A Disaggregated Perspective on Structural Change Models

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Abstract

Buera and Kaboski (2009) argue that standard three-sector models cannot account for the steep decline in industry and rise in services in the later data and conjecture that considering higher levels of disaggregation may explain some of the failures of the standard three-sector models. I build a Walrasian nine-sector model that allows for sectoral heterogeneity in industry and in services. Using actual sectoral productivity data, the model is able to reproduce the path of sectoral employment shares in six developed countries: France, Italy, Japan, the United Kingdom, the United States, and the West Germany. The model generates a transition of the labor force out of agriculture and the figures generated by the model economy matches well the level and the pace of their empirical counterpart. The model can capture more than 80 percent of the secular declines in the manufacturing employment share in France and in the United States. The model overpredicts the employment share in mining and quarrying and construction in each country (except in Italy for mining and quarrying). Three-sector models construct the "industry" aggregate by summing mining and quarrying, manufacturing, utilities, and construction. My model fails to capture the employment share in construction, whereas the model can mimic most of the secular changes in the manufacturing employment share, especially with low value for the elasticity of substitution between different goods. This is clearly observed for France and the United States. This finding can provide an explanation for the low explanatory power of three-sector closed economy models in capturing the declining industrial employment share in total employment. The model almost mimics the increases in employment share in "wholesale and retail trade, hotels and restaurants" in France, Italy, the United Kingdom, and the West Germany. On the other hand, the model fails to capture the secular trends in this sector for Japan. The magnitude of the results are sensitive to the choice of the elasticity of substitution between different goods.

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Key Words: Multi-sector models, sectoral productivities, structural transformation.

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1 Introduction

That long-run economic development is systematically associated with structural transformation in the composition of economic activity has been well established for today's developed nations. The share of agriculture in total employment, which was initially very large, has undergone a continuous decline during the course of economic development. Eventually, at an advanced stage of development, the point is reached where agriculture accounts for no more than 5 percent of the total employment. While the share of employment in agriculture is proportionally decreasing, reaching very low levels in today's richest countries, labor has been reallocated from agriculture into services. The service sector has become quantitatively the most important sector in today's developed countries.[1]

There has been a recent growing interest in multi-sector calibrated general equilibrium models to understand the sources of the structural transformation in factors of production and to quantify the impact of the shifts of resources across the sectors on aggregate growth and productivity.[2] These studies utilize two or three sector models to generate the structural transformation observed in the data. In a recent paper, Buera and Kaboski (2009b) test the two types of the models combining them in a three-sector closed economy model for the United States between the years 1870 and 2000 to see whether such a model can do reasonably well quantitatively in matching data and identify a set of puzzles including the observation that the model cannot account for the steep decline in manufacturing and rise in services in the later data.

Buera and Kaboski (2009b) argue that models incorporating home production, sector-specific distortions, differences in human capital accumulation, and openness are promising avenues to enrich the standard models mentioned above. In addition, Buera and Kaboski conjecture that considering higher levels of disaggregation may explain some of the failures of the standard three-sector models. This paper's contribution is, developing a nine-sector closed economy model, to investigate the role of disaggregation in capturing the secular trends in employment shares in today's developed countries.

I build a Walrasian model that allows for sectoral heterogeneity in industry and in services. The sectors are (1) agriculture, forestry and fishing, (2) mining and quarrying, (3) manufacturing, (4) public utilities, (5) construction, (6) wholesale and retail trade, hotels and restaurants (7) transport, storage and communication, (8) finance, insurance, and real estate (9) community, social and personal services. The model abstracts from issues of capital accumulation and international trade and it is effectively a sequence of static resource allocation problems to understand the role of the domestic sectoral productivity changes on the sectoral reallocation of employment among the nine sectors.

The model tracks the secular changes in employment shares well given the parsimonious nature of the model. Using actual sectoral productivity data for each economy, the model picks

[1]See, for example, Buera and Kaboski (2009a).

