THE STRUCTURAL TRANSFORMATION AND AGGREGATE PRODUCTIVITY IN PORTUGAL*

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Abstract

In this paper we document the structural transformation - the reallocation of labor between agriculture, manufacturing, and services - undergone by Portugal between 1956 and 1995 and the U.S. between 1870 and 1995. We document that together with the process of labor reallocation across sectors, Portugal has reduced the aggregate productivity gap with the U.S., from a relative productivity of 0.26 in 1956 to 0.55 in 1995. We calibrate a simple general equilibrium model of the structural transformation to data for the U.S. We use this model to gain insight into the factors accounting for the structural transformation in Portugal. We show that during this period Portugal featured low and roughly constant relative productivity in agriculture and services (around 22 percent), low and growing relative productivity in manufacturing (from 44 to 112 percent), and a time varying wedge on non-market activities. We find that the aggregate consequences of Portugal closing its relative productivity gap in services to levels consistent with European data would be dramatic. In addition, while productivity growth in manufacturing accounts for the reduction of the aggregate productivity gap with the U.S., unless services start to grow faster, the model implies no further closing on this productivity gap.

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1. Introduction

We address the long-run economic performance of Portugal and its process of structural transformation, whereby the agricultural sector is replaced in importance by the manufacturing sector and later by the service sector. Portugal has undergone a substantial process of structural transformation over the last 50 years, similar to the past experience of other developed economies. Together with the process of labor reallocation across sectors, Portugal has reduced the aggregate productivity gap with the U.S. over this period, from a relative productivity of 0.26 in 1956 to 0.55 in 1995.

In this paper, we investigate the role of each sector in the process of structural transformation in Portugal and their implications for aggregate productivity. We calibrate a simple general equilibrium model of the structural transformation to data for the U.S. Our analysis produces sharp conclusions about the factors accounting for the structural transformation in Portugal during the 1956-95 period and about the factors accounting for aggregate productivity growth relative to the U.S. Agriculture and services observe much lower relative productivity than manufacturing (about half) in 1956 and no systematic growth during the period, while relative productivity in the manufacturing sector increased substantially. We find that the aggregate consequences of Portugal closing its productivity gap in services relative to the U.S. to levels consistent with European data would be dramatic. As a result, while productivity growth in manufacturing accounts for the reduction of the aggregate productivity gap with the U.S., unless services start to grow faster, the model implies no further closing on this productivity gap.

We build a three-sector model of the structural transformation. Following Rogerson (2005), in our model, labor reallocation across sectors is driven by two channels: income effects due to non-homothetic preferences as in Kongsamut, Rebelo, and Xie (2001) and substitution effects due to differential productivity growth as in Ngai and Pissarides (2004). We calibrate our benchmark economy to the structural transformation of the U.S. between 1956 and 1995 and use this benchmark economy to determine the factors that underly the structural transformation in Portugal. We use this model to measure productivity differences between Portugal and the U.S. across sectors in 1956 and to gain insight into the factors accounting for the structural transformation in Portugal. We show

that during this period Portugal featured low and roughly constant relative productivity in agriculture and services (around 22 percent), low and growing relative productivity in manufacturing (from 44 to 112 percent), and a time varying wedge on non-market activities. These features are essential in accounting for the structural transformation in Portugal. Our model of the structural transformation in Portugal allow us to study the aggregate productivity implications of the factors leading to the structural transformation as well as other counterfactual situations.

The paper is organized as follows. In the next section we document the long-run performance of the Portuguese economy relative to the U.S. and the process of structural transformation in both countries. In section 3 we build a general equilibrium model of the structural transformation. We describe the calibration of the model in section 4 and present the results in section 5. In section 6 we discuss our findings and we conclude in section 7.

2. Transformation and Long-run Performance

In this section we document the economic performance and the process of structural transformation in Portugal relative to the U.S. from 1950 to 2000. We focus on labor productivity (GDP per worker) as our measure of economic performance and document the behavior of GDP per worker in Portugal relative to its behavior in the U.S.

2.1. The Behavior of Aggregate Labor Productivity

We find a substantial process of convergence in aggregate labor productivity from 1950 until the mid 1970's in Portugal relative to more developed economies. However, this process of convergence in productivity slowed down considerably in the mid 1970's. Figure 1 plots the trend GDP per worker in Portugal relative to the same measure in the U.S. and Ireland from 1950 to 2000.[1] While the two measures differ substantially, both depict a marked slowdown in the process of Portuguese convergence occurring in the mid 1970's. Aggregate labor productivity in Portugal relative to the U.S. (represented by the solid line) increased steadily from 1950 to 1975, from about 0.22 to 0.45. The rate at which GDP per worker in Portugal converged to that in the U.S. slowed-down markedly around 1975: In

[1] Trends are obtained from the data by using the Hodrick-Prescott filter.

the latter 25 years of the sample period, GDP per worker in Portugal grew from 0.45 to 0.55 relative to the U.S.[2] The dashed line documents GDP per worker in Portugal relative to Ireland. In 1974, after a period of strong convergence, Portugal and Ireland had comparable levels of GDP per worker. Since then, however, GDP per worker in Portugal has declined steadily relative to that in Ireland, reverting the convergence accomplished in the first half of the sample period. This process accentuated markedly during the 1990's, a period of substantial growth in Ireland.

To gain insight about the driving forces behind movements in output per worker we consider an aggregate production function that is common to all countries. Let output Y in a given country be characterized by a Cobb-Douglas production function that depends on the total capital stock K, total hours worked Lh, and total factor productivity (TFP) A:

$$Y = AK^{\alpha}\left(Lh\right)^{1-\alpha}. \tag{1}$$

In this expression, L represents the number of workers employed, h represents average hours worked per employed person, and α represents the share of payments to capital in total income Y (when factor markets are competitive). Notice that TFP is not directly observable in the data. Given observations on the capital stock, employment, hours worked, and output and given an estimate for the share of payments to capital in total income, we can obtain a measure of TFP as the residual in equation (1).

Equation (1) can be re-written in terms of output per worker Y/L as:

$$\frac{Y}{L} = A^{\frac{1}{1-\alpha}}\left(\frac{K}{Y}\right)^{\frac{\alpha}{1-\alpha}} h. \tag{2}$$

This equation shows that movements in GDP per worker Y/L can be decomposed into movements in TFP, movements in the capital-output ratio K/Y, and movements in the average number of hours worked h.

[2] Later on in the paper we compare the long-run performance of Portugal relative to the U.S. from 1956 to 1995 due to data restrictions on sectoral employment. For this period, relative labor productivity increased from 0.26 in 1956 to 0.55 in 1995.

Empirical evidence suggests that capital to output ratios are remarkably stable over time for many countries, including the U.S. and Portugal.[3] Therefore, we abstract from movements in capital-output ratios as a driving force of relative movements in GDP per worker across countries and focus on the contributions of relative movements in TFP and hours worked across countries in the observed behavior of GDP per worker in Portugal relative to the U.S.

In the U.S., average hours worked per year fell from $2,008$ hours (about 39 hours per week) in 1950 to $1,878$ (about 36 hours per week) in 2000. Thus, in the U.S., movements in hours worked contributed negatively towards growth in GDP per worker in this period. In Portugal, average hours worked fell more than in the U.S. over the period 1950-2000. Average hours worked were $2,344$ (about 45 hours per week) in 1950 and they had fallen to $1,715$ by 2000 (about 33 hours per week). Thus, the pattern of hours worked in Portugal relative to the U.S. suggests that hours worked contributed negatively towards the observed convergence of GDP per worker in Portugal relative to the U.S. during this period. The process of Portuguese convergence relative to the U.S. is thus consistent with higher TFP growth in Portugal relative to the U.S., which more than offsets the fall in hours worked in Portugal relative to the U.S.

