent development experiences in Spain and Portugal and show that the model is able to explain these experiences well.

Spain and Portugal are the kinds of countries which have presented problems for the Solow growth model because of their long and checkered economic history. During the 15th and 16th centuries, they where the major economic, political and cultural powers of Europe, sharing the World according to the 1492 Treaty of Tordesillas. But leadership proved difficult to maintain and between the 17th and 19th centuries, gradually these nations became more backward relative to the rest of Europe. The 20th century saw further stagnation and lengthy periods of dictatorship rule, followed by democratic movements and eventual entry as founding members of the European Union. However, even today, and particularly in Portugal, these economies do not rival those of the more developed members of the European Union. In this paper, we investigate the post World War II development experiences using the Parente and

[1] On page 299, Parente and Prescott (1994) suggest that these barriers to technology adoption may take a variety of forms such as regulatory and legal constraints, bribes that must be paid, violence or threat of violence, outright sabotage, and worker strikes. Consequently, the higher the barriers, the greater the investment required to implement new technologies.

Prescott ideas and show that barriers to technological adoption seem to have played a role and continue to constrain the economic experiences of these countries.

The barriers theory of Parente and Prescott has led to a number of important follow up studies which confirm the existence of barriers in a number of different settings. Boucekkine and Martinez (1999) introduced barriers to technology adoption in a canonical vintage capital model.[2] Hall and Jones (1999) reworded barriers to technology adoption as social infrastructure. In their view, good infrastructure encourages "the adoption of new ideas and new technologies as they are invented throughout the world."[3] Acemoglu and Zilibotti (2001) found that income disparities between LDCs and DCs arise even in the absence of policy induced barriers to technology adoption due to differences in labor force skills.[4] Ngai (2004) found that international income disparities were related to different levels of barriers to technology adoption and capital accumulation, and that these delay the turning point between growth stages.[5] Harding and Rattsø (2005) investigated the role of barriers to technology adoption on South Africa's growth.[6] And, Comin and Hobijn (2007) setup a tractable model of endogenous growth in which the returns to innovation are determined by the technology adoption decisions.[7] Our paper also contributes to this growing body of work by extending the barriers model into a tractable form and applying it to the Spanish and Portuguese post World War II development experience.

A number of recent papers have had similar objectives to ours. Blanchard and Portugal (2001) investigate the Portuguese labor markets and compare it to that of

[2]Using numerical methods, they validated the dynamics of the model and found that higher adoption costs constrain output levels in the long run, raise the magnitude of short run fluctuations, and decrease the convergence speed to the steady state.

[3]Quantitative analysis utilizing data for 127 countries from several sources indicated that differences in social infrastructure caused large disparities in income across countries.

[4]Using 1997 U. N. General Industrial Statistics data for 22 countries, they conclude that technology adoption depends also on supplies of factors of production, as different technologies fit better different factors of production.

[5]Her findings were based on the development experiences of the 124 countries from Maddison's 2001 dataset.

[6]They found that reduced barriers pre- and post- sanctions and the high barriers during sanctions explained the development of productivity.

[7]Calibrating it to U.S. data, they found that policies inducing lower barriers increase growth.

the U.S. They find that, despite the similar unemployment rates between the U.S. and Portugal, there are quite different labor market forces at work, with the Portuguese labor market exhibiting much larger employment protections and thus lower worker movement in and out of employment. Cavalcanti (2007) applies accounting methods developed in Prescott (2002) and Chari, Kehoe and McGrattan (2007) to investigate output performance in Portugal and finds that both labor inefficiencies and general economic inefficiencies are prevalent in Portugal. Our paper focuses on a more generic productivity barrier which could potentially include labor market barriers, but could also include any number of other possibilities. Our objective is not so much to identify specific barriers, but instead is to note that whatever form these barriers have taken, the ebb and flow of these barriers over time are important for explaining many of the economic turning points of both Spain and Portugal over the post war period. We find that the barriers do present a plausible explanation for the dynamic growth patterns observed in both Iberian economies over the postwar period. Furthermore, we find that the gradual reduction of the barriers over this time period has resulted in significant economic improvements.

In order to present our results in a clear format, we have organized the paper as follows. In section 2, the model is described and the closed form rules for the competitive economy are presented. Section 3 follows the calibration routine of Parente and Prescott to calibrate our model using U.S. and Japanese data. In section 4, the post World War II socioeconomic experience of the Iberian economies is reviewed and then compared to simulations from our model to assess its fit. Attention is also focused on the sources of the barriers in these two economies and particular events which likely resulted in changes in the barriers level. Section 5 concludes.

2. The Model

Our analysis is based mostly on the particular model developed in Parente and Prescott (2000).[8] In the presentation here, most of their structure and notation is

[8] The model in Parente and Prescott (2000) differs from the one in Parente and Prescott (1994)

preserved. One key difference is the formulation for the creation of both physical and technological capital. Our formulation incorporates an adjustment cost component, as suggested by Lucas and Prescott (1971), which allows us to get closed form solutions for the social planning problem, hence making the model analytically tractable. In addition to making the simulations much easier, the adjustment cost component also implies that there is a preference for smoother investment patterns and this eliminates the possibility of negative investment values that is present in the various Parente and Prescott models.

2.1. The Corporate Sector

The model abstracts from aggregate behavior and envisions everything on a per worker basis.[9] A firm that operates H_t hours per workweek, uses K_t units of physical capital per worker and Z_t units of intangible capital per worker, has a level of output per worker given by

$$Y_t = \mu_t A(\pi) H_t K_t^{\theta_k} Z_t^{\theta_z}, \tag{1}$$

where $\mu_t \equiv (1+\gamma)^{(1-\theta_z-\theta_k)t}$ and γ is related to the exogenous rate of growth for world knowledge and is assumed to be greater than zero. It is assumed that total factor productivity is governed by $A(\pi) = (1+\pi)^{-\theta_z}$ where π is a measure of the barriers to technology adoption in a particular country. Higher values of π are interpreted to correspond to countries where the barriers to technology adoption are higher. In addition, output elasticity parameters θ_k and θ_z are assumed to be positive and that $\theta_k + \theta_z < 1$. Although the production function may appear to have increasing returns to scale because the sum of the exponents adds up to more than 1, this is not the case as this is a per worker production function. Additional workers are handled simply through replication of this production function which implies that

in that the government is left out and a slightly different modelling form for the barriers is used. Both the Parente and Prescott (2000) and Prescott (2002) papers can be interpreted as reduced form models of the Parente and Prescott (1999) paper.