[2]See, for example, Buera and Kaboski (2009b), Kongsamut, Rebelo, and Xie (2001), Ngai and Pissarides (2007), Rogerson (2008) and the references therein.

up the fall in agricultural employment shares, the decline in manufacturing employment shares, and the fast rise of different service sector employment shares. There are some gaps between the data and the model in each country. Several aspects of the model can be improved, and several additional questions can be profitably addressed in the future work such as introducing capital accumulation and studying the substitution between home and market production.

The paper proceeds as follows. Section 2 introduces a nine-sector closed economy model, characterizes the competitive equilibrium, and derives equilibrium conditions for sectoral employment shares. Section 3 presents the data, calibration procedure, and quantitative results. Section 4 concludes the paper.

2 A Nine-Sector Model

I build a Walrasian nine-sector model, in which market-clearing prices achieve equilibrium in a set of interdependent commodity and factor markets. There is no uncertainty. The model abstracts from issues of capital accumulation and international trade and it is effectively a sequence of static resource allocation problems to understand the role of the domestic sectoral productivity changes on the sectoral reallocation of employment among different sectors.

2.1 The Firms

At each date there are nine goods produced. The production function for sector *j* is given by

$$Y_j = \theta_j N_j, \tag{1}$$

where Y_j is output of sector *j*, N_j is labor allocated to production, and θ_j is sector *j*'s labor productivity. Since I abstract from capital and fixed factors in production, differences in labor productivity implicitly incorporates differences due to capital as well as due to technology adoption, regulation, etc. across sectors. Firm *j* problem is given by

$$max \quad p_j Y_j - \omega N_j \qquad s.t. \qquad Y_j = \theta_j N_j, \qquad N_j > 0. \tag{2}$$

2.2 The Household

The economy is populated by an infinitely-lived representative household of constant size over time. Without loss of generality I normalize the population size to one. I assume that the household is endowed with one unit of productive time that supplies inelastically to the market. Consumption is the only determinant of the instantaneous utility function, which is given by:

$$U(C) = \log(C) \tag{3}$$

The instantaneous utility is defined over the composite consumption good (C), which is derived from nine goods:

$$C = (\gamma_A^{1/\eta}(A - \bar{A})^{(\eta-1)/\eta} + \gamma_1^{1/\eta} C_1^{(\eta-1)/\eta} + \gamma_2^{1/\eta} C_2^{(\eta-1)/\eta} + ... + \gamma_8^{1/\eta} C_8^{(\eta-1)/\eta})^{\eta/(\eta-1)}, \tag{4}$$

where A is the consumption of the agricultural good and $C_1, ..., C_8$ are the consumption of the non-agricultural goods. The parameter $\bar{A}$ represents the subsistence level of food consumption and satisfies

$$\theta_A > \bar{A} > 0. \tag{5}$$

The first inequality states that the economy's agricultural sector is productive enough to provide the subsistence level of food to all consumers (see, for example, Matsuyama 1992). The second inequality implies that preferences are non-homothetic and the income elasticity of demand for agriculture is less than unitary. It is also assumed that the representative household has enough income to purchase more than $\bar{A}$ units of agricultural good. The weight $\gamma_j > 0$ influences how consumption expenditure is allocated among the nine sectors, and $\gamma_A + \gamma_1 + \gamma_2 + ... + \gamma_8 = 1$ and the parameter η>0 is the (constant) elasticity of substitution between goods.

At each date, and given prices, the household chooses consumption of each good to maximize his lifetime utility subject to the budget constraint:

$$p_A A + p_1 C_1 + p_2 C_2 + ... + p_8 C_8 = \omega. \tag{6}$$

where p_j is the price of good-*j* output and ω is the wage-rate in the economy.

