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Structural Transformation and the Volatility of Aggregate Output in OECD Countries

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Structural Transformation and the Volatility of Aggregate Output in OECD Countries[1]

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Abstract

This paper finds a negative relationship between the employment share of the service sector and the volatility of aggregate output in the OECD—after controlling for the level of financial development. This result reflects volatility differentials across sectors: labor productivity is more volatile in agriculture and manufacturing than in services. Aggregate output would therefore become less volatile as labor moves away from agriculture and manufacturing and toward the service sector. I examine the quantitative role of these labor shifts—termed structural transformation—on the volatility of aggregate output in OECD countries. I first calibrate to the U.S. economy an indivisible labor model in which the reallocation of labor across sectors emerges endogenously from sectoral labor productivity growth differentials. The setup is then used to generate the time path of labor shares in agriculture, manufacturing and services in individual countries. Finally, I perform a set of counterfactual analyzes in which the reallocation of labor across sectors is constrained endogenously. I find that the secular shift of labor towards the service sector was volatility-reducing in OECD countries during 1970–2006.

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I. INTRODUCTION

Half a century ago, Arthur Burns, during his presidential address to the American Economic Association (Burns, 1960) stated:

> "The new stabilizing tendency is as yet weak, but it is being gradually reinforced by the spread of 'white-collar' workers...Moreover, much of this type of employment is by its nature of an overhead character and therefore less responsive to economic fluctuations than are the jobs of machine operators, craftsmen, assembly-line workers, truck drivers, labourers and others in the 'blue-collar' category."

This view is suggestive that fluctuations in aggregate output would be less pronounced as resources shift away from (high-volatility) agriculture and manufacturing towards (low-volatility) services. Many papers have since attempted to assess the quantitative role of output composition on aggregate output volatility. The subsequent interest in the topic is not surprising in light of the sharp decline in output volatility, both in the U.S. and across most OECD countries over the past few decades (see appendix).[1] This has been labeled "The Great Moderation", which is still one of the most striking macroeconomic features of the U.S. economy and other industrialized countries, although the recent global financial crisis has casted doubts on the tendency of economies to mute cycles.[2]

However, studies on the role of composition on output volatility, almost exclusively based on the U.S. economy, have led to apparently contradictory findings. McConnell and Pérez-Quirós (2000), after documenting a break in U.S. output volatility in the first quarter of 1984, find that output composition was of little importance in stabilizing output. They attribute the sharp decline in output volatility to the reduction in the magnitude of inventories investment, an extremely volatile component of durables output. Stock and Watson (2002) attribute the decreased U.S. output volatility to various factors, namely, improved policy ($20-30\%$), "good luck" in the form of smaller productivity and commodity price shocks ($20-30\%$), and other unidentified good luck factors.

McConnell and Pérez-Quirós (2000), and Stock and Watson (2002) build on the premise that, if compositional shifts were to impact the volatility of aggregate output, the series ob-

[1] All G-7 (Group of Seven) countries witnessed the great moderation to some extent. This also generalizes to OECD countries, with perhaps the exception of South Korea, Turkey and the Netherlands. The timing and magnitude of the moderation, however, differs substantially across countries (see appendix, Figure 6). For example, the great moderation can be dated back to around 1992 in the U.K., as opposed to the mid-1980s for the U.S.

[2] See Carvalho and Gabaix (2010) on the role of the financial sector on the undoing of the great moderation in the U.S. Carare and Mody (2012) also show that the great moderation was dampened by the mid-1990s, due to the increased interconnectedness of countries, including with the more volatile emerging economies.

tained by holding the shares of various GDP components constant would display no change in volatility over time.[3] Comparing the volatility of the resulting series to the original GDP series, these authors find no significant evidence that composition matters for output volatility.

Statistical support to the output compositional shifts hypothesis emerges from two recent empirical studies. Alcala and Sancho (2004) argue that the above methodology used to assess the role of composition on output volatility suffers from the same anomaly as does the fixed-weight (Laspeyres type) indexes that were used in the past to compute real aggregate series in the National Accounts, and that have been replaced by chain-weighted (Fisher type) indexes. In fact, given that sector's shares have experienced large changes over the sample period, output volatility is not immune to the particular base year one chooses. Allowing these shares to vary, the authors find that shifts across broad sectors of the U.S. economy account for about 30% of the volatility decline since the 1950's. More recently, Eggers and Ioannides (2006), decomposing output by one-digit industry, find that a little less than half of the sharp decline in U.S. volatility after the mid-1980s was accounted for by compositional shifts, and mostly the decline of manufacturing.

This paper uses a model of structural transformation whereby the reallocation of labor across sectors—that underpins output composition—emerges endogenously from changes in sectoral labor productivities. This is a major departure from the above studies which take output composition as given, thus implicitly assuming that labor allocation across sectors is independent from sectoral labor productivities. This assumption is clearly at odds with existing theories of structural transformation which precisely emphasize sectoral labor productivity differentials as one of the main driving forces behind labor mobility across sectors. When the elasticity of substitution among goods in the consumption basket is low enough, labor moves towards the less productive sectors (services here), so as to close the production gap that may emerge otherwise.

Interestingly, structural transformation is a continuous process, just as the reduction in output volatility has been steady over several decades, as noted by Blanchard and Simon (2001). The authors argue that the decline in U.S. output volatility started in the early 1950's or earlier, was temporarily interrupted in the 1970's and early 1980's, and returned to trend afterwards.[4] This empirical regularity allows me to focus, not specifically on the break that occurred in the U.S. volatility in the mid-1980s, but on the whole volatility path. Moreover, unlike related studies (exclusively U.S.-based), I consider the experience of OECD countries. In that

[3] McConnell and Pérez-Quirós (2000) hold each sector's share at its sample-wide average, whereas Stock and Watson (2002) keep them at their 1965 levels.

[4] The authors note that the interruption in the decline of volatility in the 70's was due to large supply shocks.

respect, this paper is also a contribution to the large literature that seeks to understand the differences in business cycles patterns across countries. In fact, if aggregate output volatility is found to decline with the size of the service sector, countries with a large share of labor in the service sector would tend to feature a less volatile aggregate output, all else equal. On the empirical side, the use of a panel allows one to control for potential time and country fixed-effects. For example, large swings in international business cycles that are common to many countries (such as the recent global financial crisis) would suggest a pick-up in volatility in a single country setup, a finding which may not hold in a cross-country framework that explicitly accounts for the fact that countries were simultaneously hit by the shock.

The subject tackled in this paper is closely related to Da-Rocha and Restuccia (2006), but differs from it along two dimensions. First, I emphasize the role of the service sector, whereas they examine the role of agriculture. Second, the authors simulate their model around various steady states, differing by the share of employment in agriculture. This paper instead studies volatility patterns along a transitory path towards balanced growth. I take in so doing into account the fact that countries are at different stages of the process of structural transformation, as highlighted in Da-Rocha and Restuccia (2006).[5]

In a recent paper, Moro (2012) examines the role of the structural transformation between manufacturing and services on the decline in the volatility of output in the U.S. His study, however, shares two features of the previous literature which my paper departs from. First, the author simulates his model around various steady states differing by the share of services in GDP. The shares used by the author correspond to the years 1960 and 2005 (first and last year of his sample), and to the average of the sub-periods 1960–1983 and 1984–2005. I instead examine the continuous decline in output volatility throughout the sample and evaluate the role of structural transformation on that decline. Second, the author focuses on the U.S., whereas my paper covers the OECD.[6]

From a methodological stand point, this paper is close to Duarte and Restuccia (2010) who use a model of structural transformation to quantify the role of sectoral labor allocation on aggregate productivity. But my paper differs from theirs in that I analyze fluctuations in out-

[5]The authors note: “We recognize that countries such as Turkey and even the United States are undergoing a process of structural transformation (from agriculture to non-agriculture), and that Turkey may be lagging behind in this transitory path.