[9] Because consumers and firms both make choices for hours and capital, one choosing demand and the other choosing supply, we have adopted a convention of using upper case letters to indicate choices made by firms and lower case letters to indicate choices made by consumers to keep clear who is making the choice.

the aggregate production function exhibits constant returns to scale.

Firms are assumed to hire labor and rent physical capital through competitive markets but to invest in intangible capital on their own. Investment in intangible capital in the amount I_{zt} is combined with the existing intangible capital stock Z_t and leads to future intangible capital stocks given by

$$Z_{t+1} = A_z Z_t^{1-\delta_z} I_{zt}^{\delta_z}, \tag{2}$$

where $0 < A_z$ and $0 < \delta_z < 1$. This formulation exhibits an adjustment cost element as in Lucas and Prescott (1971).

The choices of firms are governed by a desire to maximize the value of the dividend stream paid to its owners. The firm's dividends are simply revenues minus expenses and are given by

$$V_{ft} = Y_t - w_t H_t - r_{kt} K_t - I_{zt}, \tag{3}$$

where w_t is the wage rate per worker at time t, r_{kt} is the rental rate on physical capital at time t and I_{zt} is the number of units of intangible capital that the firm invests in at time t. The labor and capital markets are assumed to be competitive, which implies wage and rental rates given by

$$w_t = (1 - \theta_k - \theta_z)\frac{Y_t}{H_t}, \tag{4}$$

$$r_{kt} = \theta_k \frac{Y_t}{K_t}, \tag{5}$$

$$r_{zt} = \theta_z \frac{Y_t}{Z_t}, \tag{6}$$

where r_{zt} is the implicit rental rate on technological capital. The firms behave in the best interest of their stockholders and thus their optimization problem is to maximize

$$V(z_0) = \sum_{t=0}^{\infty} p_t V_{ft},$$

subject to (1), (2) and (3) where p_t is the price of output at date t relative to time 0.

2.2. The Consumer Sector

The consumer sector consists of a large number of identical agents who own equal initial shares of the two marketable assets in the economy. These marketable assets consist of physical capital, denoted k_t for holdings at date t, and ownership rights to one firm.[10] In addition, each household has one unit of time at each date which is allocated between labor supply and leisure consumption. Households have preferences for consumption and leisure over time given by

$$\sum_{t=0}^{\infty} \beta^t \ln(c_t - B(1+\gamma)^t h_t^{\eta}), \tag{7}$$

where $0 < \beta < 1$, $0 < B$ and $0 < \eta$. In this set up, c_t denotes consumption of goods at date t. The term $(1+\gamma)^t$ is present in the utility function in order to keep the labor supply h_t stationary over time. Without this element, as c_t grows, the labor supply would be driven to a boundary. This term can be interpreted as implying that the value of time in home production increases over time at a rate equal to the balanced growth rate for the economy.

The household physical capital stock changes over time when new investment i_{kt} is combined with the existing capital stock k_t according to

$$k_{t+1} = A_k k_t^{1-\delta_k} i_{kt}^{\delta_k}, \tag{8}$$

where $0 < A_k$ and $0 < \delta_k < 1$. As in the technological capital, this formulation is motivated by Lucas and Prescott (1971).

Then we can formulate the representative agent's objective as maximizing (7) subject to (8) and the budget constraint

$$c_t + i_{kt} = w_t h_t + r_{kt} k_t + V_{ft}. \tag{9}$$

Moreover, because households are assumed to be numerous, each household is a sufficiently small part of the economy so that they are price takers.[11]

[10] Technology capital is invested in by firms and is not traded in a market.

[11] An alternative way to formulate the budget constraint is to make use of the price relationship summarized by p_t to get $\sum_{t=0}^{\infty} p_t \left[c_t + i_{kt}\right] \leq \sum_{t=0}^{\infty} p_t \left[w_t h_t + r_{kt} k_t + V_{ft}\right]$. The form given in (9) is more convenient for the solution algorithm described in the appendix.

2.3. Competitive Equilibrium

The competitive equilibrium for this economy consists of prices $\{p_t,\, r_{kt},\, w_t : t \geq 0\}$ and allocations $k_0,\, K_0,\, Z_0, \{Y_t,\, H_t,\, K_{t+1},\, I_{zt},\, Z_{t+1},\, V_{ft},\, c_t,\, h_t,\, k_{t+1},\, i_{kt} : t \geq 0\}$, such that:

1. Agents optimize:

   i. Given $\{r_{kt},\, w_t,\, V_{ft} : t \geq 0\}$ and k_0, the allocations $\{c_t,\, h_t,\, k_{t+1},\, i_{kt} : t \geq 0\}$ solve the consumer's optimization problem.

   ii. Given $\{p_t,\, r_{kt},\, w_t : t \geq 0\}$ and z_0, the allocations $\{Y_t,\, H_t,\, K_{t+1},\, I_{zt},\, Z_{t+1},\, V_{ft} : t \geq 0\}$ solve the firms's optimization problem.