Given the behavior of hours worked and GDP per worker in Portugal relative to the U.S. over the period, we conclude that movements in aggregate productivity (as measured by TFP) were the main driving force behind the behavior of GDP per worker in Portugal relative to the U.S.

2.2. The Process of Structural Transformation

Underlying the pattern for relative labor productivity in Portugal depicted in Figure 1 is a substantial process of reallocation of resources across sectors and different patterns of labor productivity by sector. This reallocation process from the agricultural sector into the manufacturing sector and from this sector into the service sector is typically

[3] See for instance Kaldor (1961), Cooley and Precott (1995), Kongsamut, Rebelo, and Xie (2001) for the U.S. and Cavalcanti (2004) for Portugal.

referred to as the structural transformation of the economy in the development literature.[4]

The process of structural transformation has been extensively documented.[5] This process is typically characterized by a substantial fall in the share of employment in agriculture to less than 10 percent, by a steady increase in the share of employment in services, and by an hump-shaped pattern for the share of employment in manufacturing. That is, the typical process of sectoral reallocation involves an increase in the share of employment in manufacturing in the early stages of the reallocation process, followed by a decrease in the share of employment in manufacturing in the later stages.

Different economies have started the process of structural transformation at different points in time. In Figure 2 we report the shares of employment in agriculture, manufacturing, and services in the U.S. from 1869 to 1970, which are broadly consistent with the general characterization described above. By the middle of the 20^{th} century, a substantial degree of sectoral labor reallocation had already taken place in the U.S.: While in 1869 employment shares in agriculture, manufacturing, and services were 0.48, 0.24, and 0.28, by 1948 these shares were 0.10, 0.34, and 0.56. In the second half of the century, the process of labor reallocation from agriculture and manufacturing into services continued, as Figure 3 documents. From 1956 to 1995, the share of employment in agriculture in the U.S. fell from about 10 percent to 2 percent, the share of employment in the manufacturing sector fell from about 38 percent to 24 percent, while the share of employment in services increased from 52 percent to 74 percent.[6]

[4] In this paper we refer to manufacturing and industry interchangeably. In the appendix we describe in detail our definition of sectors in the data.

[5] See, for instance, Kuznets (1966), Maddison (1980), among others.

[6] Figures 2 and 3 use different data sources and the shares of employment for 1956 do not match. Nevertheless, the two figures are consistent regarding the pattern of structural transformation in the U.S.

Portugal has experienced a process of structural transformation that is also broadly consistent with the experience of other economies. Figure 4 documents the share of employment for the agricultural, manufacturing, and service sectors from 1956 to 1995. As this figure shows, Portugal has undergone a substantial process of sectoral labor reallocation in the last 50 years. The share of employment in agriculture has fallen from roughly 48 percent in 1956 to 10 percent in 1995. The share of employment in the service sector has increased steadily throughout this period, from 33 percent in 1956 to 65 percent in 1995. Similar to other countries, the share of employment in manufacturing has an hump-shaped pattern in this period: It increased from 1956 to 1980 (from roughly 20 percent to 26 percent) and it decreased thereafter (to 22 percent in 1995). This pattern of reallocation of employment across sectors over time is similar to the characterization of the structural transformation for the U.S. economy and other economies. It is interesting to note that the structural transformation in Portugal from 1956 to 1995 resembles closely the structural transformation in the U.S. economy from the period 1870 to 1956. Although Portugal is lagging behind the process of structural transformation in the U.S., it has accomplished about the same reallocation of labor across sectors than the U.S. in less than half the time (39 years as opposed to 89 years in the U.S.).

These distinct patterns of employment across sectors observed both in Portugal and the U.S. over the period 1956-1995 are associated with distinct patterns of labor productivity across sectors. In the U.S., labor productivity increased in all sectors, specially so in the agricultural sector. Figure 5 documents the GDP per worker in each sector from 1956 to 1995. The annualized growth rates of labor productivity over this period were 3.4 percent in agriculture, 2.4 percent in manufacturing, and 1.4 percent in the service sector. In 1956 labor productivity in manufacturing and services were 2.2 and 1.7 times that of agriculture. By 1995, labor productivity in manufacturing and services had fallen to 1.5 and 0.8 times that of agriculture.

The pattern of labor productivity across sectors in Portugal is distinct from that in the U.S. Figure 6 plots the GDP per worker in each sector from 1956 to 1995 in Portugal. The annualized growth rates of labor productivity over this period were 4.6 percent in manufacturing, 4.0 percent in agriculture, and 1.7 percent in the service sector. The pattern for labor productivity and share of employment across sectors is determinant for aggregate

labor productivity. In the following sections we build and calibrate a general equilibrium model of the structural transformation. We use this model to asses the role of each sector in the process of structural transformation in Portugal and their implications for relative aggregate productivity.

3. Basic Model

We develop a simple model of the structural transformation of an economy where at each date three goods are produced: agriculture, manufacturing, and services. Our baseline economy features linear technologies in labor with potentially differential productivity growth across sectors and preferences for agriculture and services that feature income elasticities different than one. We calibrate our benchmark economy to U.S. data from 1956 to 1995. We show that this basic framework captures the salient features of the structural transformation in the U.S. for the calibrated period.

3.1. Description of Economic Environment

Production At each date there are three goods produced: agriculture (a), manufacturing (m), and services (s) according to the following constant returns to scale production functions:

$$Y_i = A_i L_i, \quad i \in \{a, m, s\}, \tag{3}$$

where Y_i is output in sector i, L_i is labor allocated to production in sector i, and A_i is a sector-specific technology parameter. When comparing our model to data, we associate the labor input L_i with the employment level of sector i. We assume that there is a continuum of representative firms in each sector that are competitive in output and factor markets. At each date, given the price of good- i output p_i and wages w, a representative firm in sector i solves:

$$\max_{L_i \geq 0} \{ p_i A_i L i - w L_i \}, \tag{4}$$

where L_i is the demand of labor in sector i.

Population The economy is populated by an infinitely-lived representative household of constant size over time. (Without loss of generality we normalize the population size to

one.) The household has preferences over consumption goods as follows:

$$\sum_{t=0}^{\infty}\beta^t u(c_t, c_{a,t}), \quad \beta \in (0,1),$$

where $c_{a,t}$ is the consumption of agricultural goods at date t and c_t is the consumption of a composite of manufacturing and service goods at date t. The per-period utility is given by:

$$u(c_t, c_{a,t}) = \log(c_t) + V(c_{a,t}),$$

where $V(c_{a,t})$ is non-homothetic, i.e., there is a subsistence level of agriculture $\bar{a}$ below which the household cannot survive. This feature of preferences has a long tradition in the development literature. It has been emphasized as a quantitative important feature leading to the movement of labor away from agriculture in the process of structural transformation. (See for instance Echevarria (1997), Laitner (2000), Kongsamut, Rebelo, and Xie (2001), Caselli and Coleman (2001), Gollin, Parente, and Rogerson (2002), and Ngai and Pissarides (2004) among many others.) Following Gollin, Parente, and Rogerson (2002), we simplify the specification of V by assuming that in addition to the subsistence feature of preferences, V is such that households only care to consume the subsistence amount. Formally, $V(c_a) = -\infty$ when $c_a < \bar{a}$, and $V(c_a) = \min\{c_a, \bar{a}\}$ when $c_a \geq \bar{a}$. This feature of preferences makes our analysis much more tractable. We shall see in Section 5 that this simple preference specification captures the share of employment in the agricultural sector in the data remarkably well.