[6]Another minor difference between my analysis and Moro (2012)’s is that he pools agriculture together with manufacturing, whereas I consider a three-sector model (agriculture, manufacturing, and services). It is fair to note, however, that distinguishing agriculture from manufacturing was less relevant for his analysis which focused on the U.S., as the country had little employment left in agriculture in 1960. I consider agriculture and manufacturing separately given that many OECD countries still had a sizable share of their employment in agriculture throughout the sample period.

put around the trend (business cycle frequency), whereas they examine trends in aggregate productivity (low frequency).

The first step of my analysis consists in building a model of structural transformation that is calibrated to the experience of a given country (the U.S.), in order to put discipline on preference parameters. Labor reallocation across sectors in the model is mainly driven by sectoral labor productivity growth differentials. In the second step of the analysis, the deep parameters of the model are kept unchanged from the first step, and country-specific sectoral labor productivity processes are fed into the model, which then generates the time path of labor in agriculture, manufacturing and services in individual OECD countries.[7] Finally, in order to quantify the role of structural transformation on the volatility of aggregate output, I perform a set of counterfactual experiments in which labor mobility across sectors is constrained endogenously.

The counterfactual experiments need to be based on an approach which controls the process of structural transformation (long term process), while keeping the cyclical properties of the exogenous variables unaltered. This is because the paper emphasizes the role of structural transformation on output fluctuations (short-run dynamics). I proceed as follows: For each country, I decompose sectoral labor productivities into permanent components (divers of structural shifts in labor) and transitory components (exogenous sources of output fluctuations). Now, feeding the same permanent productivity component across sectors in the model—keeping the transitory components unchanged—allows me to shut down most of the secular shift of labor across sectors.[8] The resulting aggregate output series are then constructed and their volatility evaluated. I find that labor reallocation toward the service sector was volatility-reducing in the OECD during 1970–2006.

The remainder of the paper proceeds as follows. Section II provides some empirical facts about structural transformation and output volatility in OECD countries. In Section III, I present and calibrate a model of structural transformation to the U.S. experience. Section IV uses the model from Section III to generate the process of structural transformation in individual OECD countries and to perform a set of counterfactual analyses. Section V draws concluding remarks.

[7]It is indeed critical that the model matches not only the process of structural transformation in the benchmark economy, but also in other countries in the sample. This is because the counterfactual analysis that follows is performed on the entire set of countries.

[8]The counterfactual experiment still, however, generates some labor reallocation of labor, due to uneven income elasticities of demand across sectors.

II. EMPIRICAL EVIDENCE

This Section documents some facts related to structural transformation and volatility, using annual data for 21 OECD countries over the period 1970–2006.[9] The volatility of a variable Y at any point t in time is computed as the standard deviation of the growth rate of Y over a rolling window. I consider a 10-year backward-looking window, so that the volatility at date t is the standard deviation of growth from period $t-9$ to period t.[10] Computations suggest (see Table 5 in appendix) that agriculture is more volatile than manufacturing, which is in turn more volatile than services. This fact is robust across OECD countries and is quantitatively important: labor productivity is about half as volatile in services as in manufacturing and is nearly twice as volatile in agriculture as in manufacturing in any OECD country.[11] Varying the window value for computing the volatilities does not alter these results.

Another empirical regularity is the process of structural transformation, which typically involves three stages, as described by Kuznets (1966). Countries are characterized by a sizeable labor force in agriculture in the first stage. For example, at the beginning of the sample (1970), the share of employment in agriculture—as a percentage of the civilian employment—was 63% in Turkey, nearly 50% in South Korea, 41% in Greece, and 30% in Portugal and Spain. Countries then progressively shift resources from agriculture to manufacturing in the second stage. The third stage is characterized by the shift of employment away from manufacturing and towards services. For example, the U.S., the U.K. and Canada now have more than 70% of their employment in the service sector, and less than 3% in agriculture.

Putting the above two pieces together, it is expected that the volatility of aggregate output would decrease as countries undergo the process of structural transformation. In order to investigate this conjecture empirically, Figure 1 portrays the volatility of aggregate output in OECD countries against the employment share of the service sector. [12] The vertical axis of the chart on the left panel of Figure 1 represents the volatility of aggregate output growth in

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[9]The countries covered are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, and the United States.

[10]For a window value w, the volatility of a variable Y in a given country i at date t is then defined as:

$$\sigma^i_{t,w}(y) = \left(\frac{1}{w-1} \sum_{s=t-w+1}^{t} \left(y^i_s - \bar{y}^i_{t,w} \right)^2 \right)^{1/2}, \quad \text{where} \quad \bar{y}^i_{t,w} = \frac{1}{w} \sum_{s=t-w+1}^{t} y^i_s.$$

where y is the growth rate of the variable Y.

Note that $\sigma^i_{T,T}(y) = \sigma^i(y)$, the usual standard deviation.

[11]These volatility facts also extend to sectoral output.

[12]A window value of 20 quarters is standard in the literature that studies the volatility of output growth at quarterly frequency (see Alcala and Sancho, 2004; Blanchard and Simon, 2001; McConnell, Pérez-Quirós, and

a panel of OECD countries. The horizontal axis represents the average employment share of the service sector over the same window that is used to compute the volatility of output. A coordinate on that chart is therefore related to a given country at a given point in time. The chart on the right panel is the cross-sectional representation of the chart on the left panel, that is values have been averaged across time. It therefore provides a cross-country picture of the link between output volatility and the employment share of the service sector.

Figure 1. Employment Share of the Service Sector and Aggregate Output Volatility in the OECD, 1970–2006.

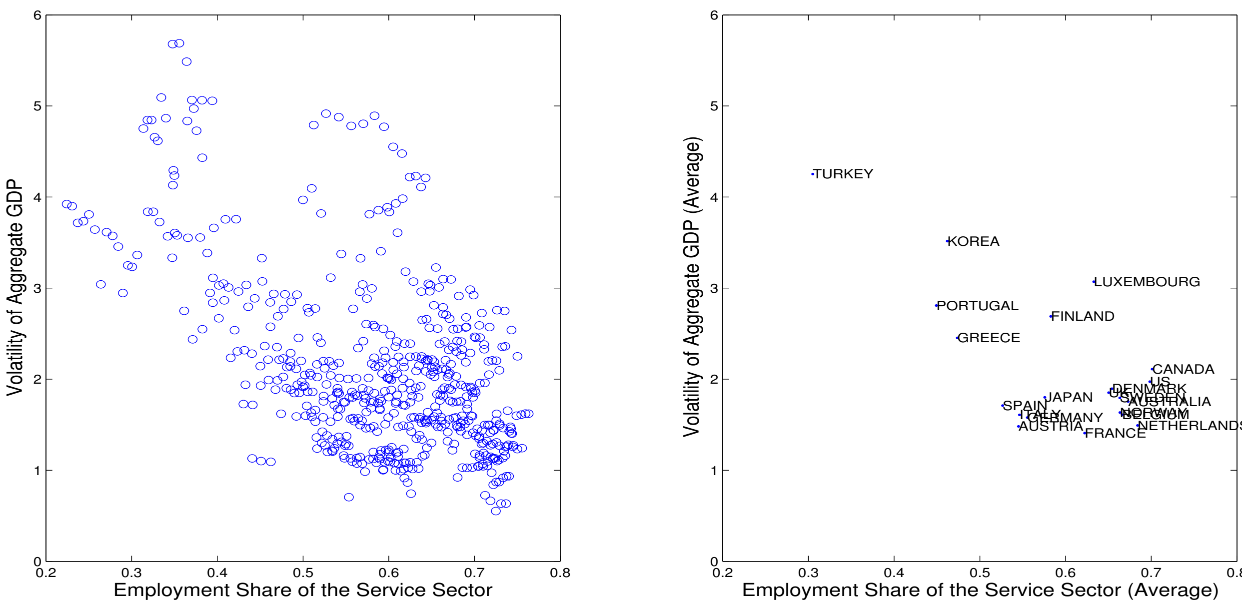

Figure 1 therefore indicates that a high share of employment in the service sector tends to be associated with a low volatility of aggregate output growth, both in the panel data structure (left panel chart) and across countries (right panel chart). The correlation between these two variables is -0.68 across countries and -0.56 in the panel. However, correlation does not necessarily imply causality. This correlation may indeed be induced by a third factor. For example, more developed countries tend to have both a less volatile output growth (see, e.g., Acemoglu and Zilibotti, 1997; Koren and Tenreyro, 2007) and a high share of employment in the service sector, given that they are further ahead in the process of structural transformation. The correlation between output volatility and GDP per capita, proxy for the level of development, is -0.54 across countries and -0.45 in the panel. These values are all smaller than the