2. Markets clear:

   i. Goods market: $c_t + i_{kt} = Y_t - I_{zt}$, for $t = 0, 1, ...$

   ii. Labor market: $h_t = H_t$, for $t = 0, 1, ...$

   iii. Physical capital market: $k_t = K_t$, for $t = 0, 1, ...$

2.4. Decision Rules

Although it is numerically feasible to solve for the competitive equilibrium using the expressions implicit in its definition, it is much easier to work with the social planning decision rules. The social planner is simply an integrated consumer-producer that makes all consumption, investment and production decisions simultaneously. The planner takes as its objective the consumer utility function and maximizes this subject to all the consumer and producer constraints described above. In the appendix, the formal specification of the social planning problem is given and solved. The decision rules that solve this problem are given by:[12]

$$\begin{aligned}
i_{kt} &= a_k y_t \quad \text{where} \quad a_k = \frac{\beta\delta_k\theta_k}{1-\beta(1-\delta_k)}, \\
i_{zt} &= a_z y_t \quad \text{where} \quad a_z = \frac{\beta\delta_z\theta_z}{1-\beta(1-\delta_z)}, \\
c_t &= (1 - a_k - a_z) y_t,
\end{aligned}$$

[12] Here we use lower case letters to denote all choice variables because they all come from the representative planner which is a combined consumer and firm problem.

and

$$h_t = \left[\frac{(1-\theta_k-\theta_z)A(\pi)k_t^{\theta_k}{z_t}^{\theta_z}}{B\eta(1+\gamma)^{(\theta_z+\theta_k)t}}\right]^{\frac{1}{\eta-1}}.$$

3. Calibration

The model is calibrated analogously to Parente and Prescott (1994, 2000). We begin by setting the barrier parameter π equal to zero to correspond to the U.S. economy baseline. Then we assign values for most parameters based on observations of the U.S. economy. For those parameters corresponding to variables for which there are no data, values are determined based on convergence information between U.S. and Japan during the post World War II period. Finally, as in Parente and Prescott (2000), we assume the principle of common technology across countries, hence all model parameters except π are the same in the U.S., Spain and Portugal.[13]

The parameter γ is set to 0.02 to correspond to the observed 2 percent annual growth rate of per capita output and β is set to 0.9716 to correspond to a 5 percent risk free interest rate.[14] Next, η is set to 10.0 to correspond to a labor supply elasticity of 0.11.[15]. Given these parameters, the remaining parameters were jointly calibrated to match other statistics. Table 1 below indicates the outcome of this calibration procedure along with these other statistics which were matched.[16]

<Table 1 here>

[13] As the authors explained on p.67, without this principle there would be no discipline to the analysis. Moreover, they demonstrated that this should not raise any controversy as barriers at the plant level lead to differences in TFP at the aggregate level.

[14] The risk free interest rate r is defined by introducing privately issued real bonds into the household budget constraint. These bonds have a zero net supply, and in balance growth the first order condition for bonds implies $r = \exp(\gamma - \ln\beta) - 1$.

[15] This elasiticity value is relatively low and corresponds to most empirical estimates of the male supply elasticity. Such a value seemed more appropriate for our purposes where the focus is on long run outcomes rather than business cycle outcomes. With more elastic labor supply calibrations, the model will imply bigger changes in labor hours in transitional economies.

[16] Most of these calibration statistics come from Parente and Prescott (2000). The growth rate for per capita GDP in the U.S of 2%, the k_t/y_t ratio of 2.5, the i_{kt}/y_t ratio of 0.20, the after tax interest rate of 5% and the fraction of time devoted to labor of 0.4 come from page 75, while the average i_{zt}/y_t ratio of 0.30 is within the range defined on page 76.

Most of the calibrated parameters are consistent with those found in Parente and Prescott (2000). We did find a larger value of θ_k and a smaller value of θ_z. Although our value for θ_k of 0.2 is slightly larger than their value of 0.16, we don't regard this as significant. Our value may even have some merit as it is closer to standard Cobb-Douglas production function estimates which lie between 0.3 and 0.4. Our value for θ_z of 0.3 is quite a bit smaller than Parente and Prescott's value of 0.55. This reflects differences in the capital accumulation modeling structures. Because our model has an adjustment cost technology built into the capital accumulation formulations for the two capital stocks, the rate of convergence is dampened since the adjustment cost formulation induces slower investment programs. As discussed in Barro and Sala-I-Martin (1995), the rate of convergence is also related to the sum of θ_k and θ_z, with higher values for this sum implying slower convergence. Since the adjustment cost formulation already induces slower convergence, our sum of these two variables cannot be as large as in Parente and Prescott or convergence rates would not match those observed between the U.S. and Japan.

4. Iberian Development Experiences

In this section we investigate the Spanish and Portuguese postwar development experiences. We begin with some background about each economy. This will provide insight into turning points in which the barriers to technology adoption changed in each of these countries. With this history in mind, we then turn to the evaluation of each economy. Next we explore the impact of intangible capital on the simulation results to see what this component adds to the models performance. Finally, we wrap the section up with a review of some recently collected data which suggests that the barriers we discuss are likely still a problem.

4.1. Background

Even though geographic proximity is really not enough to imply similar economic outcomes, the Portuguese and Spanish development experiences are very similar.[17]

[17] Obvious counter examples abound such as the U.S. and Mexico.

Probably most important to the similar economic paths is the long shared history of the two countries and the brotherly rapport they have with each other.[18] These countries seem to routinely do what the other does. So both spent most of the 20th century under a dictatorship, had their golden years in the post World War II period, became democratic in the mid 1970s, joined the European Community in 1986, the European Single Market and European Union in 1993, and were among the 12 European countries that adopted the Euro currency in 2000.

In Figure 1, output per worker in Portugal and Spain relative to the U.S. over the postwar period is plotted. It shows the striking similarities between the Iberian economies. This recent economic history played out as follows.

<Figure 1 here>

Between World War II and the OPEC-induced international energy crisis in 1973, the Spanish economy experienced an unprecedented period of growth boosted by the massive and profound transformation of the industrial sector. Industrial productivity increased by 100 percent between 1964 and 1973. Consequently, Spain's industry became technologically sophisticated (Tortella 2000, p.327-58). In contrast, Portugal focused more on the progressive opening of its economy to the world; the merchandise export growth rate between 1959 and 1973 was 11 percent per year whereas in industrialized countries it was 8.9 percent (Baklanoff 1992, p.11).