2.3 Competitive Equilibrium

Given a set of prices$\{p_A, p_1, p_2, ..., p_8, \omega\}$, a competitive equilibrium consists of consumption decisions that are the household's allocations $\{A, C_1, C_2, ..., C_8\}$, and labor allocations for the firms, $\{N_A, N_1, N_2, ..., N_8\}$ such that given prices, the firm's allocations solve its profit maximization problem, the household's allocations solve the household's utility maximization problem, and all product and factor markets clear:

1. The demand of labor from firms must equal this exogenous supply at every date:

$$N_A + N_1 + N_2 + ... + N_8 = 1. \tag{7}$$

2. Since there is no international trade or capital accumulation the following conditions hold at each date implying that the market must clear for each goods and services produced:

$$A = Y_A, \quad C_1 = Y_1, \quad ..., \quad C_8 = Y_8. \tag{8}$$

The equilibrium employment shares are given by the solution of the following system of equations, which combines the first-order conditions and the feasibility conditions:

$$(\gamma_A/\gamma_1)(\theta_A/\theta_1)^{\eta-1} = (N_A - (\bar{A}/\theta_A))/N_1 \tag{9}$$

$$(\gamma_1/\gamma_j)(\theta_1/\theta_j)^{\eta-1} = N_1/N_j, \quad j = 2, 3, ..., 8. \tag{10}$$

3 Quantitative Analysis

3.1 Data and Calibration

The source for all the sectoral data is the Groningen Growth and Development Centre (GGDC) 10-sector database.[3] The GGDC 10-sector database includes annual data on gross value added at both current and constant prices from 1950 to 2005 for selected Latin America, Asia, and OECD countries as well as data on persons employed, which allows the derivation of labor productivity (value added per worker) series. Employment is defined as "all persons employed ", thus including all paid employees, but also self-employed and family workers.

The GGDC 10-sector database covers the ten main sectors of the economy as defined in the International Standard Industrial Classification, Revision 2: (1) agriculture, forestry and fishing, (2) mining and quarrying, (3) manufacturing, (4) public utilities, (5) construction, (6) wholesale and retail trade, hotels and restaurants (7) transport, storage and communication, (8) finance, insurance, and real estate, (9) community, social and personal services, and (10) government services. Together these ten sectors cover the total economy. I exclude government services so that I have nine-sector for each country under investigation. Table 1 presents the sample period for each country under investigation.

All time series are de-trended using the Hodrick-Prescott filter with a smoothing parameter of 6.25 before any ratios are computed.[4] I normalize productivity levels across sectors in each country to one for the initial year. I use data on sectoral labor productivity growth in each country to obtain the time paths of sectoral productivity for the sample period. I set $\gamma_A = 0.01$ to match the long-run share of employment in agriculture following Duarte and Restuccia (forthcoming).[5]

Next, $\bar{A}$, $\gamma_1, ..., \gamma_8$ are calibrated to match the shares of employment in each sector and in each country for the initial year. I consider η to be a free parameter in order to study the implication of this parameter value for the findings. The parameter η determines how much labor will be reallocated among the sectors in response to uneven changes in productivity in each sector.

[3] The sources and methods document available at http://www.ggdc.net/dseries/10-sector.html provides a detailed discussion of the construction of the employment and value added series on a country-by-country basis. See, also, Timmer and de Vries (2007).

[4] I am interested in long-term trends, not in yearly fluctuations. I follow Ravn and Uhlig (2002) for choosing 6.25 as a smoothing parameter. The features that I emphasize also hold for other smoothing parameter values for annual data such as 100 and 400.

[5] I assume a long-run share of 1 percent since the share of employment in agriculture has been falling steadily. Although this target is somewhat arbitrary, the results are not sensitive to this choice.

The recent literature provides a narrow range of estimates for η. Duarte and Restuccia (forthcoming) calibrate a three-sector economy to the U.S. data for the period from 1956 to 2004 and set η equal to 0.40. Bah (2008) reports an elasticity of 0.45 using the data for the U.S. for the period 1950-2000. Similarly, Rogerson (2008) uses the data for the U.S. economy in 1950 and 2003 and sets η equal to 0.44. Ngai and Pissarides (2008) cite the empirical literature and argue that the elasticity of substitution lies between 0.1 and 0.3. I report the results with two values of η, which are 0.1 and 0.45. Calibrated parameters for each country are reported in Table 2.