Kahn, 2002, among many others). The corresponding 5-year window for annual data would be too small for computing standard deviations. I therefore choose larger windows.

correlation between output volatility and the employment share of the service sector, suggesting that the employment share of the service sector may explain reduced volatility beyond the level of development. To check this conjecture, I regress output volatility on both the employment share of the service sector and the level of GDP per capita, and find that GPD per capita is not significant, whereas the employment share of the service sector is.[13] Another key factor that might affect output volatility is the level of financial markets development.[14] I run a regression in which I also control for the GDP share of the credit to the private sector, proxy for the level of financial development, and the effect of the employment share of the service sector on output volatility remains highly significant. I also perform a wide range of robustness checks, such as varying the window for computing the volatility, replacing the above measure of volatility by the standard deviation of the de-trended series, and the qualitative results are unaltered.[15]

In the next section, I present an indivisible labor model of structural transformation that broadly captures the time path of labor shares in agriculture, manufacturing and services in the U.S. and in the remaining OECD countries. The setup is subsequently used to examine the contribution of these secular labor shifts on the reduced-volatility of aggregate output in the sample.

III. The Model

The model of structural transformation presented in this paper is a modified version of Duarte and Restuccia (2010) to include indivisible labor, as in Da-Rocha and Restuccia (2006). I use the indivisible labor model to circumvent the lack of a comprehensive data on sectoral hours worked for the relatively large sample of countries covered in the paper (sectoral employment data are used instead).

[13]Output volatility is obviously explained by several other factors beyond these two, but this simple exercise allows me to assess whether the observed correlation between the employment share of the service sector and aggregate output volatility is due to the fact that both variables are linked to a third one, namely, the level of development. A similar regression with GDP per capita as the only explanatory variable obviously leads to the conclusion that output volatility decreases with the level of development.

[14]See Dynan, Elmendorf, and Sichel (2006) on the role of financial innovation in reducing the volatility of economic activity.

[15]The de-trended series are obtained by taking the difference between the (log of the) original series and the series obtained by applying the Hodrick-Prescott (HP) filter to the (log of the) original series. I choose a smoothing parameter of $\lambda = 100$, standard for annual observations.

A. The Economic Environment

The economy consists of 3 sectors, namely, agriculture (a), manufacturing (m), and services (s).[16] Production in each sector is undertaken using a linear technology with labor as the only input:

$$Y_i = A_i L_i \ , \quad i \in \{a, m, s\}, \tag{1}$$

where A_i is the sector-specific labor productivity, and L_i is the labor input that goes to sector i. A_i is thus a measure of the productivity per worker. It is exogenous and captures any factor that may affect production beyond the labor input, such as capital and local institutions.[17]

There are no externalities nor any other distortion in this economy. Since the focus of the paper is not on prices, I adopt the social planner approach. The economy is populated by a continuum of identical and infinitely-lived households of measure one, who form the basis for the labor force. Population grows over time at an exogenous rate η, and each household is endowed with a unit of time in each period. Because I use employment data (rather than data on hours worked), I consider an indivisible labor model as in Hansen (1985), based on the seminal work by Rogerson (1988). In that setup, an agent either works full time (for a constant number of hours), or does not work at all.[18] Following Da-Rocha and Restuccia (2006), the baseline indivisible labor model is extended to allow for heterogeneity in the number of hours worked across sectors (see Section III.D on the calibration of hours worked by sector). As a consequence, households care about which sectors they are allocated to in the model, unlike in the standard real business cycle model.

The reason why I choose to use employment data over hours worked is the lack of a comprehensive dataset on hours worked for the relatively large set of countries that I am considering in this paper. For example, data on hours worked from the 10-Sector Database are only

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[16] The terms manufacturing and industry are used interchangeability throughout the paper and both refer to the broader concept of industry which includes mining and construction beside manufacturing strictly speaking.

[17] See Choi, Kim, and Ma (2012) for an open economy structural transformation model with learning-by-doing and endogenous labor productivity in the non-agricultural sector.

[18] The model is thus partially silent about the intensive margin of the labor input. Hansen (1985) shows that he extensive margin of labor accounts for most of the fluctuations in total labor input. He makes the following variance decomposition, where H is the total number of hours worked, h is the average number of hours worked per worker, and L is the number of workers ($H_t = h_t L_t$):

$$\sigma^2_{\log H_t} = \sigma^2_{\log h_t} + 2cov(\log h_t, \log L_t) + \sigma^2_{\log L_t} \tag{2}$$

where the variables are deviations from trend. He finds that 55% of the variance of H is due to variations in L, while only 20% of this variance can be directly attributed to h, the remainder of the variations in H being due to the covariance term.

available for 9 out of the 21 countries in the sample.[19] One advantage of using employment data though is that they are likely to be measured more accurately, compared to data on hours worked.

In each period, an agent works with a probability π_t, independent across individuals. As a consequence, L_t/N_t, the employment to population ratio, is the data counterpart of the equilibrium value of π_t. The probability that an agent works in sector i is given by $\pi_{i,t} = L_{i,t}/N_t$, so that $\pi_{a,t} + \pi_{m,t} + \pi_{s,t} = \pi_t$. It is of interest at this stage to define the probability of working in sector i, conditional on working: $n_{i,t} = L_{i,t}/L_t = \pi_{i,t}/\pi_t$. Note that one therefore has: $n_{a,t} + n_{m,t} + n_{s,t} = 1$.

B. Preferences

The representative household has preferences over the consumption of all three goods. There are two standard channels to generating reallocation of labor across sectors. One can either assume a low (less than 1) elasticity of substitution among goods (see Ngai and Pissarides (2007)) or non-homothetic preferences. In the latter case it is usual to assume an income elasticity of demand for the agricultural good less than unity (see Gollin, Parente, and Rogerson, 2002, 2007), and/or an income elasticity for the demand of services above unity (see Kongsamut, Rebelo, and Xie (2001)). One can also combine a low elasticity of substitution among goods and non-homothetic preferences (see Rogerson (2008)). In principle, a trade-off does exist: allowing for both channels to operate reduces the reliance on how low the elasticity of substitution among goods needs to be in order to generate substantial reallocation of labor across sectors. The specification adopted in this paper is close to Duarte and Restuccia (2010), which is somewhat an hybrid of the above specifications. However, I focus on the extensive margin of labor for the reasons mentioned above, which makes the Hansen (1985) indivisible labor model more appropriate.