Soon after the 1973 oil shock, both countries went through a period of social and economic turmoil. The military coup of April 1974 ousted the long-lived authoritarian regime of António de Oliveira Salazar (1932-68) and Marcelo Caetano (1968-74), whereas the Spanish dictatorship (1939-75) ended with the death of Francisco Franco. It is noteworthy that both countries followed a negotiated model of transition to democracy where, according to Colomer (1991, p.1283), pacts among political elites and consensus among citizenry sought to avoid acts of revenge, violent confrontations, and civil war.

[18] In ancient times, Portugal was actually a part of (what is now known as) the Kingdom of Spain and was formed by Afonso Henriques, son of Teresa of León (daughter of King Alfonso VI of León).

Along with democratization came changes in the economic system. The Portuguese revolutionaries nationalized commercial banks and most heavy and medium size industries in order to emasculate the old elite's economic base. Moreover, the dismemberment of the colonial empire resulted in the loss of a significant source of income (Baklanoff 1992, p.1). Spain, on the other hand, experienced a smoother transition process skillfully managed by the new chief of state, King Juan Carlos I, who had lived in exile in Portugal till Franco's death. In addition, the transition was likely smoother because the new middle class was dismayed at the impact radical economic measures had on the Portuguese economy (Baklanoff 1978, p. 179). As a result, priority was given to stop-gap economic measures such as the Moncloa Pacts, which assured a degree of moderation for increases in prices and salaries (Tortella 2000, p.454).

The turbulent road to stability culminated with the accession of the Iberian countries to the European Community in 1986. This step boosted economic growth in both countries mainly due to the inflow of structural funds, foreign direct investment, and gradual privatization of state monopolies along with deregulation of prices and markets. These economic "good times" proved short lived and ended in 1992-93 when most West European economies were caught in the midst of economic recessions and struggled to implement the provisions of the Maastricht Treaty, which called for serious constraints on fiscal and monetary policies. The criteria to adhere to the European Monetary Union included: "inflation over 12 months could not exceed by more than 1.5 percentage points the average rate among the three EC countries with the lowest inflation; long-term nominal interest rates over 12 months could not exceed by more than 2 percentage points the average for the same three countries; the currency had to remain in the narrow band of the exchange rate mechanism for at least two years without devaluation; the budget deficit should not exceed 3 percent of GDP; and total public debt could not exceed 60 percent of GDP" (Maxwell 1994, p.51).

The Maastricht rules may have reduced the public sector deficit, but the decline in public investment in physical capital and research and development inhibited economic growth in both countries. On the other hand, the adhesion to the European single market in 1993 (free movement of people, goods and services), may have aggravated the European Monetary System's impact as it exposed domestic firms to increasing foreign competition. In fact, Gunther et. al. (2004, p.369) argue that these were the major causes for stagnation of Spanish productivity during the 1996-2001 period. Despite these deterrents, both countries experienced modest growth in the late 1990s, probably nourished by the continuing privatization of parastate industries and market deregulation. It is worth mentioning that Portugal was at the time one of the largest "privatizers" in the OECD, with revenues amounting to approximately 2.8, 4.7, 3.9, and 1.5 percent of GDP between 1996 and 1999 (Torres 2000, p.122).

Most recently, between 2000 and 2003, a series of international adverse shocks impacted the Iberian Economies. These events included, for example, the international stock market crash in March of 2000, and a gradual increase in oil prices along with a worsening terms of trade. Relatively, Portugal ended up worse off probably due to its higher degree of openness.

Based on this history, we identify four regime changes in the Iberian economies. First, in 1960, due to radical changes in industrial and foreign trade policies. Second, 1974 in Portugal and 1975 in Spain, due to the social and economic turmoil and its repercussions. Third, in 1986 when European Community membership meant changes in domestic fiscal and monetary policies and massive inflows of structural funds. And fourth, in 1994, because of the European Single Market and EU entries and inherent domestic policy constraints.

These regime changes are also identified by other authors. Lopes (2004a, p.53) defines the period 1960-1973 as the Portuguese golden years and Blakanoff (1992, p.13) concludes that the 1974 Portuguese revolution marks the end of the exceptionally rapid economic growth and structural change initiated in 1960. Tortella (2000, p.327) indicates that 1960 was the beginning of an unprecedented growth period in

Spain. Cheung and Chinn (1996, p.148), Fulvio (2001, p.35), and Escosura e Roses (2007, p.5), found that in 1975 there is a statistically significant break in the Spanish growth trend. Lopes (2004a, p.48) identifies the period 1986-94 as a complete business cycle for the Portuguese economy. Jimeno et al. (2006, p.38) point to 1986 has the year when there was a structural break in Spanish labor productivity growth, using a Sup-Wald test. Finally, Gunther et al (2004, pp.364-70) state that the Spanish economic expansion of the late 1980s came to an abrupt end by 1994 and was then followed by a strong recovery based on fiscal reform and influx of structural investment funds from the EU.

4.2. Spain

Given our own analysis, and the corroborating views of others, we now turn to assessing the postwar economic experiences in Spain and Portugal based on barriers to technology adoption over these subintervals. We begin by focusing on the Spanish experience. Using data from Maddison (2007), the 1945 Spanish output per worker was 21.63 percent of the U.S. level. To initialize our model economy to this output level we used relative levels of physical and technological capitals of 15.66 and 11.76 percent, respectively. From this initial condition, we selected barrier parameters given by those in Table 2 and simulated the model forward in time. Figure 2 plots our simulated data with that of the observed postwar Spanish experience.[19]

<Figure 2 here>

<Table 2 here>

The simulation is consistent with the observed economic path. The barriers also show an expected pattern. After an initial high level of barriers, these decreased by 67.44 percent between 1960 and 1974. At this time, Spain was experiencing an average 7 percent growth in output per capita, and in particular, automobile production was increasing at an extraordinary pace of 22 percent per annum (Tortella 2000, p.331).

[19] As in Parente and Prescott (1994), both the Spanish, Portuguese and U.S. data were smoothed using the Hodrick-Prescott filter. We used a smoothing parameter of 100.