The composite consumption c_t is given by:

$$c_t = \left[b c_{m,t}^{\rho} + (1-b)(c_{s,t} + \bar{s})^{\rho} \right]^{\frac{1}{\rho}},$$

where $\bar{s} > 0$, $b \in (0,1)$, and $\rho < 1$. Given $\bar{s}$, these preferences imply that the income elasticity of consumption of service goods is greater than one. The variable $\bar{s}$ can be interpreted as a constant level of production of service goods at home. Kongsamut, Rebelo, and Xie (2001) assume similar preferences but they abstract from reallocation due to differential productivity growth between manufacturing and services. Our model allows both channels to be operating during the structural transformation and our calibration strategy described in the next section disentangles the contribution of each factor. We

found that for reasonable parametrization of preferences and productivity growth, the movement away from manufacturing to services in the U.S. from 1956 to 1995 cannot be captured by the model without an income elasticity greater than one for services. Our approach to modeling the home sector for services is reduced form. Rogerson (2005) considers a generalization of this feature where people can allocate time to market and non-market production of service goods. However, we argue that our simplification is not as restrictive as it first may appear since we abstract from labor hours in our model.

The problem of the household is also static, at each date and given prices, the household chooses consumption of each good to maximize the per period utility subject to the budget constraint. Formally,

$$\max_{c_i \geq 0} \left\{ \log \left[b c_m^{\rho} + (1-b)(c_s + \bar{s})^{\rho} \right]^{\frac{1}{\rho}} + V(c_a) \right\}, \tag{5}$$

subject to

$$p_a c_a + p_m c_m + p_s c_s = w.$$

In what follows we normalize the wage rate to one.

Market Clearing We assume that the household is endowed with one unit of productive time that supplies inelastically to the market, so the demand of labor from firms must equal this exogenous supply at every date:

$$L_a + L_m + L_s = 1. \tag{6}$$

This specification implies that labor inputs in the model L_i are associated with the shares of employment in the data. Also at each date the market must clear for each good produced:

$$c_a = Y_a, \quad c_m = Y_m, \quad c_s = Y_s. \tag{7}$$

3.2. Equilibrium of the Model

Equilibrium A *competitive equilibrium* is a set of prices $\{p_a, p_m, p_s\}$, allocations $\{c_a, c_m, c_s\}$ for the household, and allocations $\{L_a, L_m, L_s\}$ for firms such that: (i) Given prices, firm's allocations $\{L_a, L_m, L_s\}$ solve the firm's problem in (firms), (ii) Given prices, household's allocations $\{c_a, c_m, c_s\}$ solve the household's problem in (hh), and (iii)

markets clear: equations (6) and (7) hold.

Characterization The first order condition from the firm's problem implies that the benefit and cost of a marginal unit of labor must be equal. This implies that prices of goods are inversely related to productivity:

$$p_i = \frac{1}{A_i},$$

since the wage rate is normalized to one. Our specification of $V(c_a)$ implies that $c_a = \bar{a}\sqrt{2}$ and, therefore, the resource constraint of agricultural goods implies that the labor allocation in agriculture is determined solely by the subsistence constraint and labor productivity in agriculture, i.e., labor in agriculture must satisfy:

$$L_a = \frac{\bar{a}}{A_a}. \tag{8}$$

The first order conditions for consumption of manufacturing and service goods implies:

$$\frac{b}{(1-b)}\left(\frac{c_m}{c_s + \bar{s}}\right)^{\rho-1} = \frac{p_m}{p_s},$$

and using the market clearing conditions for output in manufacturing and services and for labor we obtain:

$$L_m = \frac{(1-L_a) + \frac{\bar{s}}{A_s}}{1+x}, \tag{9}$$

where

$$x \equiv \left(\frac{b}{1-b}\right)^{\frac{1}{\rho-1}}\left(\frac{A_m}{A_s}\right)^{\frac{\rho}{\rho-1}},$$

and L_a is given by (8).

Discussion Note that when $\bar{s} = 0$, equation (9) can be written as $L_s / L_m = x$. If $\rho = 0$ then the composite consumption good is a Cobb-Douglas aggregate of consumption of manufacturing and service goods and differential productivity growth across these two

sectors will cause no reallocation of labor in this model. Our model is consistent with the observed labor reallocation across the manufacturing and service sectors as labor productivity grows in the manufacturing sector relative to services when the elasticity of substitution between these goods is low ($\rho < 0$). When $\bar{s}$ is strictly positive, however, the model can imply a given amount of labor reallocation from manufacturing to services as labor productivity in services grows for higher elasticity of substitution ρ .

4. Calibration

We calibrate our benchmark economy to U.S. data for the period from 1956 to 1995. Our calibration strategy involves selecting parameter values so that the equilibrium of the model matches a given set of statistics in the data.

4.1. Description

We assume that a model period is one year. We need to select the following parameters values: b , ρ , $\bar{a}$, $\bar{s}$, and the time series of productivity for each sector $A_{i,t}$ for t from 1956 to 1995 and $i \in \{a, m, s\}$. A summary of our calibrated parameters and targets is in Table 1.

Table 1: Parameter Values and Targets

Parameter	Value	Target U.S. Data
$A_{i,56}$	1.0	Normalization
$\bar{a}$	0.1	Employment in Ag. 1956
$A_{a,t}$	$\{\cdot\}$	Employment in Ag. 1957-1995
γ_m	2.4%	Productivity Growth in Ind.
γ_s	1.4%	Productivity Growth in Svc.
b	0.04	Employment in Ind. 1957-1995
$\bar{s}$	0.77	Employment in Ind. 1957-1995
ρ	-1.5	Aggregate Productivity Growth

Our baseline calibration strategy is to restrict the parameters values to match the structural transformation of the U.S. for the 1956-1995 time period. Since labor allocation in agriculture is determined independently of the state of the other sectors in our model, our calibration procedure can be roughly divided in two parts. First, we calibrate productivity and subsistence in agriculture so that the equilibrium of the model matches the share of

employment in agriculture. Second, we calibrate the other parameters of the model to match the share of employment in manufacturing (thus, the share of employment in services is also matched by market clearing).