The planner's objective function reads:

$$\sum_{t=0}^{\infty} \beta^t \left[U\left(\frac{C_{a,t}}{N_t}, \frac{C_t}{N_t}, 1-h_t \right) \right] N_t, \quad 0 < \beta < 1,$$

where N is the population size so that $C_i/N = c_i$ is the per capita consumption of good or service $i \in \{a,m,s\}$. h is the per-capita hours worked, so that $1-h$ is leisure (households are

[19] Data on sectoral hours worked also exist for few other countries from the ILO database, but this covers only a very short period of time, mostly running from 1990 on.

endowed with a unit of time). The following specification is adopted for the utility function:

$$U(c_{a,t}, c_t, h_t) = \omega \log(c_{a,t} - \bar{a}) + (1-\omega)\log(c_t) + \phi \log(1-h_t), \quad 0 < \omega, \phi < 1,$$

where $\bar{a}$ can be thought of as the subsistence level of agricultural goods. This parameter—which implies a lower than one income elasticity of agricultural goods—will drive labor out of agriculture as income rises, consistently with the data. [20]

The composite of the manufacturing and service goods takes the general CES functional form:

$$c = \left[\theta c_m^{(\varepsilon-1)/\varepsilon} + (1-\theta)(c_s + \bar{s})^{(\varepsilon-1)/\varepsilon}\right]^{\varepsilon/(\varepsilon-1)} \tag{4}$$

where $0 < \theta < 1$, and $0 < \varepsilon < 1$ is a constant elasticity of substitution between the two goods. $\bar{s} > 0$ implies an income elasticity of the service good that is greater than unity.[21] This induces the planner to shift resources out of manufacturing and towards services as income rises.[22]

C. Analytical Solution to the Model

The planner problem, in per capita terms, reads:

$$\underset{\{\pi_{a,t};\pi_{m,t};\pi_{s,t}\}_{t=0}^{\infty}}{Max} E_0 \sum_{t=0}^{\infty} \beta^t \qquad [\omega \log(c_{a,t} - \bar{a}) + (1-\omega)\log c_t + \tag{5}$$

$$\phi \left(\pi_{a,t}\log(1-\bar{h}_a) + \pi_{m,t}\log(1-\bar{h}_m) + \pi_{s,t}\log(1-\bar{h}_s)\right)]$$

subject to:

[20] An alternative way to drive labor out of agriculture at a high pace is provided in Duarte and Restuccia (2006) who adopts the following specification:

$$V(c_{a,t}) = \begin{cases} -\infty & \text{if} \quad c_{a,t} < \bar{a} \\ \min(c_{a,t}, \bar{a}) & \text{otherwise.} \end{cases} \tag{3}$$

But that modeling approach predicts a constant level of agricultural consumption through time ($\bar{a}$), which is at odds with the observation that output in agriculture fluctuates a lot. Although this specification was innocuous in the authors' long-run analysis, it is clearly not suitable for studying fluctuations around the trend.

[21] $\bar{s}$ is generally thought of as a short cut to accounting for household production, since higher income drives people out of their home and leads to a rise in the demand for market services.

[22] Duarte and Restuccia (2010) note that $\bar{s}$ is needed for the model to be able to drive labor towards services while relying on a reasonable value of ε. In principle, one could also assume a non-unity income elasticity for the manufacturing good, a possibility which I rule-out, given that Herrendorf, Rogerson, and Valentinyi (2012) show that this doesn't make a quantitative difference.

$$c_{a,t} \leq A_{a,t}\pi_{a,t}; \quad c_{m,t} \leq A_{m,t}\pi_{m,t}; \quad c_{s,t} \leq A_{s,t}\pi_{s,t}$$
$$c_t = \left(\theta c_{m,t}^{(\varepsilon-1)/\varepsilon} + (1-\theta)(c_{s,t}+\bar{s})^{(\varepsilon-1)/\varepsilon}\right)^{\varepsilon/(\varepsilon-1)} \tag{6}$$
and
$$\pi_{a,t+}\pi_{m,t} + \pi_{s,t} = \pi_t$$

Since sectoral productivities are observed before the production is undertaken, the solution to this problem is a sequence of static conditions.[23] Because the focus here is not on the level of employment, but on its allocation across sectors instead, the level of aggregate employment L_t (and therefore π_t) is treated exogenously.[24] Duarte and Restuccia (2010) and Da-Rocha and Restuccia (2006) adopt a similar approach. They consider the total number of hours worked to be exogenous in their divisible labor model. It is therefore implicitly assumed that the sectoral allocation of labor occurs only after the decision on the total labor input has been taken. The latter decision is indeed likely to be affected by factors such as macroeconomic policies or aggregate productivity shocks that are common to all sectors.

The solution to the planner's problem can be casted in two stages. First, for a given value of the labor share in agriculture, π_a, the planner solves for the share of labor in manufacturing and services (π_m and π_s), with $\pi_m + \pi_s = \pi - \pi_a$. In the second stage, the planner optimizes on π_a given π_m and π_s, both function of π_a from the first stage.

The optimal reallocation path in the first stage is given by the following relation:

$$\frac{\pi_s + \bar{s}/A_s}{\pi_m} = \left(\frac{1-\theta}{\theta}\right)^{\varepsilon} \left(\frac{\log(1-\bar{h}_m)}{\log(1-\bar{h}_s)}\right)^{\varepsilon} \left(\frac{A_s}{A_m}\right)^{\varepsilon-1} \tag{7}$$

If hours worked per worker are identical across sectors, then one obtains a relation which is standard in the literature on structural transformation. When they are allowed to differ, the sector with the lower number of hours worked tends to attract more labor, everything else equal. In fact, for given sectoral labor productivities, the sector with the higher number of hours worked per worker induces more disutility to the worker. But everything else is not equal. In fact, since $\varepsilon < 1$, Equation (7) implies that a lower relative productivity in services drives labor out of manufacturing and towards services.[25] The intuition for this result is as follows: the low elasticity of substitution between manufacturing and services implies that households would like to have a fairly balanced consumption bundle of both goods. To ensure

[23] I have therefore removed the time subscript to simplify the notations.

[24] One may think of the planner problem as one in which aggregate employment is determined first. The distribution of labor across sectors then follows next.

[25] This is in line with Baumol's 1967 prediction on the evolution of the progressive and stagnant sectors.

that, the social planner has to shift resources out of the most productive sector and towards the less productive one.

Equation (7) also implies that, for a given value of ε, the reallocation of labor towards services intensifies with $\bar{s} > 0$. In fact, combining Equation (7) with the equilibrium condition $\pi_m + \pi_s = \pi - \pi_a$, one gets:

$$\pi_s = \frac{1}{1+\Psi}\left[\Psi(\pi - \pi_a) - \bar{s}/A_s\right], \tag{8}$$

where:

$$\Psi = \left(\frac{1-\theta}{\theta}\right)^{\varepsilon}\left(\frac{\log(1-\bar{h}_m)}{\log(1-\bar{h}_s)}\right)^{\varepsilon}\left(\frac{A_s}{A_m}\right)^{\varepsilon-1}. \tag{9}$$

Equation (8) suggests that an upward trend in productivity A_s drives labor toward the service sector, to an extent that increases with $\bar{s}$.

Also, data show (see Section III.D on calibration) that hours worked per worker are lower in the service sector than in manufacturing. The planner therefore has an additional incentive to move labor towards the service sector, beside the two standard channels (low elasticity of substitution and non-homothetic preferences) identified earlier in the literature on structural transformation.[26] In fact, $\frac{\log(1-\bar{h}_m)}{\log(1-\bar{h}_s)} > 1$ for $\bar{h}_m > \bar{h}_s$, so that the object Ψ is larger than if hours worked per worker were identical across sectors.

Solving for π_a in the second stage one obtains the following closed-form solution:

$$\pi_a = \frac{(\bar{a}/A_a)(1+\Psi)(1-\omega) + \omega(\pi + \bar{s}/A_s)(\alpha_m/\alpha_a + \Psi\alpha_s/\alpha_a)}{\omega(\alpha_m/\alpha_a + \Psi\alpha_s/\alpha_a) + (1+\Psi)(1-\omega)}, \tag{10}$$

where Ψ is given by Equation (9) and $\alpha_i = \log(1-\bar{h}_i),\ i \in \{a, m, s\}$.