In fact, Tortella (2000) characterizes this period as the Spanish Industrial revolution, and the automobile sector its leading source because it fostered the development of at least three additional industries: rubber production, iron and steel, and petroleum refining. In the mid 1970s, the social and economic turmoil linked to democratization decreased the ease of adopting new technologies and the barriers increased. Once the country stabilized and gained its EC membership in 1986, the barriers diminished slightly. But it was not until the post Single European Market and EU enforcement that the barriers to technology adoption returned to a level similar to that recorded during the 1960s.

4.3. Portugal

Again, using data from Maddison (2007), Portugal's 1945 output per worker was 19.21 percent of the U.S. level. In our model, this is consistent with relative levels of physical and technological capitals of 13.11 and 11.10 percent, respectively. Next, using barrier parameters given in Table 3, the model was simulated. Figure 3 compares the simulation results with the observed data for the Portuguese economy.

<Figure 3 here>

<Table 3 here>

Similar to the Spanish economy, Portugal had a high level of barriers to technology adoption immediately after WWII. This is not surprising since both dictatorships had protectionist policies in place and their industries were relatively uncompetitive. Changes in international trade policies associated with EFTA in 1960 and OECD entry in 1961, along with the success of "Foment Plans", radically transformed the Portuguese industry in the 1960s, leading to a 57.26 percent decrease in the barriers to technology adoption. The lower barriers associated with the 1960-73 period corroborate Parent and Prescott's (1994, p.319) conjecture that greater trade openness weakens deterrents to technology adoption. Nonetheless, this is a relatively lower decrease in barriers than occurred in Spain. We speculate that the reason lies in the sources of growth, as Portugal did not have very many spillovers like the ones generated by the Spanish automobile industry.

Unfortunately, these golden years were over by 1973. The international oil crisis and the social and economic repercussions of the "Carnation Revolution" were shocks in the 1970s that decreased firm's ability to adopt new technologies. As in the Spanish economy, Portugal's entrance in the EC eventually lowered the barriers again. But, contrary to its neighbor, Portuguese barriers increased after 1994. We conjecture that this derives from the relatively lower ability of its industry to adopt new technologies, due mainly to the scarcity of skilled workers. According to the World Development Indicators 2006, between 1993 and 2003, only 10 percent of the Portuguese labor force had tertiary education whereas in Spain this share accounted for 24 percent.

4.4. Assessing the Impact of Intangible Capital on Transitions

One of the key innovations of the Parente and Prescott (2000) model is the intangible capital term in the production function. The presence of this term slows the rate of convergence in their model relative to the standard Solow type models. Parente and Prescott (2000) argue this term improves the fit. In this subsection, we assess the need for this term by conducting an experiment in which intangible capital is removed from production.

In structuring this exercise, we wanted to be careful not to simply set θ_z equal to zero, as this would have required a completely new calibration of the model. Such an exercise would not reveal whether the differences were due to eliminating intangible capital from production or because of the different calibration. Instead, to keep the simulations closely comparable to the earlier results, we preserved the original calibration. This meant that we left the θ_z term on the barrier component and set the θ_z term on the intangible capital component to zero. In addition, we left investment in z_t in the national income constraint, but assumed that this followed a constant growth rate of γ rather than following an optimal choice rule.

The results for Spain are summarized in Figure 4 and Table 4. This table shows that the barriers were considerable higher without the intangible capital in production. This is not surprising, because without intangible capital, the model needed to be rescaled. Figure 4 compares the simulations for the model without intangible capital with the data. As expected, the fit is not as good. The simulations show that the model without intangible capital does not track the true Spanish data as well as the model with intangible capital which was presented in Figure 2.

<Figure 4 here>

<Table 4 here>

The results for Portugal are similar and are summarized in Figure 5 and Table 5. The latter also shows that the barriers were considerable higher without the intangible capital in production. Similarly, Figure 5 shows that the fit is not as good, id est, our simulations indicate that the model without intangible capital does not capture the true Portuguese data as well as the model with intangible capital (Figure 3).

<Figure 5 here>

<Table 5 here>

4.5. Recent Evidence of Barriers

Recently a number of sources have begun collecting data which can be used to infer barrier levels. Unfortunately, the data does not go back to 1945, so it is not possible to use it as a confirmation of our barrier values over the entire interval. However, it does provide a useful snapshot of recent barrier experiences.

According to the World Bank Development Indicators database, in 2006 the percentage of managers surveyed that considered corruption as a major business constraint was 7.8 and 15.4 percent in Portugal and Spain respectively. This same survey found that the percentage of managers lacking confidence in courts to uphold property rights was 47.7 and 16.6 percent respectively and for overall court related issues that pose business constraints, 17.8 and 7.9 percent. This survey also found that crime was considered a barrier for 15.7 and 9.8 percent of the managers respectively.

Another indicator of the barriers to adopt new technologies might be the time required to enforce a contract. In Portugal the time is 320 days, while Spain is about half that at 169 days. In addition, the lower availability of R&D technicians in Portugal, 246 per million people on average between 1996 and 2003 versus Spain with 607, might dissuade technology adoption (WDI 2006).

Worker strikes are another source that Parente and Prescott (1994) regard as a barrier to technology adoption. Data published by the European Industrial Relations Observatory in 2000, 2003 and 2005 indicates that Spain lost more working days than Portugal. Between 1997 and 2003, Spain lost an annual average of 176 days per 1000 employees whereas Portugal only 26 days. This created an upward pressure on the Spanish barriers to technology adoption but not sufficiently enough to offset the comparative advantage on the other barriers that comprise the total level of barriers.[20]

Finally, we analyzed the data published by the Global Entrepreneurship Monitor Reports. In order to use these datasets we loosely use deterrents to entrepreneurship as a proxy for barriers to technology adoption. In terms of access to venture capital, the Spanish perceived it to be better than the Portuguese, even though both considered it inadequate (De Castro et al. 2002, p.45). The survey averages were -0.94 for Spain and -1.10 for Portugal where very bad was coded -2.5, adequate was coded 0 and very good was coded 2.5. Another GEM measure of interest is the perceived adequacy of governmental programs in assisting new and growing firms. Again, Portugal scores lower than Spain, but the difference is rather small. However, both would be considered as slightly inadequate (Medina et al. 2001, p.29). On the other hand, when assessing the adequacy of governmental regulations the Spanish clearly perceived them better than the Portuguese, giving an average score of 0.42 and –0.82, respectively (De Castro et al. 2002, p.51).