In particular, we proceed as follows. First, we normalize productivity levels across sectors to one in 1956, i.e., $A_i = 1$ for all $i \in \{a, m, s\}$. Second, given the normalization for $A_{a,56} = 1$, we choose $\bar{a}$ to obtain the share of employment in agriculture in U.S. data in 1956. Third, given $\bar{a}$ we use equation (8) to choose $A_{a,t}$ to match the share of employment in agriculture in U.S. data at every date from 1957 to 1995. This calibration implies an annual average labor productivity growth in agriculture during this period of 3.4%, which is consistent with the data for labor productivity growth in U.S. agriculture.[7]

In the second component of our calibration, we need to restrict $\bar{s}$, b, ρ and the annual average growth rates of productivity for manufacturing and services to match the share of employment in manufacturing. Therefore, the data on employment in manufacturing cannot uniquely restrict all these parameters. We proceed as follows. We assume that labor productivity growth in manufacturing and services are 2.4% and 1.4%. These estimates are consistent with our own calculations using the Groeningen Growth and Development Centre data and the Penn World Table. Given ρ and b, $\bar{s}$ is chosen to match the share of employment in manufacturing in the U.S. in 1956. Then b is chosen so that, given the time path for relative productivity, the model matches the time path for the share of employment in manufacturing. Since ρ determines how much relative productivity growth is needed to produce a given reallocation of labor across sectors, ρ will induce different patterns of aggregate productivity growth. We choose ρ to match average aggregate productivity growth during the period (at 1956 prices). We calculate that the average labor productivity growth in the U.S. between 1956 and 1995 is 1.7% in the Penn World Table. Our calibrated value for ρ is -1.5. This value is consistent with the assumed value in Rogerson (2005) in his analysis of the U.S. and European employment and in the middle range of values in Ngai and Pissarides (2004).

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[7] Annual average growth rates over the period 1956-1995 are computed as $\gamma_i = \left(\frac{A_{i,95}}{A_{i,56}}\right)^{1/39} - 1$

4.2. Results of Benchmark Economy

Our calibration restricted preference and technology parameters of our model to match the data for the U.S. structural transformation during the period 1956-1995. The share of employment implied by our model are reported in Figure 7 (dotted lines), together with data on the shares of employment in the U.S. (solid lines). The equilibrium employment shares for manufacturing and services implied by our model match closely the process of structural transformation of the U.S. over this period.[8] The model implies a fall in the employment share in manufacturing from about 38 percent in 1956 to 26 percent in 1995, while the employment share in services increases from about 53 percent to 72 percent. We found that, given the observed growth rates of labor productivity in the U.S., this process of labor reallocation between manufacturing and services could not be accomplished in the model without an income elasticity greater than one in services. (See Kongsamut, Rebelo, and Xie, 2001 and Ngai and Pissarides, 2004 for a detailed discussion of relative productivity vs. income effects in the process of structural transformation.)

5. Quantitative Analysis

In this section, we use our quantitative model calibrated to the U.S. to gain understanding into the process of structural transformation in Portugal. Our calibrated benchmark economy puts discipline on technology and preferences, allowing us to gain insight into the role of productivity differences in the process of structural transformation in Portugal. In this section, we perform four experiments aimed at gaining insight into the structural transformation in Portugal. Then, we perform counterfactual exercises that assess the aggregate implications of different factors that drive the process of structural transformation in Portugal. Our main findings in this section are that manufacturing productivity growth accounts for the reduction in the aggregate productivity gap with the U.S. during the 1956-1995 period and that the lack of relative growth in services has kept Portugal lagging behind in aggregate productivity relative to the U.S.

[8] Note that our model matches the share of employment in agriculture by construction.

5.1. Structural Transformation in Portugal

We take four steps aimed at understanding the structural transformation in Portugal. First, we consider an economy identical in terms of preferences and technologies to the benchmark economy except in the level of economy-wide productivity, in order to match the observation that output per worker in Portugal was 26 percent of the U.S. level in 1956. Second, we allow for different relative productivities across sectors in 1956 that are consistent with the observed shares of employment across sectors in Portugal in 1956. Third, we consider an economy that in addition to the features described above has productivity growth across sectors that is driven by observations on sectoral productivity in Portugal. Finally, we consider a time-varying wedge between market and non-market activities that allows us to match the process of structural transformation in Portugal.

Economy-wide Productivity Our first experiment involves using the benchmark economy but with lower aggregate labor productivity in 1956. As documented in section 2, output per worker in Portugal was 26 percent the output per worker in the U.S. in 1956. Our first experiment assumes that labor productivity in each sector was 26 percent of the respective sector in the U.S., i.e. $A_{i,56} = 0.26$ for $i \in \{a, m, s\}$ instead of 1 in our calibration of the benchmark economy. The results of this experiment in terms of the share of employment across sectors are reported in Figure 8 where the solid lines represent the data and the dashed lines the model. Focusing first on the share of employment implications for 1956, the model implies too little employment in agriculture and services and too much employment in manufacturing relative to the data. In other words, in the context of our model, Portugal being 26 percent of the frontier productivity in all sectors implies much less employment in agriculture and much more employment in manufacturing than in the data, suggesting that Portugal may be less than 26 percent productive at agriculture and more than 26 percent productive in manufacturing in 1956 relative to the U.S. This result suggests our second step in constructing the structural transformation in Portugal.

Relative Sectoral Productivity in 1956 We set sectoral productivity in 1956 so that the model matches the share of employment across sectors in Portugal in 1956 (in addition to the relative aggregate productivity of 26 percent in 1956). Our calibration of this

experiment implies that agriculture, manufacturing, and services must be 21, 44, and 22 percent as productive as in the benchmark economy in 1956.[9] The results of this experiment are reported in Figure 9. While the model matches the share of employment across sectors in 1956 exactly by construction of our calibration in this experiment, the time path of the shares of employment are different than in the data, specially in agriculture. This result is to be expected since we know from the sectoral productivity observations that productivity growth in agriculture was slower in Portugal than in the U.S. from 1956 to about 1975 but faster thereafter. This slower productivity growth should reduce the amount of labor released from agriculture by the model over time. This leads to our next step in constructing the structural transformation of Portugal which is to consider the sectoral productivity growth observed in Portugal.

Productivity Growth in Portugal As noted above, Portugal is not riding along the same technological process as the U.S. While in 1956 relative sectoral productivity in Portugal were all below the U.S. level, Portugal experienced higher annualized rates of labor productivity growth in all three sectors than the U.S. In this experiment, we use the growth rates in agriculture, manufacturing, and services in Portugal implied by the smoothed path of these variables between 1956 and 1995, together with the features of the two previous experiments. The employment shares implied by the model are plotted in Figure 10. The employment share in agriculture implied by the model matches very closely the data. This result suggests that the simple characterization of preferences for agricultural goods that we use in our model has implications for labor allocations in the agricultural sector that are consistent with the data. The share of employment in services implied by the model grows faster than in the data, while the share of employment in manufacturing implied by the

[9] Recall from Figures 2 and 4 that Portugal underwent a structural transformation in agriculture between 1956 and 1995 that resembles closely the structural transformation that the U.S. underwent between 1870 and 1956. Hence, an alternative calibration of $\bar{a}$ and productivity growth in agriculture to our benchmark would be to select these parameters to match the structural transformation of the U.S. between 1870 and 1956. Normalizing the productivity level of agriculture in 1870 to one, this alternative calibration would imply that $\bar{a} = 0.48$ and a level of productivity in agriculture in 1956 of 4.8. This implies an annualized average rate of productivity growth in agriculture of 1.84%. (Note that this rate of growth is less than half the observed growth rate of productivity during the 1956 to 1995 period in the U.S.) If this level of productivity represents the frontier in the world, then Portugal in 1956 should have observed a share of employment in agriculture of 10% as opposed to the 48% in the data. We conclude that Portugal is not riding along the same technological process as the U.S. There are factors (either institutional or policy driven) that lead to a large share of employment in agriculture in Portugal in 1956.

model declines. We conclude that there may be factors, perhaps not technological, that are preventing the "normal" movement of people from manufacturing to services. We consider as our next step a wedge between non-market and market activities that summarizes all the possible forces that prevent reallocation to services. Prescott (2004) and Rogerson (2005) argue that taxes on market activities may be behind the employment problem in European countries.