3.2 Results

Figure 1 - 6 show the model predicted sectoral employment shares with $\eta = 0.1$ and $\eta = 0.45$ and compare with the actual data for each country. By construction, the model matches exactly the sectoral shares of employment for the initial year used in the calibration. The model generates a transition of the labor force out of the agriculture and the figures generated by the model economy matches well the level and the pace of their empirical counterpart. Moreover, the value of η does not change the model predictions significantly. For example, for $\eta = 0.1$ ($\eta = 0.45$) the model predicts a decline in agricultural employment share in the United States of 9.0 (8.8) percentage points between 1950 and 2005. The actual fall was 8.7 percent.

Of greater interest is the fact that there is a close match between the model and the data in non-agricultural sectors as well. The model can capture more than 80 percent of the secular declines in manufacturing employment share in France and in the United States. The share of manufacturing declined from 31.3 percent in 1950 to 14.6 percent in 2005 in the United States. The model predicted manufacturing employment share, with $\eta = 0.1$, is 18.7 percent. In 2005, the employment share in manufacturing in France was 18.8 percent. The model, with $\eta = 0.1$, predicts 21.0 percent: given the initial share of 28.4 percent, there is a lot of predictive power in the model. The model overpredicts the employment share in mining and quarrying and construction in each country (except in Italy for mining and quarrying).

Three-sector models construct the "industry" aggregate by summing mining and quarrying, manufacturing, utilities, and construction. Üngör (2009) calibrates a three-sector closed economy model with hierarchic preferences for each of the G7 economy between 1978 and 2007 and shows that the model fails to match the industrial employment share (and therefore the service sector employment shares) in the G7 economies. A major problem is that productivity growth in industry relative to services is not high enough to move the labor out of the industrial sector. This problem is robust under different values of the elasticity of substitution between industry and services.[6]

This paper's nine-sector model fails to capture employment share in construction, whereas the model can mimic most of the secular changes in manufacturing employment share, especially with low value for the elasticity of substitution between different goods. This is clearly observed

[6] Üngör observes that the model gets close to match the data as the elasticity of substitution decreases, i.e., the model with $\eta = 0.1$ fits better, relatively, compared to the other two cases ($\eta = 0.3$ and $\eta = 0.45$). The fit of the model does not improve substantially with the values of η smaller than 0.1. The results are available at http://www-scf.usc.edu/~ungor/Ungor_China_appendix.pdf

for France and the United States. This finding can provide an explanation for the low explanatory power of three-sector models in capturing the declining industrial employment share in total employment.

The model almost mimics the increases in employment share in "wholesale and retail trade, hotels and restaurants" in France, Italy, the United Kingdom, and the West Germany. For example, the share of wholesale and retail trade, hotels and restaurants increased from 15.0 percent in 1950 to 23.2 percent in 1991 in the West Germany. The model predicts it is 22.8 percent when $\eta = 0.1$, and 21.9 percent with $\eta = 0.45$ in 1991. On the other hand, the model fails to capture the secular trends in this sector for Japan.

4 Concluding Remarks

This paper suggests that introducing sectoral heterogeneity into the structural transformation models may provide deeper understanding that three-sector models can fail to deliver. Sectoral heterogeneity matters for economic development. For example, Bernard and Jones (1996) study the role of sectors in aggregate productivity movements in 14 OECD countries between 1970 and 1987. Bernard and Jones (1996) employ data on total factor productivity for (a maximum of) fourteen OECD countries and six sectors over the period 1970 to 1987. The six sectors are agriculture, mining, manufacturing, utilities, construction, and services. They find convergence in services and report that convergence does not hold for the manufacturing sector. Services is by far the most significant sector accounting for one-third of aggregate convergence to the United States during the period.[7]

Valentinyi and Herrendorf (2008) measure the factor income shares at the sectoral level for the the United States considering the model sectors agriculture, manufactured consumption, services, equipment, and construction and find that the capital shares differ across sectors.

I conclude that future studies of structural transformation should incorporate sectoral heterogeneity in industry and in services.

[7] There is quite a large literature on convergence at the sectoral level. For example, see, Sørensen (2001) and Wong (2006) and the references therein.