When $\alpha_a = \alpha_m = \alpha_s = \alpha$, Equation (10) boils down to:

$$\pi_a = (1-\omega)\frac{\bar{a}}{A_a} + \omega(\pi + \bar{s}/A_s), \tag{11}$$

which is similar to the relation in Duarte and Restuccia (2010). Since A_a and A_s are increasing over time, $\bar{a}/A_a$ and $\bar{s}/A_s$ both vanish in the long-run. Since π will also be constant then, the share of labor that goes to agriculture is dictated by ω, the share of the agricultural good in the utility function.

[26]Note that this additional channel comes from the fact that I use employment data, instead of data on hours worked, due to data limitations in my relatively large sample.

D. Calibration

In this section, I calibrate the model to the U.S. experience over the period from 1970 to 2006. The time unit in the model is a year. The calibration consists in assigning values to the parameters $\bar{h}_a$, $\bar{h}_m$, $\bar{h}_s$, $\bar{a}$, $\bar{s}$, ω, ε, θ, $A_{a,0}$, $A_{m,0}$ and $A_{s,0}$. I follow the standard practice in the literature on structural transformation in normalizing initial productivities to one, as choice of units (see Duarte and Restuccia 2006, 2010; Gollin, Parente, and Rogerson 2002; Rogerson 2008, among many others.)

$\bar{h}_i$, $i \in \{a, m, s\}$ are simply set to match the average per capita fraction of discretionary time devoted to sector i over the sample period. Data on total sectoral annual hours worked and persons employed in the U.S. are available from the 10-Sector Database. I aggregate these series into the three broad sectors considered in this paper, namely, agriculture, manufacturing, and services. From these sectoral data, I compute the total number of annual hours worked per person employed for each sector, which I first divide by 365 to obtain daily working hours, and further by 16 to obtain the figure as a fraction of the discretionary time available to individuals.[27] After adjusting for an employment to population ratio of 66%—a standard calibration value in the real business cycles literature—one gets: $\bar{h}_a = 0.49$, $\bar{h}_m = 0.54$, and $\bar{h}_s = 0.46$. These figures imply that a service sector employee spends on average 15% less hours working than a manufacturing employee, and 7% less than an employee in agriculture. Interestingly aggregate hours worked per worker from these computations average nearly to the calibrated value of 0.5 that Hansen (1985) obtains in a one sector RBC model.

ω is set so as to imply a long-run share of employment in agriculture of 1%.[28] I set the weight of the manufacturing good in the CES aggregate of manufacturing and services consumption (θ) to 0.02. This value is in the range of calibrated values in the literature and, given the calibration of the other parameters of the model, provides a good fit of the data. The remaining parameters $\bar{a}$, $\bar{s}$, and ε are calibrated jointly, using a procedure similar to the one described in Duarte and Restuccia (2010). Given an initial value for ε, $\bar{a}$ and $\bar{s}$ are chosen so as to match the initial share of labor in agriculture (using Equation (11)), and in services (using Equation (7)). Now, given these computed values for $\bar{a}$ and $\bar{s}$, ε is re-computed to match the time path of the service sector's labor share, as given by Equation (7). The value obtained for ε is again used to recompute $\bar{a}$ and $\bar{s}$, and the procedure is re-iterated until convergence is achieved. The calibrated values are summarized in Table 1 below.

[27] It is assumed in the RBC literature that people sleep for 8 hours out of the 24 hours in a day.

[28] Duarte and Restuccia (2010) set a similar target. The main quantitative results of the paper are unaffected by reasonable changes in that parameter.

Table 1. Parameter Values

$A_{i,0}$	$\bar{h}_a$	$\bar{h}_m$	$\bar{h}_s$	ω	$\bar{a}$	$\bar{s}$	θ	ε
1	.49	.54	.46	.01	.02	.94	.02	.41

Two key parameters that drive the reallocation of labor from manufacturing to services following sectoral productivity changes are $\bar{s}$, which characterizes the non-homotheticity of preferences, and ε which is the elasticity of substitution between services and manufacturing goods. The value of 0.94 obtained here for $\bar{s}$ is close to the calibrated values of 0.89 in Duarte and Restuccia (2010), and the value of 0.77 in Duarte and Restuccia (2006). The elasticity of substitution, ε, is calibrated at 0.41, very close to the values obtained elsewhere in the literature. For example, the corresponding values implied by Rogerson (2008) and Duarte and Restuccia (2010) are respectively 0.44 and 0.40.[29]

Figure 2 portrays the time path of sectoral labor allocation in the United States as implied by the model. For the sake of comparison, the corresponding time series in the data are also displayed. The model captures the pattern of structural transformation in the U.S. economy pretty well. Moreover it nicely fits the entire time path of the employment share of agriculture, although I only target its initial share.

IV. Results

A. Taking the Model to the Data

The next step consists to using the model to replicate the time path of labor shares in agriculture, manufacturing and services in the remaining OECD countries over the period 1970–2006. Now that I have put discipline on preference parameters,[30] the initial level of sectoral labor productivities are needed to generate the time path of sectoral labor shares for the remaining countries in the sample, using Equation (7) and (11). Given the initial productivity levels and the time path of sectoral labor productivities growth in country j, $(\tau_{i,t}^{j})_t$, the time

[29]These two values are obtained from a transformation $1/(1-\rho)$ of the authors' parameter values -1.28 and -1.5, due to the difference in specifications.

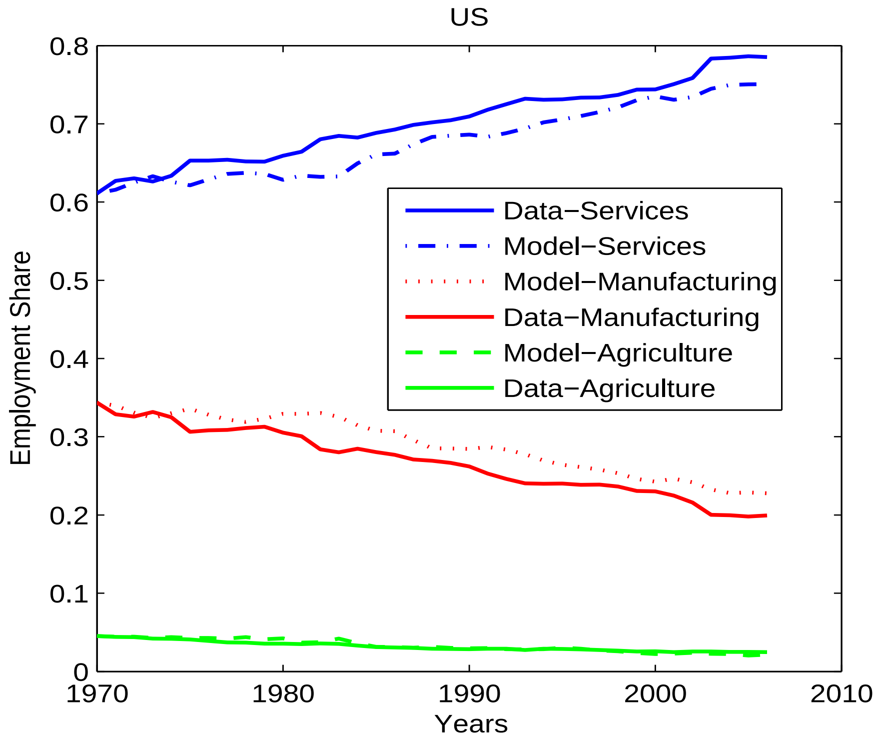
[30]The only preference parameter which is allowed to vary across countries is $\bar{s}$. Recall that $\bar{s}$ can be viewed as a shortcut to modeling home production of service goods. Duarte and Restuccia (2010) argue that $\bar{s}$ can therefore not be constant across countries with large differences in labor productivity in services. $\bar{s}$ is then set so as to keep the ratio $\bar{s}/A_s$ constant across countries.

path of sectoral labor productivities are uncovered sequentially, using the relation:

$$A^j_{i,t+1} = (1+\tau^j_{i,t})A^j_{i,t} \tag{12}$$

Following Duarte and Restuccia (2010), initial labor productivity levels for any country in the sample are simply set to match three targets: the initial labor share in agriculture and services, and the initial aggregate productivity relative to the U.S.