Structural Transformation in Portugal The previous discussion implies that our simple framework does not capture the process of labor reallocation between manufacturing and services observed in Portugal between 1956 and 1995. In this experiment we add a time-varying barrier to market activities so that the model matches the Portuguese structural transformation in this period, as reported in Figure 11. The resulting time varying barrier to market activities has the feature that it grows almost monotonically from 1 in 1956 to 5 in 1995. Our benchmark economy with lower relative sectoral productivity in 1956, faster productivity growth, and a time varying wedge in non-market activities is able to reproduce closely the pattern of labor reallocation observed for Portugal in 1956-1995. We use this economy as the basis of our counterfactual experiments in the next subsection.

Relative Sectoral Productivity Our model of the structural transformation implies patterns of sectoral labor productivity relative to the U.S. that are consistent with aggregate data. These relative sectoral productivities are plotted in Figure 12. The model implies that labor productivity in manufacturing in Portugal converged fast relative to the U.S. during this period, from 0.44 in 1956 to 1.12 in 1995. Labor productivity in agriculture and services in Portugal, however, experienced very limited improvement relative to the U.S. during this period: In 1956 relative productivity in agriculture and services were 0.21 and by 1995 they were 0.26 and 0.25. Notice that the model imposes discipline on the relative sectoral productivities in 1956. Their pattern thereafter is implied by data on productivity growth by sector in each country.

5.2. Counterfactuals

Our previous analysis suggests that productivity in agriculture and services in Portugal are behind the aggregate productivity differences of Portugal relative to the U.S. In this section, we use our general equilibrium model to isolate the importance of each

sector in the structural transformation for aggregate productivity and sectoral labor allocations.

Closing the Productivity Gap in Agriculture Our model implies that productivity in agriculture in Portugal was 21 percent in 1956 and 26 percent in 1995 relative to the U.S. In sharp contrast, Rogerson (2005) suggests that the productivity gap in agriculture between Europe and the U.S. required to reproduce relative labor allocations in this sector in 2000 was 0.97. Therefore, we ask what the aggregate productivity implications woud be in the case in which Portugal closes the productivity gap in agriculture to 0.97 by 1995. To produce this catch up in productivity, labor productivity in agriculture in Portugal would need to grow at an annual rate of 7.5 percent instead of the 4 percent observed in the data. The labor allocation and aggregate productivity implications of this counterfactual are summarized in Table 2 and in Figure 13. While closing the productivity gap in agriculture produces an important reallocation of employment from agriculture to services by 1995 (the shares of employment change from 10.6 to 2.9 percent in agriculture and from 65.4 to 72.5 percent in services) the aggregate productivity implications of this change are relatively small: The annualized growth rate of aggregate productivity increases from 3.7 percent in the Benchmark Portugal to 3.8 percent in this counterfactual and aggregate productivity in Portugal relative to the U.S. in 1995 increases from 0.55 to 0.57. The intuition behind this result is that while improving productivity in agriculture produces an important reallocation of labor, this reallocation shifts labor mostly towards services. As we documented previously, the service sector in Portugal has a roughly similar relative productivity to that in agriculture. In addition, the direct effect of the sharp improvement in agricultural productivity in the aggregate falls over time, as the associated fall in the share of employment in agriculture reduces the weight of this sector in the aggregate economy.

Table 2: Counterfactuals

	Benchmark PT	Prod. Agriculture	Prod. Services	Prod. Ag. & Svc.
Prod. Growth in Ag. γ_{A_a} (%)	4.0	7.5	–	7.5
Prod. Growth in Svc. γ_{A_s} (%)	1.7	–	5.1	5.1
Share of Employment 1995 (%):				
Agriculture	10.6	2.9	10.6	2.9
Industry	24.0	24.6	23.6	24.8
Services	65.4	72.5	65.8	72.3
Aggregate Prod. (PT/US):				
1956	0.26	0.26	0.26	0.26
1995	0.55	0.57	0.90	0.97
Growth (%)	3.7	3.8	5.1	5.3

Closing the Productivity Gap in Services Our model implies that productivity of services in Portugal relative to the U.S. was 21.7 percent in 1956 and 24.9 percent in 1995. As in the case of agriculture, these numbers are in sharp contrast with the productivity gap in services between Europe and the U.S. suggested by Rogerson (2005), 0.89, required to reproduce relative labor allocations in 2000. In this counterfactual we ask what the labor allocation and aggregate implications are of a change in productivity in services from 21.7 percent in 1956 to 89 percent in 1995. This remarkable change in relative productivity in services generates almost no effect in the shares of employment across sectors. The reason is that this improvement in the relative productivity of services generates no effect in the allocation of labor in agriculture in our model and two opposing effects in the allocation of labor across industry and services. On the one hand, higher productivity in services relative to manufacturing, all else equal, reallocates labor towards services due to the low substitutability between these two goods in preferences $(\rho<0)$. On the other hand, higher productivity in the production of market services relative to non-market services (constant $\bar{s}$), all else equal, reallocates labor towards manufacturing. In this counterfactual, these two opposing effects roughly cancel each other and the effects on labor allocations are small. However, this change in relative productivity has an important effect in aggregate productivity because the improvement in productivity occurs in a large sector of the economy that is growing in size due to the structural transformation. The growth rate in aggregate productivity increases to 5.1 percent annually, leading to a relative aggregate productivity of 0.90 in 1995 as documented in the dotted-dashed line in Figure 13.

Closing the Productivity Gap in Agriculture and Services While we found that improving agricultural productivity by itself did not have large aggregate productivity effects, when combined with improvements in the service sector, improving agricultural productivity can have important aggregate effects. In this counterfactual we combine the improvements in productivity described in the previous two counterfactuals. As documented in Table counterfactuals, higher productivity in agriculture implies that there is a substantial release of labor from agriculture to services (as in the first counterfactual). In turn, higher relative productivity in services implies that this reallocation of labor has a higher aggregate effect than in the second counterfactual. In this counterfactual, relative aggregate productivity in 1995 is 0.97 compared to 0.9 in the case of improvement in the service sector only.

5.3. Discussion

Our analysis produces sharp conclusions about the factors accounting for the structural transformation in Portugal during the 1956-95 period and about the factors accounting for aggregate productivity growth relative to the U.S. Agriculture and services observe much lower relative productivity than manufacturing (about half) in 1956 and no systematic growth during the period, while relative productivity in the manufacturing sector increased substantially. While our analysis is silent about the factors accounting for this behavior of relative productivity over time, we suspect that competition within each sector may be responsible for this differential performance across sectors. Manufacturing is composed of a number of tradable goods while agriculture, and specially services, are composed of a number of non-tradable goods. Our analysis suggests that finding ways of improving labor productivity in the service sector relative to the U.S. would have large consequences for aggregate productivity. However, these policies cannot rely on foreign competition. In addition, while manufacturing productivity has accounted for all the aggregate productivity growth in Portugal relative to the U.S. during the period, its role in determining aggregate productivity in the future is mitigated by its decreasing share in employment. (Recall that Portugal has already started a second phase of structural transformation whereby employment is moving from manufacturing to services.) We conclude that only relative productivity growth in services can provide further closing of the aggregate productivity gap with the U.S.

We documented that aggregate productivity in Portugal relative to the U.S. slowed down since 1975. Our analysis suggests that this relative slowdown is accounted for by relatively faster growth in manufacturing in the U.S. starting in 1975 and by the decline in the share of employment in manufacturing in the process of structural transformation in Portugal.