Based on these recent sources, it is hard to argue that the level of barriers in the Iberian economies were largely different. However, they do mostly indicate that they are somewhat higher in Portugal than in Spain. More importantly, they indicate that both countries still need to reduce their barriers.

[20] It should also be noted that most of these lost days were related to "Accidents, health and safety", while Portuguese strikes were driven by "Pay" disputes, so to some extent this lopsided data may not be very reliable for indicating barriers.

5. Conclusion

A new growth theory presented by Parente and Prescott (1994, 2000, 2005) suggests that countries may converge to different steady states due to barriers to technological adoption. This paper applied this theory to assess the Spanish and Portuguese development experiences in the post World War II period.

In order to get a model with closed form solutions we imposed a new formulation for the capital investment functions that accounted for an adjustment cost, as advocated by Lucas and Prescott (1971). This innovation on the Parente and Prescott's model resulted in an improved simulation exercise because it eliminated the concern about negative investment values.

Our numerical experiments indicated that the barriers levels have been persistently higher in Portugal than in Spain. More importantly, the barriers levels of these countries have been positively correlated till 1993, when both joined the European Single Market. Afterwards, the barriers evolved in opposite directions, augmenting the disparity in output per worker among the Iberian economies. Finally, we showed evidence to corraborate our belief that at least in recent years the barriers levels were higher in Portugal than in Spain.

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Tables

Table 1 - Initial Calibration

Parameter	Value	Empirical Fact to Match
π	0	Normalized for U.S. baseline
θ_z	0.30	Rate of convergence matches Japan
θ_k	0.20	Rate of convergence matches Japan
γ	0.02	Growth rate for per capita GDP is 2%
A_z	1.585	Implied by the output production function
δ_z	0.0974	Average i_{zt}/y_t ratio 0.30
A_k	1.305	Average k_t/y_t ratio 2.5
δ_k	0.0974	Average i_{kt}/y_t ratio 0.20
β	0.9716	After tax interest rate of 5%
B	620	Fraction of time devoted to labor of 0.4
η	10.00	Labor supply elasticity $(\gamma - 1)^{-1} = 0.11$

Table 2 - Spanish Barriers

	π	$\frac{y^{Spain}}{y^{U.S.}}$
$1945-1959$	2.3777	0.2878
$1960-1974$	0.7741	0.4714
$1975-1985$	1.1191	0.4909
$1986-1993$	1.0731	0.5180
$1994-2003$	0.7849	0.5772

Table 3 - Portuguese Barriers

	π	$\frac{y^{Portugal}}{y^{U.S.}}$
$1945-1959$	3.0424	0.2537
$1960-1973$	1.3002	0.3917
$1974-1985$	1.4836	0.4294
$1986-1993$	1.2523	0.4702
$1994-2003$	1.3314	0.4876

Table 4 - Spanish Barriers, $\theta_z = 0$

	π	$\frac{y^{Spain}}{y^{U.S.}}$
$1945 - 1959$	8.0949	0.2878
$1960 - 1973$	2.2674	0.4714
$1974 - 1985$	2.2394	0.4909
$1986 - 1993$	1.8711	0.5180
$1994 - 2003$	1.1867	0.5772

Table 5 - Portuguese Barriers, $\theta_z = 0$

	π	$\frac{y^{Portugal}}{y^{U.S.}}$
$1945 - 1959$	11.3130	0.2537
$1960 - 1973$	4.0373	0.3917
$1974 - 1985$	3.3939	0.4294
$1986 - 1993$	2.5369	0.4702
$1994 - 2003$	2.2933	0.4876

Figure Legends

Figure 1

Title: Output per worker relative to U.S.; Source: Maddison (2007).

Vertical axis: Fraction of U.S. GDP per capita.

Horizontal axis: Years.

Dark triangle: Spain.

Dark square: Portugal.

Figure 2

Title: Spain - Data versus Model.

Vertical axis: Fraction of U.S. GDP per capita.

Horizontal axis: Years.

Dark triangle: Data.

Clear triangle: Model.

Figure 3

Title: Portugal - Data versus Model.

Vertical axis: Fraction of U.S. GDP per capita.

Horizontal axis: Years.

Dark square: Data.

Clear square: Model.

Figure 4

Title: Spain - Data versus Model, $\theta_z = 0$.

Vertical axis: Fraction of U.S. GDP per capita.

Horizontal axis: Years.

Dark triangle: Data.

Clear triangle: Model.

Figure 5

Title: Portugal - Data versus Model, $\theta_z = 0$.

Vertical axis: Fraction of U.S. GDP per capita.

Horizontal axis: Years.

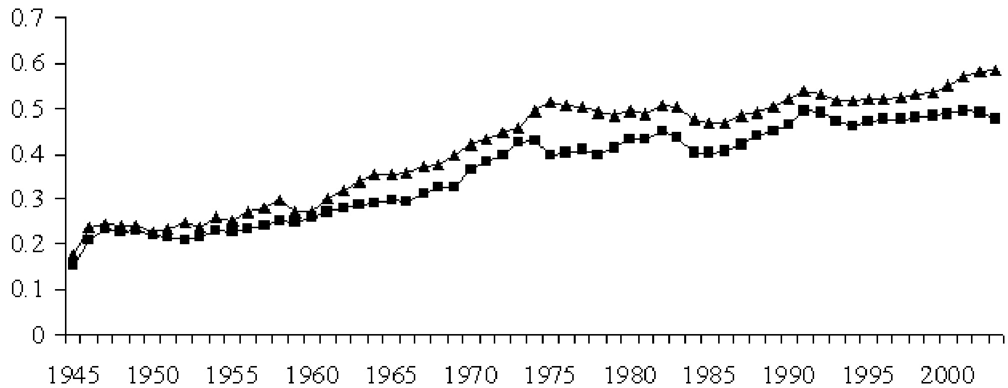
Dark square: Data.