Figure 2. Sectoral Labor Reallocation in the U.S.: Model vs. Data.

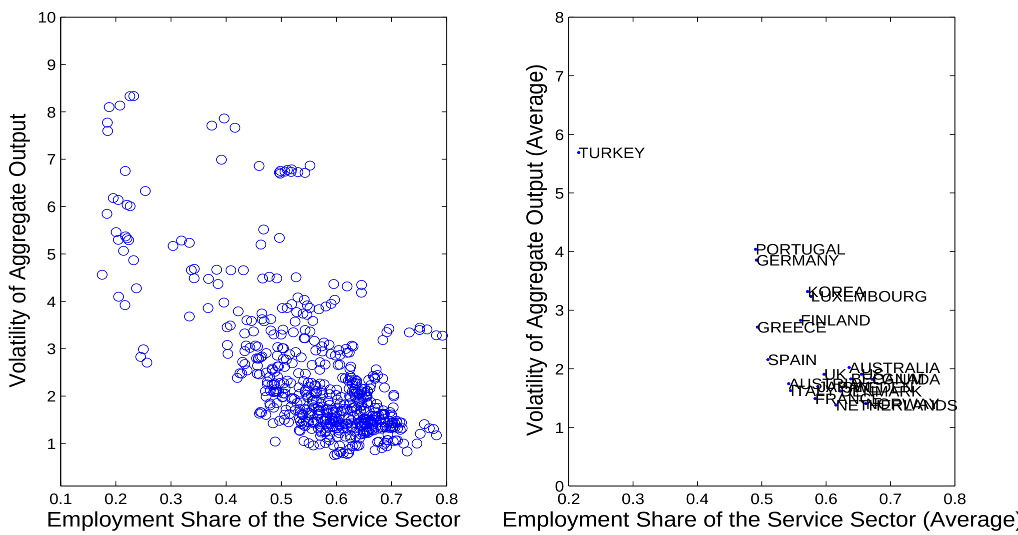


The reallocation of labor across sectors generated by the model for OECD countries is portrayed in Figure 4, along with the corresponding figures in the data. Overall, the model does a good job in mimicking the process structural transformation in OECD countries but in Germany, South Korea, and Turkey. In fact, although the model captures well the reallocation of labor out of agriculture in Germany and South Korea, it fails to predict the reallocation of labor out of manufacturing in the magnitude of what is observed in the data. Trade seems to have played a major role in South Korea, which my closed economy framework would not capture. This is consistent with Betts, Giri, and Verma (2011) findings.[31] The authors show that, while the closed and open economy versions of their model (which focuses exclusively on South Korea) both capture much of the decline in the agriculture's employment share during 1963–2010, only their open economy variant is able to generating the sizable employment

[31] See also Yi and Zhang (2011), Choi, Kim, and Ma (2012), and Teignier (2012) for models of structural transformation in an open economy.

increase that was observed in manufacturing over that period. Also, my model is not successful in explaining the process of structural transformation in Turkey. Perhaps a more targeted model is needed in the case of Turkey where more than 60% of the labor force was still in agriculture at the beginning of the sample period, substantially higher than in a typical OECD country where the corresponding value was as half as large at most.[32] In their empirical analysis, Carare and Mody (2012) find that emerging economies such as Korea and Turkey have continued to experience high volatility while most advanced economies have converged to low volatility levels.

Figure 3. Employment Share of the Service Sector and Aggregate Output Volatility in the OECD (1970–2006): Model



B. Counterfactual Experiments

In this section, I perform a set of counterfactual experiments to assess the quantitative role of the secular labor reallocation across sectors on the volatility of aggregate output in OECD countries. For such an exercise to be meaningful, the model should be able to replicate the negative relationship between the volatility of aggregate output and the employment share of the service sector found in the data. Figure 3 suggests that the model does pass the test pretty comfortably, with a few exceptions. Although the model predicts that Turkey has the most volatile aggregate output in the sample, as it is the case in the data, the model tends to over-estimate the volatility of aggregate output in Turkey. Aggregate output volatility in Germany is also much higher in the model than in the data. Some potential explanations of the mixed success of the model in the cases of Turkey and Germany are provided in Section IV.A. Nonetheless, the overall patterns are preserved.

[32]Trade might also have played a role in the case of Turkey.

One particular feature of this study is that it emphasizes long-run dynamics (structural transformation) in analyzing short-run dynamics (output volatility). I tailor the counterfactual experiments to that particular feature of the analysis. The approach adopted here is therefore different from standard practices in the real business cycle literature where models are simulated around a steady state—after an appropriate de-trending of the system. In fact labor keeps shifting across sectors as countries undergo the process of structural transformation. The counterfactual experiments are designed in a way that restricts the permanent and systematic shifts of labor toward the service sector. The volatility of the resulting aggregate output series are therefore computed and compared to that obtained in the baseline. This allows me to pin down the contribution of permanent labor shifts using the case in which labor is allowed to move freely across sectors as a benchmark. Given that labor shares across sectors are endogenously determined, one cannot simply set their values in performing this exercise. One should instead change sectoral labor productivities—the driving exogenous forces—accordingly. In order to shut down structural transformation (long-run dynamics), I use the HP-filter to decompose labor productivities into permanent and cyclical components as follows:

$$A_i = A_i^{trend} + A_i^{cycle} \quad i = a, m, s \tag{13}$$

where A_i^{trend} is the trend component of labor productivity in sector i (A_i), and A_i^{cycle} is the corresponding cyclical component. In the first counterfactual experiment, I keep labor productivity unchanged in services and agriculture, and assumes that the trend of labor productivity in manufacturing is the same as in services, the cyclical component remaining unchanged. It is indeed critical for the analysis here that the cyclical behaviour of labor productivities be preserved. Changing both the trend and cyclical components of labor productivity would make it hard to disentangle the effect of structural transformation on aggregate output volatility simply because the volatility of aggregate output also depends on the volatility of sectoral labor productivities. Also, the initial values of labor productivities are kept the same as in the baseline. This ensures that labor shares are the same in the baseline and in the counterfactual experiments at the beginning of the sample period (recall that the initial labor productivities are set so as to meet three targets: initial labor share in agriculture and services, and aggregate productivity relative to the U.S. in the first period).

The labor productivity series in the first counterfactual experiment are therefore given by:

$$A_{i,0}^1 = A_{i,0}, \quad i = a, m, s \tag{14}$$

$$A_{a,t}^1 = A_{a,t}; \quad A_{m,t}^1 = A_{s,t}^{trend} + A_{m,t}^{cycle}; \quad A_{s,t}^1 = A_{s,t}, \quad \text{for} \quad t = 2, ..., T. \tag{15}$$

The second counterfactual differs from the first one only in that the labor productivity in agriculture is also distorted. I assume that its trend is also the same as in the service sector, the cyclical component remaining unchanged, so that:

$$A^2_{i,0} = A_{i,0}, \quad i = a, m, s \tag{16}$$

$$A^2_{a,t} = A^{trend}_{s,t} + A^{cycle}_{a,t}; \quad A^2_{m,t} = A^{trend}_{s,t} + A^{cycle}_{m,t}; \quad A^2_{s,t} = A_{s,t}, \quad \text{for} \quad t = 2, ..., T. \tag{17}$$

Table 2. The Role of Structural Transformation on Aggregate Output Volatility

	Change[1] in the Share of Employment			Change[2] in Aggregate Output Volatility
	Agriculture	Manufacturing	Services	
Model	-12.2	-13.3	25.5	-38
Counterfactual 1	-13.3	-6.2	18.4	-26.0
Counterfactual 2	-5.0	-7.2	12.2	-17.8