It is well known that distribution services represent a large portion of final-good prices in developed economies. For instance, the U.S. Department of Agriculture reports that out of every dollar spent on food in the U.S., eighty cents correspond to distribution and marketing services, while only twenty cents correspond to the producer price that farmers receive. Therefore, low relative productivity in services may be partly responsible for the observed low relative productivity in agriculture. While our model does not explicitly account for the role of distribution services, the last counterfactual in the previous subsection suggests that if improvements in productivity in services go along with improvements in productivity in agriculture, the aggregate productivity implications are amplified.

Our analysis suggests that there has been an increasing wedge on non-market activities. This wedge could represent an increasing role of taxes and other regulations in the market economy. While this wedge is important in the model to account for some features of the structural transformation in Portugal, as discussed in subsection 5.1, we emphasize that this wedge is not important for aggregate productivity in Portugal relative to the U.S. In fact, the counterfactual situation where this wedge is not present would imply that employment would have moved faster out of manufacturing into services. Since manufacturing in Portugal is relatively more productive than services, aggregate productivity growth would have been lower in this counterfactual situation than with the wedge.

6. Conclusions

From 1956 to 1995, GDP per worker in Portugal relative to the U.S. increased from 0.26 to 0.55. This reduction of the aggregate productivity gap with the U.S. was associated with a process of labor reallocation across sectors of production, typically referred to as the structural transformation. In this paper we build a general equilibrium

model of the process of structural transformation. Using this model we are able to disentangle the role of sectoral labor productivity growth in the reduction of the aggregate productivity gap of Portugal relative to the U.S. We find that relative labor productivity in manufacturing increased substantially and played an important role in this process. In turn, relative labor productivity in agriculture and services lagged behind. We find that the aggregate consequences of Portugal closing its productivity gap in services relative to the U.S. to levels that are consistent with relative productivity levels in Europe would be dramatic.

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A Data Sources and Definitions

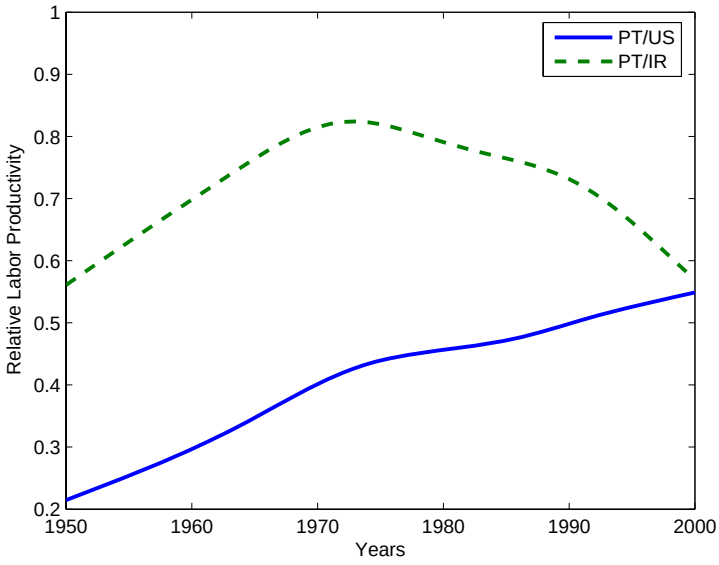
We use the following data sources:

- Banco de Portugal, Séries Longas para a Economia Portuguesa.
- Groningen Growth and Development Centre and the Conference Board, August 2005, http://www.ggdc.net. We use the following databases: Total Economy Database and 10-Sector Database.
- Historical Statistics of the U.S. (1975): Persons Engaged in Production, by Industry Divisions: 1869 to 1970.
- OECD Employment Database.
- Penn World Tables Version 6.1.

We adopt the following sectoral definitions. We include in agriculture the following sectors: agriculture, forestry, and fishing. We include in manufacturing: mining, manufacturing, public utilities, and construction. Services include: wholesale and retail trade; transport and communication; finance, insurance, and real estate; community, social, and personal services; and government services.

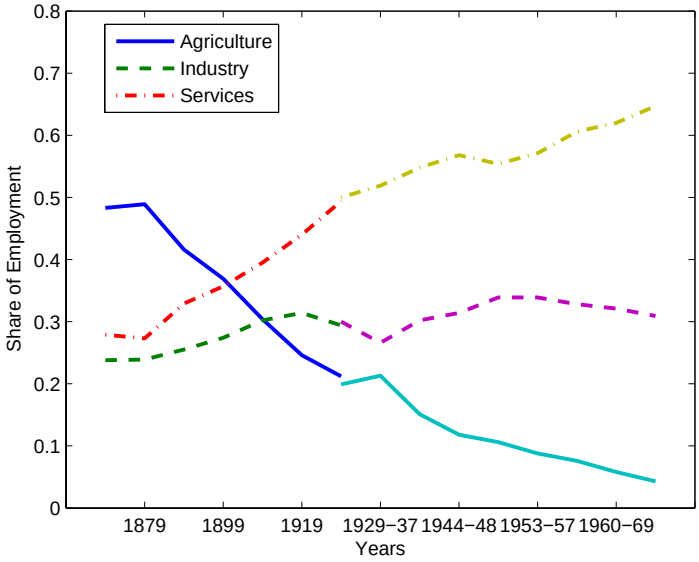
All observations (except the historical shares of employment in the U.S.) are smoothed using the H-P filter.

Figure 1
Relative Labor Productivity in Portugal



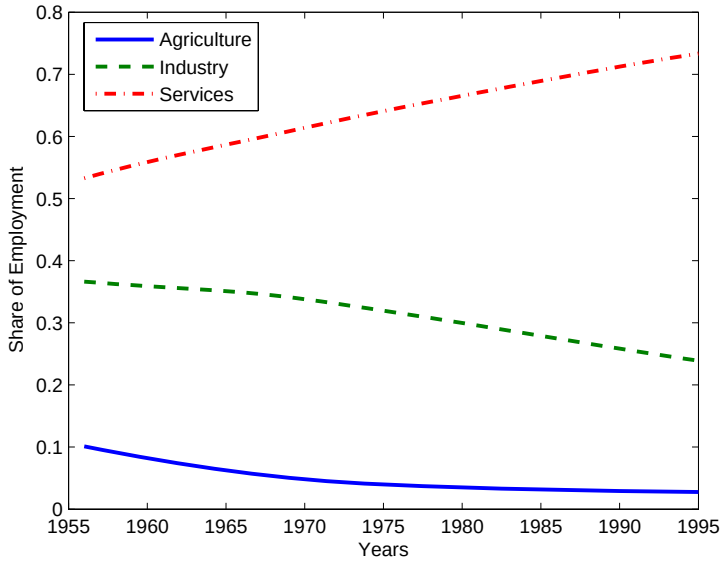
Source: Penn World Tables Version 6.1.