Clear square: Model.

Figures

1

Feb10



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Output per worker relative to U.S.; Source: Maddison (2007).

2

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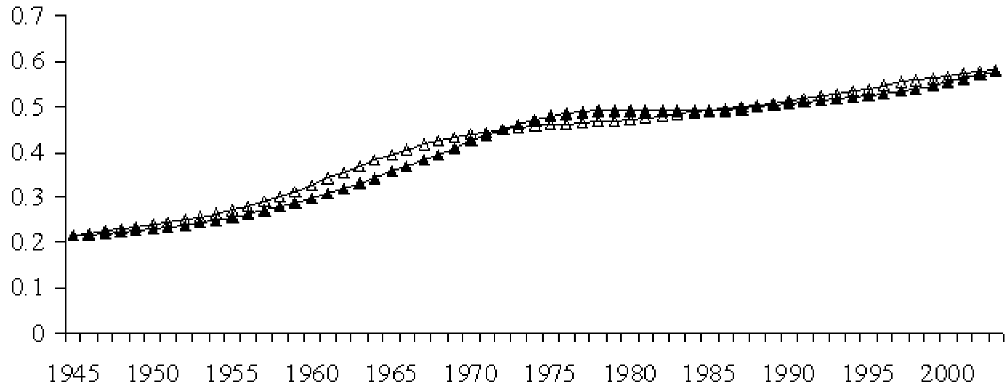

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Spain - Data versus Model.

3

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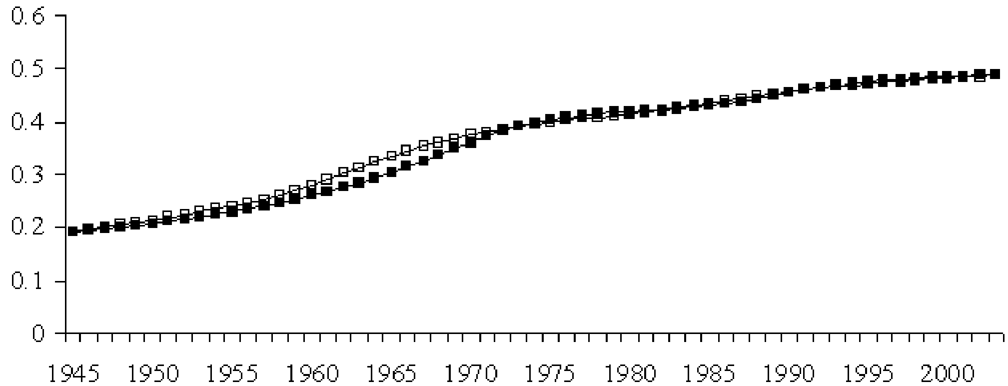

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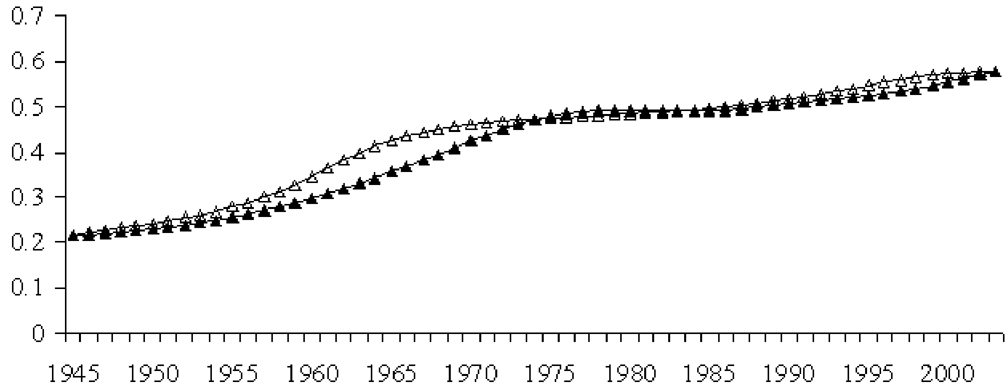

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Spain - Data versus Model, $\theta_z = 0$.

5

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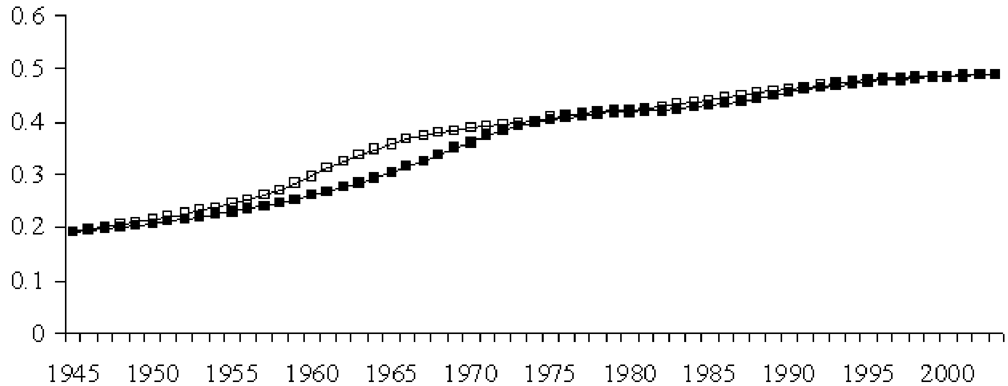

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Portugal - Data versus Model, $\theta_z = 0$.