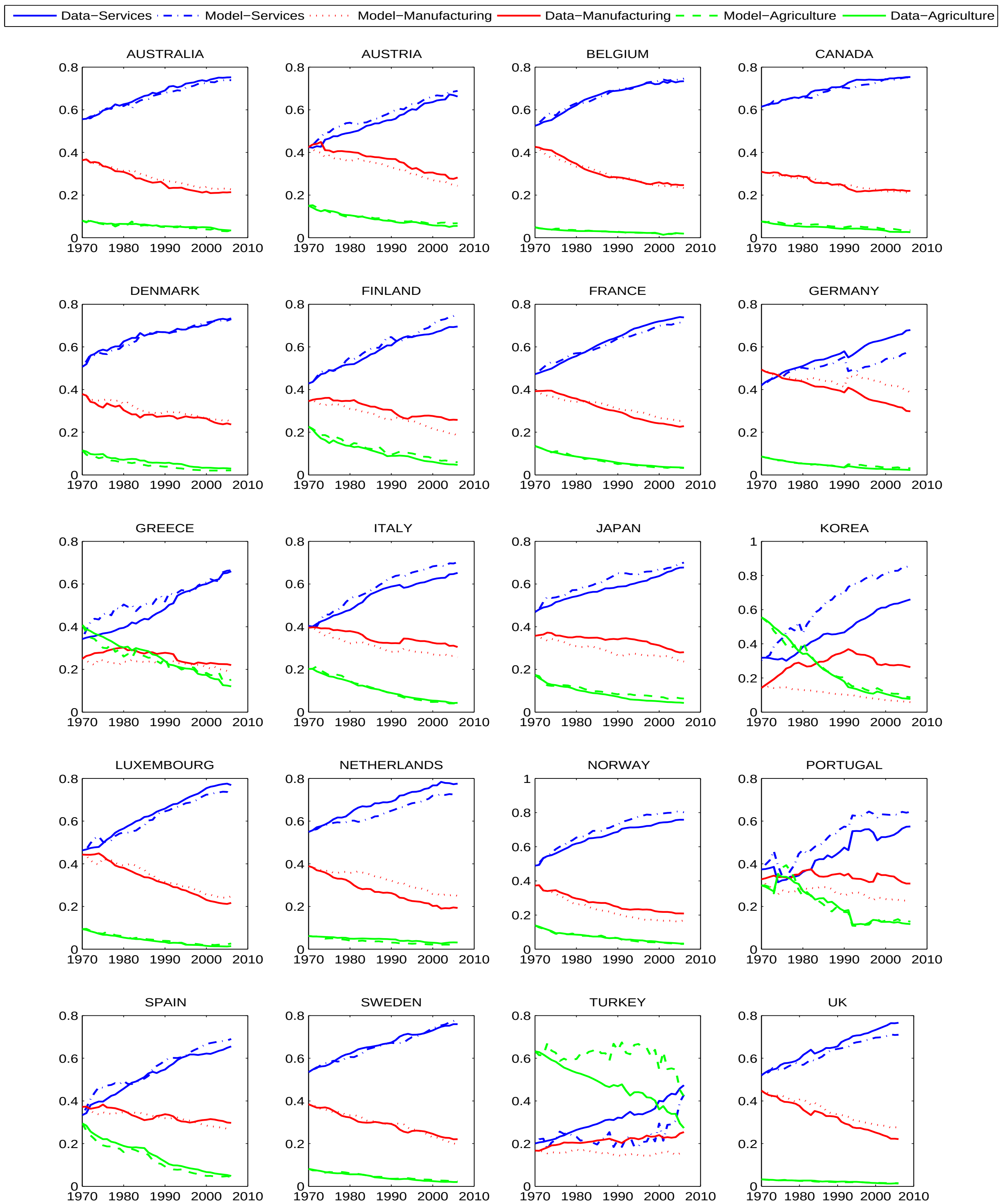
[1]Change from the first to the last period of the sample (in percentage points).

[2] Change from the beginning to the end of the sample (in percent). Recall that volatility is computed as the standard deviation of output growth over a rolling window of 10-year.

Table 2 presents the results obtained after feeding the above labor productivity series into the model. The average decline in the volatility of aggregate output across OECD countries in the model is about 38% over the sample period, with an increase of 25.5 percentage points in the employment share of the service sector (benchmark). The decline in the volatility of aggregate output is reduced to 26% in the first counterfactual experiment when the employment share of the service sector increases by only 18.4 percentage points, and to 17.8%—only half of the drop in the benchmark—when the shift of labor toward the service sector is further constrained to around 12.2 percentage points (second counterfactual experiment).[33] These findings suggest that the reallocation of labor toward the the service sector, driven by sectoral labor productivity growth differentials, played an important role in the decline in the volatility of aggregate output in OECD countries during 1970–2006.

[33]It is worth noticing that one cannot completely shut down labor reallocation toward the service sector in any of these counterfactual experiments, given the greater than one income elasticity of demand for services.

Figure 4. Sectoral Labor Reallocation in OECD Countries: Model vs. Data



V. Conclusion

This paper uses a three-sector indivisible labor model to evaluate the role of structural transformation—secular reallocation of labor across sectors—in the decline overtime in aggregate output volatility in OECD countries. The reallocation of labor across sectors in the model emerges endogenously from differences in sectoral labor productivity growth. The model is first calibrated to match the experience of the U.S. economy during 1970–2006, and then used to generate the time path of employment shares in agriculture, manufacturing and services in individual OECD countries over that episode.

In order to quantify the impact of structural transformation (long term process) on the volatility of aggregate output (short run dynamics), the paper performs a set of counterfactual experiments in which the reallocation of labor across sectors is constrained endogenously. This is achieved by modifying sectoral labor productivity processes in a way that distorts their long-run dynamics, but preserves their short-run dynamics. Imposing the same labor productivity trend across sectors limits the systematic reallocation of labor toward the service sector (precisely because labor reallocation in the model emerges endogenously from differences in sectoral labor productivity growth). The role of structural transformation in aggregate output volatility is then pinned-down by comparing the volatility of output generated by the counterfactual experiment to the one obtained in the baseline with full labor mobility. I find that the shift of labor toward the relatively stable service sector did contribute significantly to the decline in aggregate output volatility in the OECD between 1970 and 2006. More specifically, limiting the extent of labor shift from manufacturing to services does reduce the volatility of aggregate output by about a third between the first and last period of the sample. This fraction rises to about one-half when the shift of labor out of agriculture is also restricted. These results are consistent with the negative relationship between the volatility of aggregate output and the employment share of the service sector presented in the empirical section of the paper.

There is a natural extension to this paper. Due to data availability for the range of countries covered in the paper, the sample starts in 1970. At the time, countries like the U.S., the U.K., and Canada had very few amount of labor left in agriculture—typically less than 10% of their total employment. Extending the data back in the early 1950s for all OECD countries would substantiate the results obtained in this paper. This implies for instance uncovering sectoral labor productivities in less advanced countries like Poland, Uruguay and the Czech Republic, which itself might be model-based.

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Appendix A. Data and Sources

I construct a panel data set containing the following OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, and the United States. Data are gathered from various sources including the OECD database (Annual Labor Force Statistics–Summary Statistics, National Accounts for OECD countries–Main Aggregates, and Detailed Tables—(sourceOECD, 2008)), the World Bank Development Indicators online, and the 10-Sector Database (see Van Ark (1996)). The panel is balanced and covers annual observations for the period 1970-2006. This makes a total of 771 observations for each variable.

Data is available for the total working-age (15-64) population (N), the total civilian labor force (L), as well as the number of persons employed (including self-employment) in three broad sectors of the economy: agriculture (L_a), industry (L_m) and services (L_s).