Figure 2
Share of Employment by Sector – U.S. Historical Data



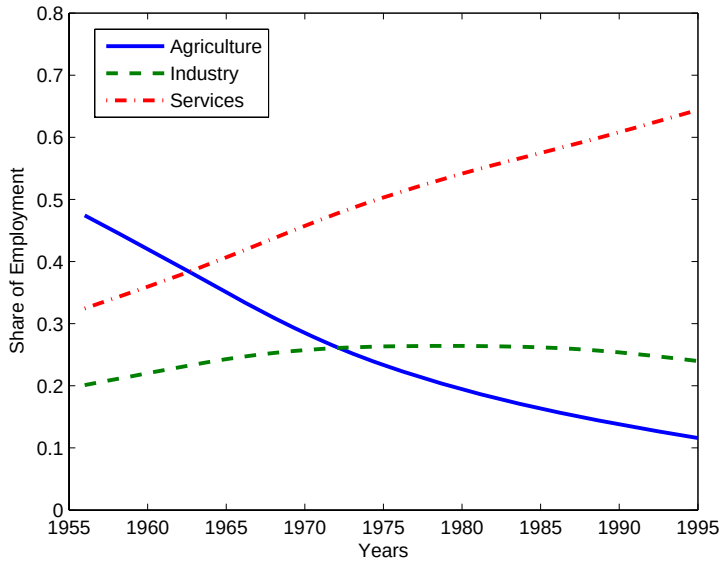
Source: Historical Statistics of the U.S. (1975)

Figure 3
Share of Employment by Sector – U.S.



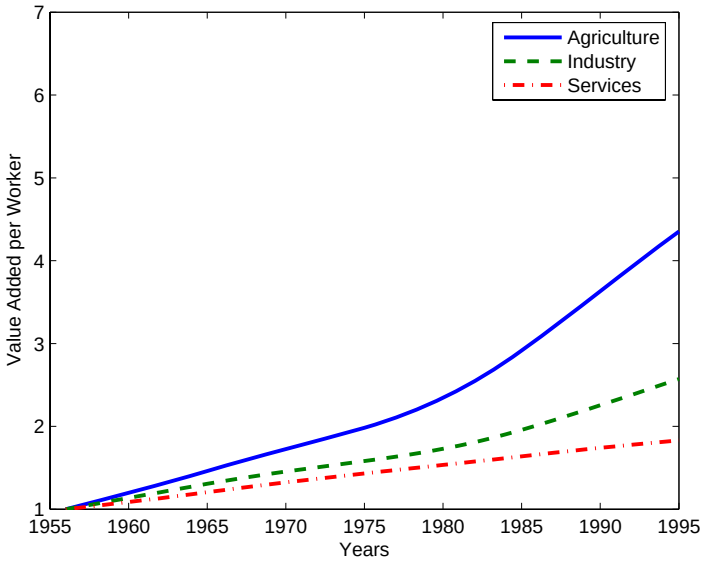
Source: OECD and author's calculations.

Figure 4
Share of Employment by Sector – Portugal



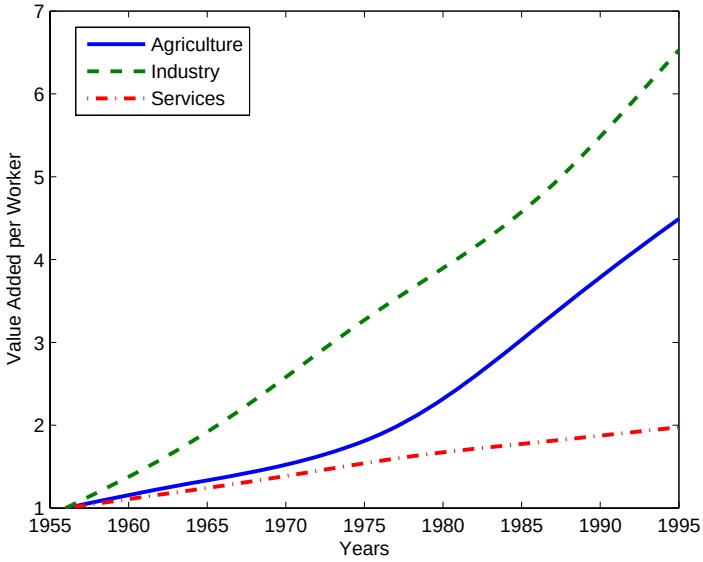
Source: Banco de Portugal and author's calculations.

Figure 5
Labor Productivity by Sector – U.S.



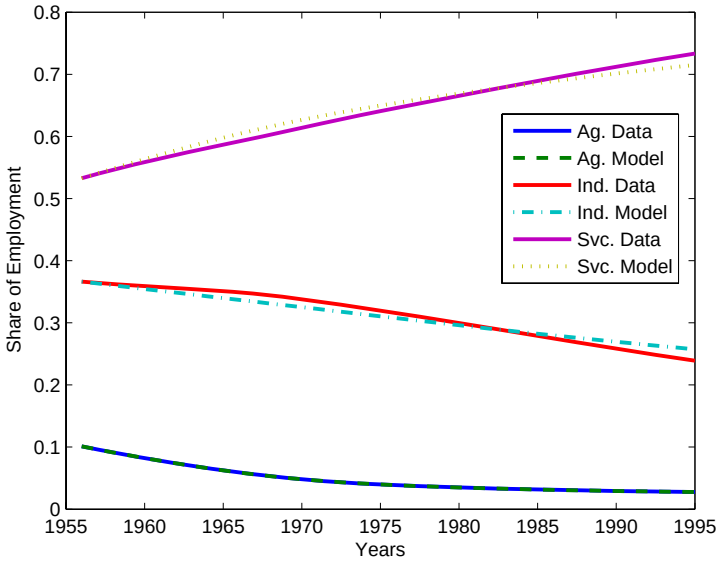
Source: Groningen Growth and Development Centre (2005) and author's calculations.

Figure 6
Labor Productivity by Sector – Portugal



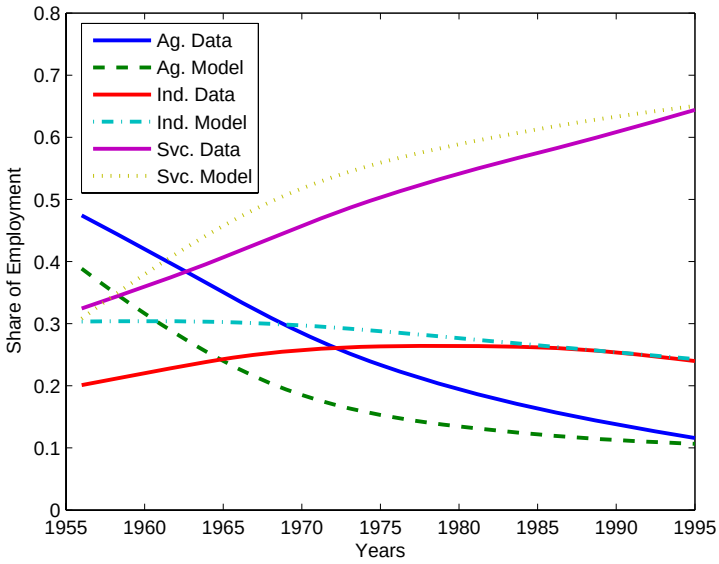
Source: Banco de Portugal and author's calculations.