Mathematical Appendix

Because of the unusual interpretation that the labor market situation is located at a boundary, it is easiest to think of the social planning problem as a two step problem where in the first step a representative agent makes all the allocation decisions taking prices as given and then in the second step equilibrium rental rates and wage rates are applied. To this end, the Lagrangian for this problem is

$$\begin{aligned}\mathcal{L}(\cdot) &= \sum_{t=0}^{\infty} \beta^t \left\{ \ln(c_t - B(1+\gamma)^t h_t^{\eta}) \right. \\ &\quad \left. + \lambda_t \left[r_{kt}k_t + r_{zt}z_t + w_t h_t - c_t - k_{t+1}^{\frac{1}{\delta_k}} (A_k)^{\frac{-1}{\delta_k}} k_t^{\frac{\delta_k - 1}{\delta_k}} - z_{t+1}^{\frac{1}{\delta_z}} (A_z)^{\frac{-1}{\delta_z}} z_t^{\frac{\delta_z - 1}{\delta_z}} \right] \right\}.\end{aligned}$$

The first order conditions for $t = 0, 1, \ldots$ are

$$\frac{\partial \mathcal{L}(\cdot)}{\partial c_t} : \frac{1}{c_t - B(1+\gamma)^t h_t^{\eta}} - \lambda_t = 0, \tag{10}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial h_t} : \frac{-B(1+\gamma)^t \eta h_t^{\eta-1}}{c_t - B(1+\gamma)^t h_t^{\eta}} + \lambda_t w_t = 0, \tag{11}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial k_{t+1}} : -\lambda_t \left(\frac{1}{\delta_k}\right)\left(\frac{i_{kt}}{k_{t+1}}\right) + \beta\lambda_{t+1}\left[r_{kt+1} - \left(\frac{\delta_k - 1}{\delta_k}\right)\left(\frac{i_{kt+1}}{k_{t+1}}\right)\right] = 0, \tag{12}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial z_{t+1}} : -\lambda_t \left(\frac{1}{\delta_z}\right)\left(\frac{i_{zt}}{z_{t+1}}\right) + \beta\lambda_{t+1}\left[r_{zt+1} - \left(\frac{\delta_z - 1}{\delta_z}\right)\left(\frac{i_{zt+1}}{z_{t+1}}\right)\right] = 0, \tag{13}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial \lambda_t} : r_{kt}k_t + r_{zt}z_t + w_t h_t - c_t - i_{kt} - i_{zt} = 0. \tag{14}$$

Substituting in (4), (5) and (6) gives the social planner's first order conditions for $t = 0, 1, \ldots$ of

$$\frac{\partial \mathcal{L}(\cdot)}{\partial c_t} : \frac{1}{c_t - B(1+\gamma)^t h_t^{\eta}} - \lambda_t = 0, \tag{15}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial h_t} : \frac{-B(1+\gamma)^t \eta h_t^{\eta-1}}{c_t - B(1+\gamma)^t h_t^{\eta}} + \lambda_t \frac{(1-\theta_k-\theta_z) y_t}{h_t} = 0, \tag{16}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial k_{t+1}} : -\lambda_t \left(\frac{1}{\delta_k}\right)\left(\frac{i_{kt}}{k_{t+1}}\right) + \beta\lambda_{t+1}\left[\theta_k \frac{y_{t+1}}{k_{t+1}} - \left(\frac{\delta_k - 1}{\delta_k}\right)\left(\frac{i_{kt+1}}{k_{t+1}}\right)\right] = 0, \tag{17}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial z_{t+1}} \quad : \quad -\lambda_t \left(\frac{1}{\delta_z}\right)\left(\frac{i_{zt}}{z_{t+1}}\right) + \beta\lambda_{t+1}\left[\theta_z \frac{y_{t+1}}{z_{t+1}} - \left(\frac{\delta_z - 1}{\delta_z}\right)\left(\frac{i_{zt+1}}{z_{t+1}}\right)\right] = 0, \tag{18}$$

$$\frac{\partial \mathcal{L}(\cdot)}{\partial \lambda_t} \quad : \; y_t - c_t - i_{kt} - i_{zt} = 0. \tag{19}$$

To find the decision rules we use the method of undetermined coefficients. We guess the functional forms

$$i_{kt} = a_k y_t, \tag{20}$$

$$i_{zt} = a_z y_t, \tag{21}$$

$$\frac{1}{\lambda_t} = a_\lambda y_t, \tag{22}$$

where a_k, a_z and a_λ are constants to be determined. Substituting these into (17) and solving for a_k gives

$$a_k = \frac{\beta\delta_k\theta_k}{1-\beta(1-\delta_k)}.$$

Substituting these into (18) and solving for a_z gives

$$a_z = \frac{\beta\delta_z\theta_z}{1-\beta(1-\delta_z)}.$$

To find the consumption decision rule substitute (20) and (21) into (19) and solve for c_t to get

$$c_t = (1 - a_k - a_z)y_t. \tag{23}$$

We can interpret $(1 - a_k - a_z)$ as the marginal propensity to consume out of income. Note, this is simply the decision rule from the Solow model. To find the labor decision rule we substitute (15) into (16) and using (1) gives get

$$B(1+\gamma)^t \eta h_t^\eta = (1-\theta_k-\theta_z)y_t = (1-\theta_k-\theta_z)A(\pi)h_t(1+\gamma)^{(1-\theta_z-\theta_k)t}k_t^{\theta_k}{z_t}^{\theta_z}.$$

Now solving for h_t gives

$$h_t = \left[\frac{(1-\theta_k-\theta_z)A(\pi)k_t^{\theta_k}{z_t}^{\theta_z}}{B\eta(1+\gamma)^{(\theta_z+\theta_k)t}}\right]^{\frac{1}{\eta-1}}.$$

Finally, we need to verify that our guess was correct by verifying that a_λ is a constant. To do this, substitute (15) into (16) to get

$$B(1+\gamma)^t \eta h_t^\eta = (1-\theta_k-\theta_z)y_t. \tag{24}$$

Next, substitute (22) into (15) to get

$$c_t - B(1+\gamma)^t h_t^\eta \;=\; a_\lambda y_t.$$

Now substituting in (23) and (24) and solving for a_λ gives

$$a_\lambda = (1 - a_k - a_z) - \frac{1 - \theta_k - \theta_z}{\eta}.$$

which is a constant and thus confirms our guess.