The sectors are defined by the International Standard Industrial Classification, revision 3 (ISIC II). Agriculture includes forestry, hunting and fishing (ISIC divisions 1-5). Industry corresponds to ISIC divisions 10-45 (mining, manufacturing, construction, electricity, water, and gas), and services to ISIC divisions 50-99 (wholesale and retail trade-including hotels and restaurants, transport, and government, financial, professional, and personal services such as education, health care, and real estate services).

I collect data on sectoral real value added (a measure of real output at the sector level). To insure comparability across countries in the same spirit as PWT data, this measure is in constant $US and constant PPP (OECD base year).

Sectoral productivities are computed as sectoral valued added (VA) per person employed: $A_i = VA_i/L_i, i = a,m,s$. Gross Domestic Product (Y) in the model is simply defined as the sum of value added across sectors.

APPENDIX B. TABLES AND FIGURES

Figure 5. Summary Statistics on Sectoral Volatilities Across OECD Countries.

Countries	Employment Share (Average in %)			Labor Productivity (Average volatility)				Output (Average volatility)			
	Agriculture	Manufacturing	Services	Agriculture	Manufacturing	Services	Aggregate	Agriculture	Manufacturing	Services	Aggregate
AUSTRALIA	5.7	26.9	67.2	14.8	3.6	1.8	2.1	13.8	3.0	1.6	1.8
AUSTRIA	8.9	36.3	54.8	4.5	3.2	2.1	1.7	3.5	2.4	1.3	1.5
BELGIUM	2.9	31.0	66.1	9.4	3.0	1.3	1.5	6.4	3.2	1.5	1.6
CANADA	4.7	25.4	70.0	5.1	2.7	0.8	1.1	5.2	3.8	1.4	2.1
DENMARK	6.1	28.7	65.2	9.3	3.8	2.6	1.7	8.2	3.7	1.5	1.9
FINLAND	10.9	30.8	58.3	7.4	3.4	1.1	1.6	6.7	3.8	2.0	2.7
FRANCE	6.9	30.9	62.2	6.7	1.2	0.7	0.7	6.6	2.0	1.0	1.4
GERMANY	4.5	39.7	55.8	9.7	4.6	2.3	3.2	6.5	2.9	1.3	1.6
GREECE	25.6	26.1	48.3	9.3	4.4	2.8	2.4	6.9	4.4	1.7	2.5
ITALY	10.7	34.9	54.4	4.5	3.2	1.7	1.5	3.8	2.7	1.2	1.6
JAPAN	8.5	33.7	57.8	4.3	3.0	1.2	1.5	4.4	3.4	1.2	1.8
KOREA	25.0	28.1	47.0	8.3	3.5	2.4	2.2	7.2	6.0	2.2	3.5
LUXEMBOURG	4.1	32.5	63.4	12.0	4.0	2.6	2.4	11.3	4.2	3.2	3.1
NETHERLANDS	4.5	27.2	68.4	6.4	3.4	2.4	2.1	4.6	2.3	1.3	1.5
NORWAY	7.0	27.0	66.0	7.9	3.8	1.3	1.7	6.1	3.0	1.5	1.6
PORTUGAL	20.7	33.9	45.4	14.3	4.9	5.2	3.1	6.6	4.5	3.0	2.8
SPAIN	14.5	33.1	52.4	6.9	2.2	1.4	1.1	6.9	3.0	1.4	1.7
SWEDEN	4.4	29.3	66.3	5.4	3.1	1.2	1.3	4.6	3.8	1.1	1.8
TURKEY	47.5	21.3	31.2	6.8	5.2	2.8	4.0	4.4	5.1	2.8	4.3
UNITED KINGDOM	2.2	32.5	65.3	6.8	3.5	1.5	1.6	6.4	2.9	1.5	1.9
UNITED STATES	3.2	26.8	70.1	9.2	2.5	1.0	0.9	8.8	4.0	1.3	2.0
Average	10.9	30.3	58.8	8.0	3.4	1.9	1.9	6.6	3.5	1.7	2.1

Figure 6. The Volatility of Aggregate Output in OECD Countries (actual and trend).

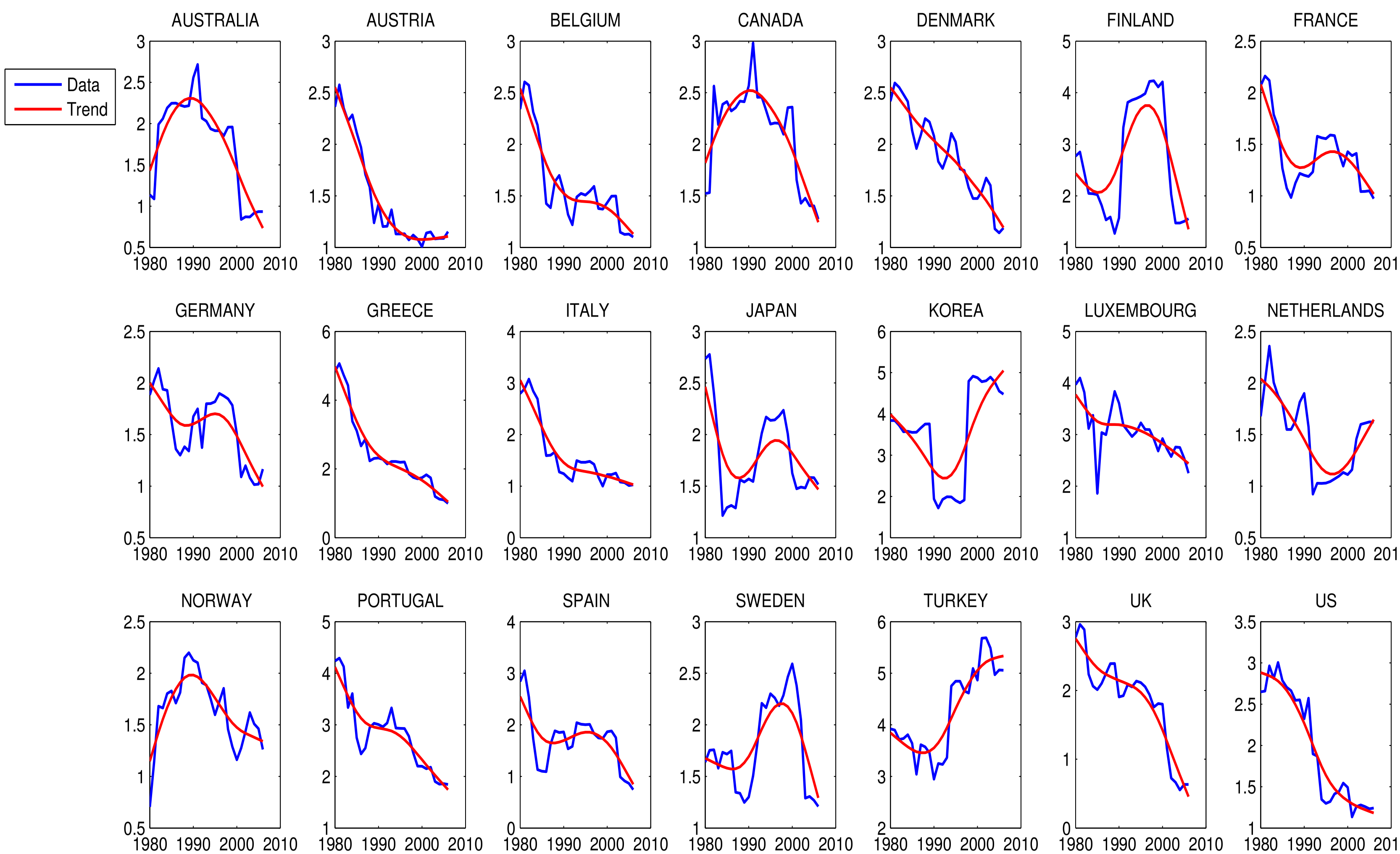

Figure 7. **Sectoral Annual Hours Worked per Person Engaged in the US (in thousands).**