Figure 7
Share of Emplyment by Sector – Model vs. U.S. Data



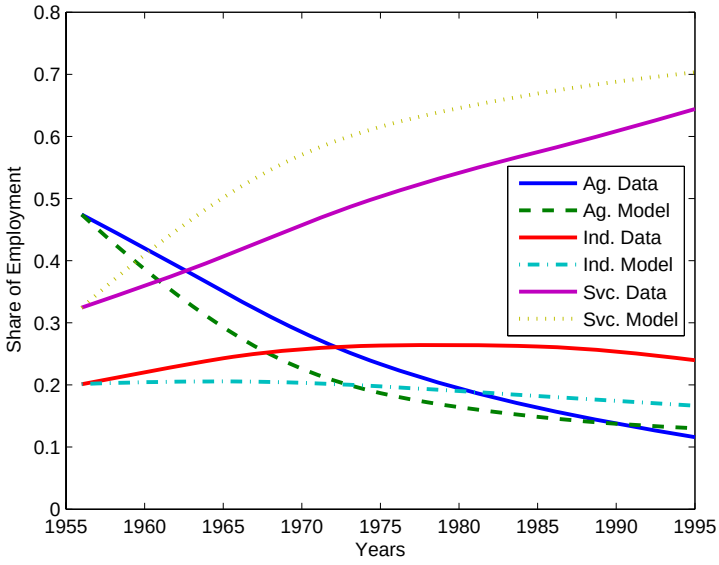
Source: OECD and author's calculations.

Figure 8
Share of Emplyment by Sector – Model vs. PT Data



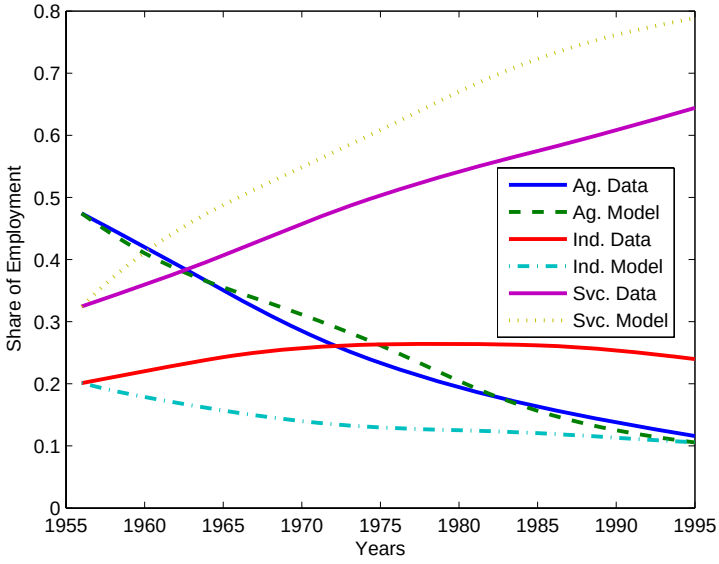
Source: Banco de Portugal and author's calculations.

Figure 9
Relative Sectoral Productivity in 1956 – Model vs. PT Data



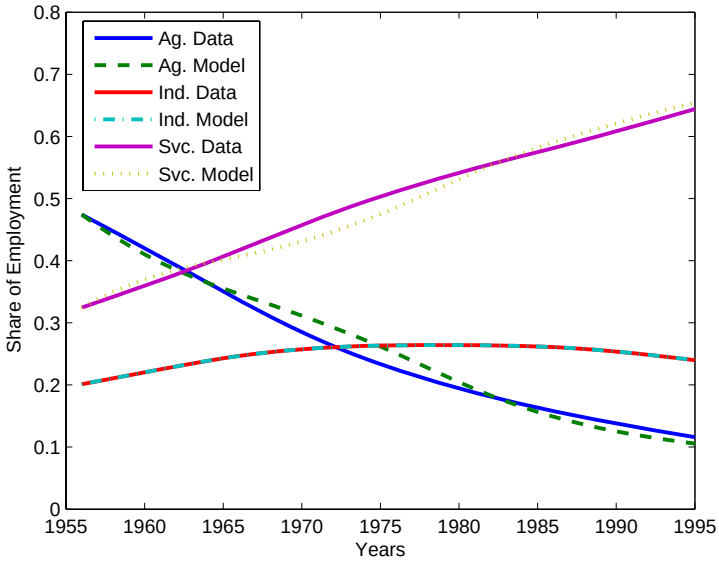
Source: Banco de Portugal and author's calculations.

Figure 10
Sectoral Produtivity Growth PT – Model vs. PT Data



Source: Banco de Portugal and author's calculations.

Figure 11
Non- market Wedge – Model vs. PT Data



Source: Banco de Portugal and author's calculations.

Figure 12
Sectoral Productivity (PT/US)

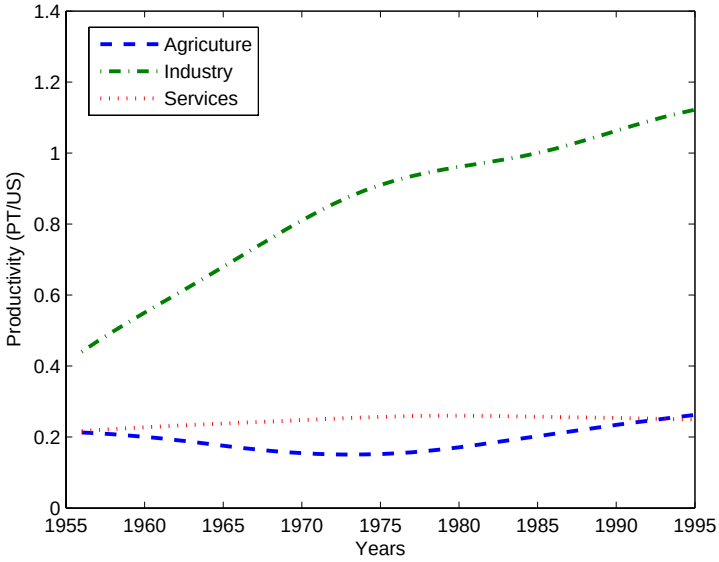
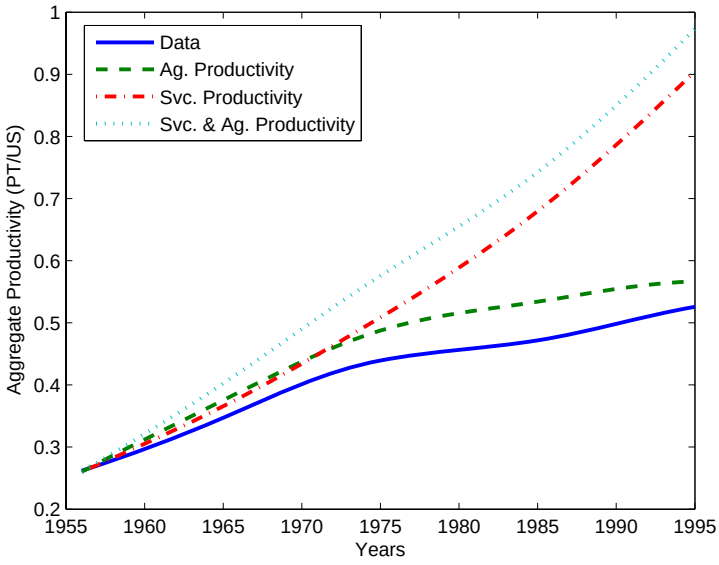


Figure 13
Counterfactuals on Sectoral Productivity



These counterfactuals refer to changes in sectoral productivity from 1956 to 1995. Ag. Productivity refers to the counterfactual situation where the relative productivity in agriculture changes from 0.21 to 0.97 Svc. Productivity refers to the situation in which relative productivity in services changes from 0.22 to 0.89. Ag. And Svc Productivity refers to the counterfactual situation in which both relative sectoral productivity change as describe above.