References

[1] **Bah, Elhadj.** 2008. "A Three-Sector Model of Structural Transformation and Economic Development." http://mpra.ub.uni-muenchen.de/10654/1/MPRA_paper_10654.pdf

[2] **Bernard, Andrew B., and Charles I. Jones.** 1996. "Productivity Across Industries and Countries: Time Series Theory and Evidence." *The Review of Economics and Statistics*,, 78(1): 135-46.

[3] **Buera, Francisco J., and Joseph P. Kaboski.** 2009a. "The Rise of the Service Economy." http://kaboski.econ.ohio-state.edu/services.pdf

[4] **Buera, Francisco J., and Joseph P. Kaboski.** 2009b. "Can Traditional Theories of Structural Change Fit the Data?" *Journal of the European Economic Association*, 7(2-3): 469-77.

[5] **Duarte, Margarida, and Diego Restuccia.** Forthcoming. "The Role of the Structural Transformation in Aggregate Productivity." *Quarterly Journal of Economics*.

[6] **Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie.** 2001. " Beyond Balanced Growth" *Review of Economic Studies* , 68(4): 869-882.

[7] **Matsuyama, Kiminori.** 1992. "Agricultural Productivity, Comparative Advantage, and Economic Growth." *Journal of Economic Theory*, 58(2): 317-34.

[8] **Ngai, Rachel L., and Christopher A. Pissarides.** 2008. "Trends in Hours and Economic Growth." *Review of Economic Dynamics*, 11(2): 239-56.

[9] **Ravn, Morten O., and Harald Uhlig.** 2002. "On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations." *Review of Economics and Statistics*, 84(2): 371-76.

[10] **Rogerson, Richard.** 2008. "Structural Transformation and the Deterioration of European Labor Market Outcomes." *Journal of Political Economy*, 116(2): 235-59.

[11] **Sørensen, Anders.** 2001. "Comparing Apples to Oranges: Productivity Convergence and Measurement across Industries and Countries: Comment." *American Economic Review*, 91(4): 1160-67.

[12] **Timmer, Marcel P., and Gaaitzen J. de Vries.** 2007. "A Cross-Country Database For Sectoral Employment and Productivity in Asia and Latin America, 1950-2005." Groningen Growth and Development Centre Research Memorandum GD-98, Groningen: University of Groningen.

[13] **Üngör, Murat.** 2009. "De-industrialization of the Riches and the Rise of China: Online Appendix." http://www-scf.usc.edu/~ungor/Ungor_China_appendix.pdf

[14] **Valentinyi, Ákos, and Berthold Herrendorf.** 2008. "Measuring factor income shares at the sectoral level." *Review of Economic Dynamics*, 11(4): 820-35.

[15] **Wong, Wei-Kang.** 2006. "OECD Convergence: A Sectoral Decomposition Exercise." *Economic Letters*, 93(2): 210-14.

Table 1: Countries and Sample Periods

Country	Sample Period
France	1954 - 2005
Italy	1951 - 2005
Japan	1953 - 2003
United Kingdom	1948 - 2005
United States	1950 - 2005
West Germany	1950 - 1991

Table 2: Calibration

Parameter	France	Italy	Japan	United Kingdom	United States	West Germany
$\bar{A}$	0.2993	0.5138	0.4600	0.0549	0.1000	0.2568
γ_1	0.0185	0.0045	0.0286	0.0695	0.0215	0.0465
γ_2	0.4047	0.4457	0.3400	0.3848	0.3483	0.4636
γ_3	0.0096	0.0108	0.0129	0.0162	0.0100	0.0114
γ_4	0.1319	0.1297	0.0965	0.0859	0.0814	0.1098
γ_5	0.2140	0.2026	0.2233	0.2189	0.2747	0.2022
γ_6	0.0822	0.0677	0.0908	0.1021	0.1082	0.0741
γ_7	0.0944	0.0431	0.0667	0.0675	0.0916	0.0437
γ_8	0.0347	0.0859	0.1311	0.0452	0.0543	0.0387

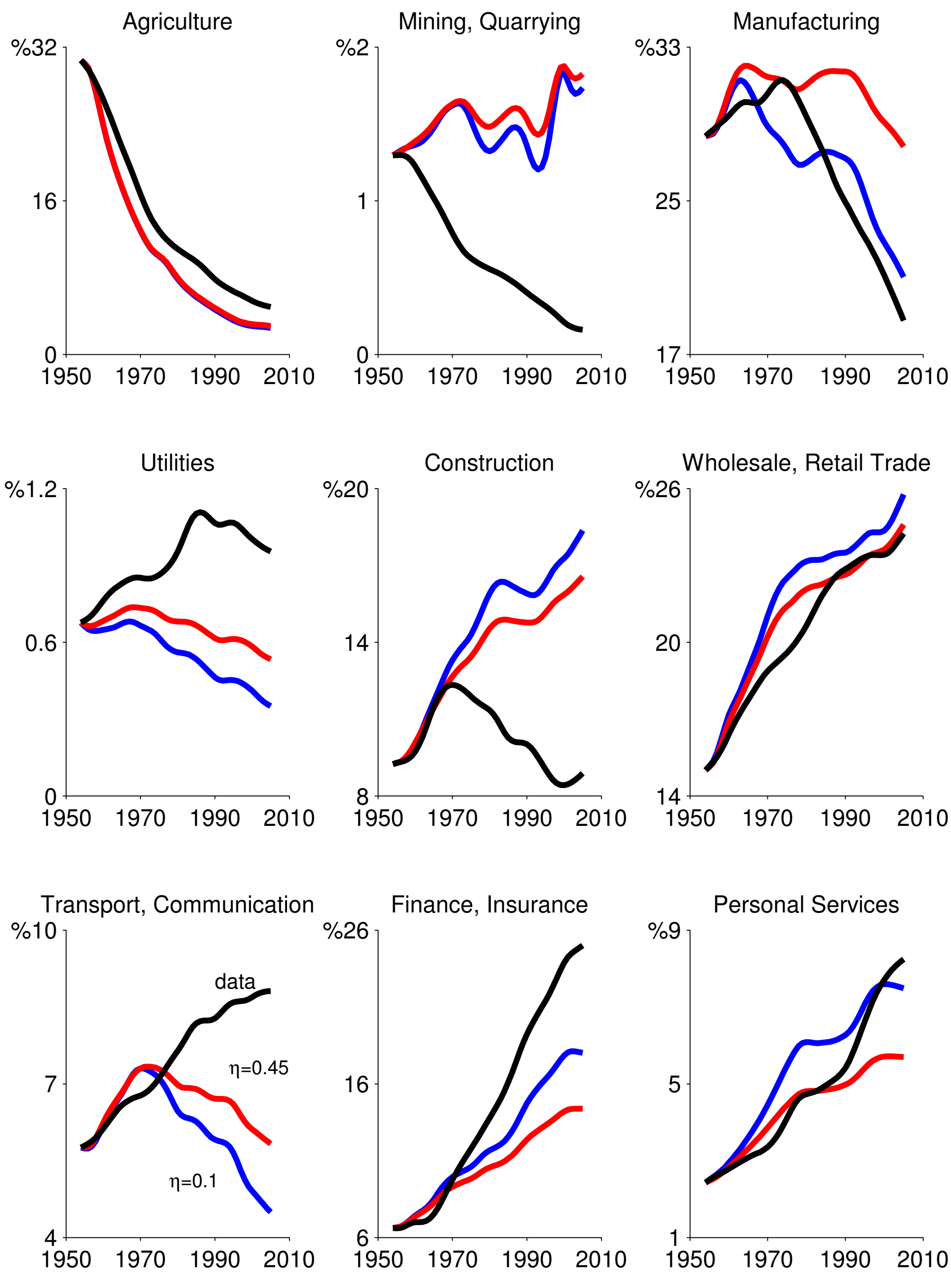

Figure 1: Sectoral Employment Shares, Data versus Model, France: 1954-2005

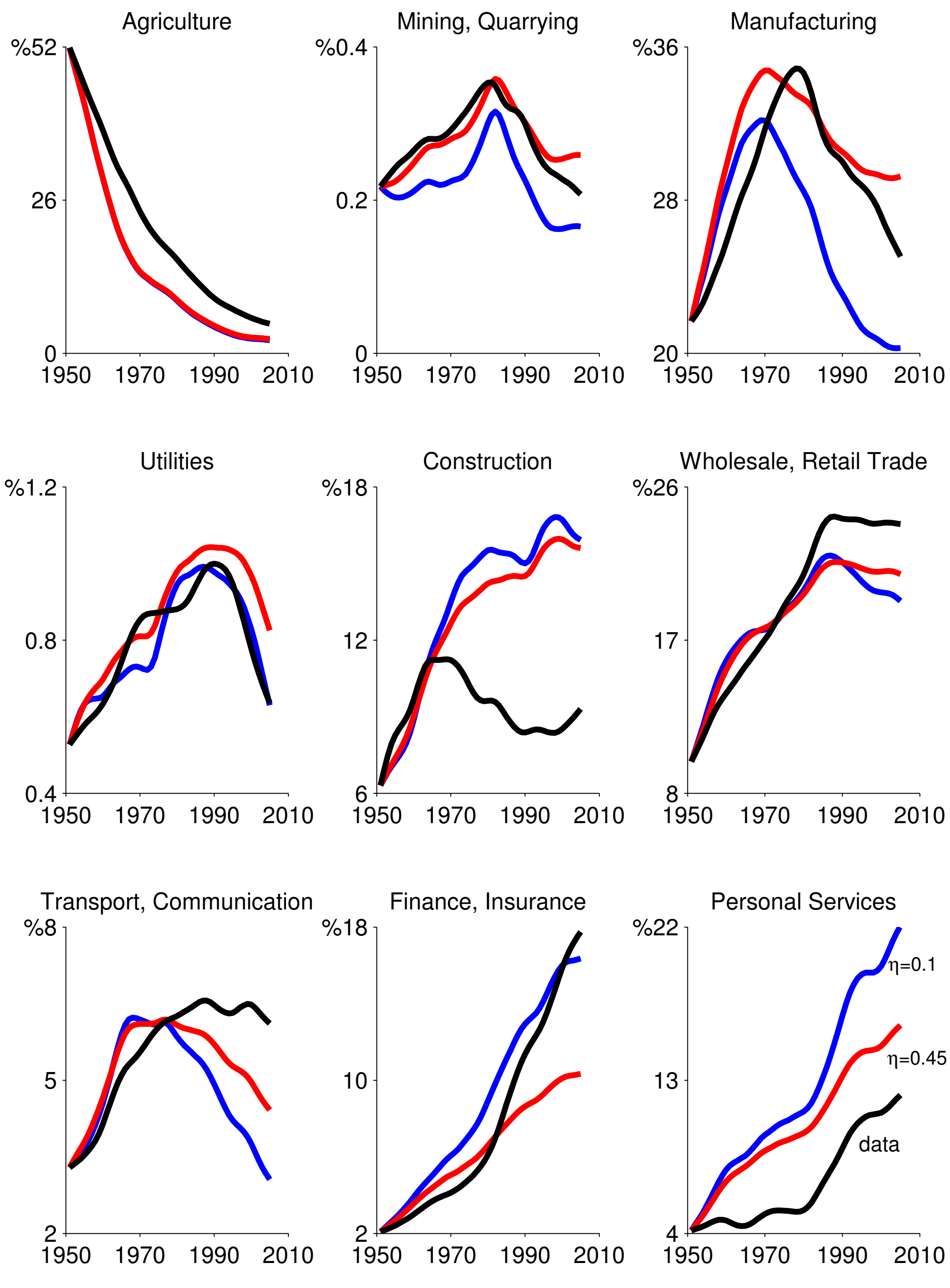

Figure 2: Sectoral Employment Shares, Data versus Model, Italy: 1951-2005

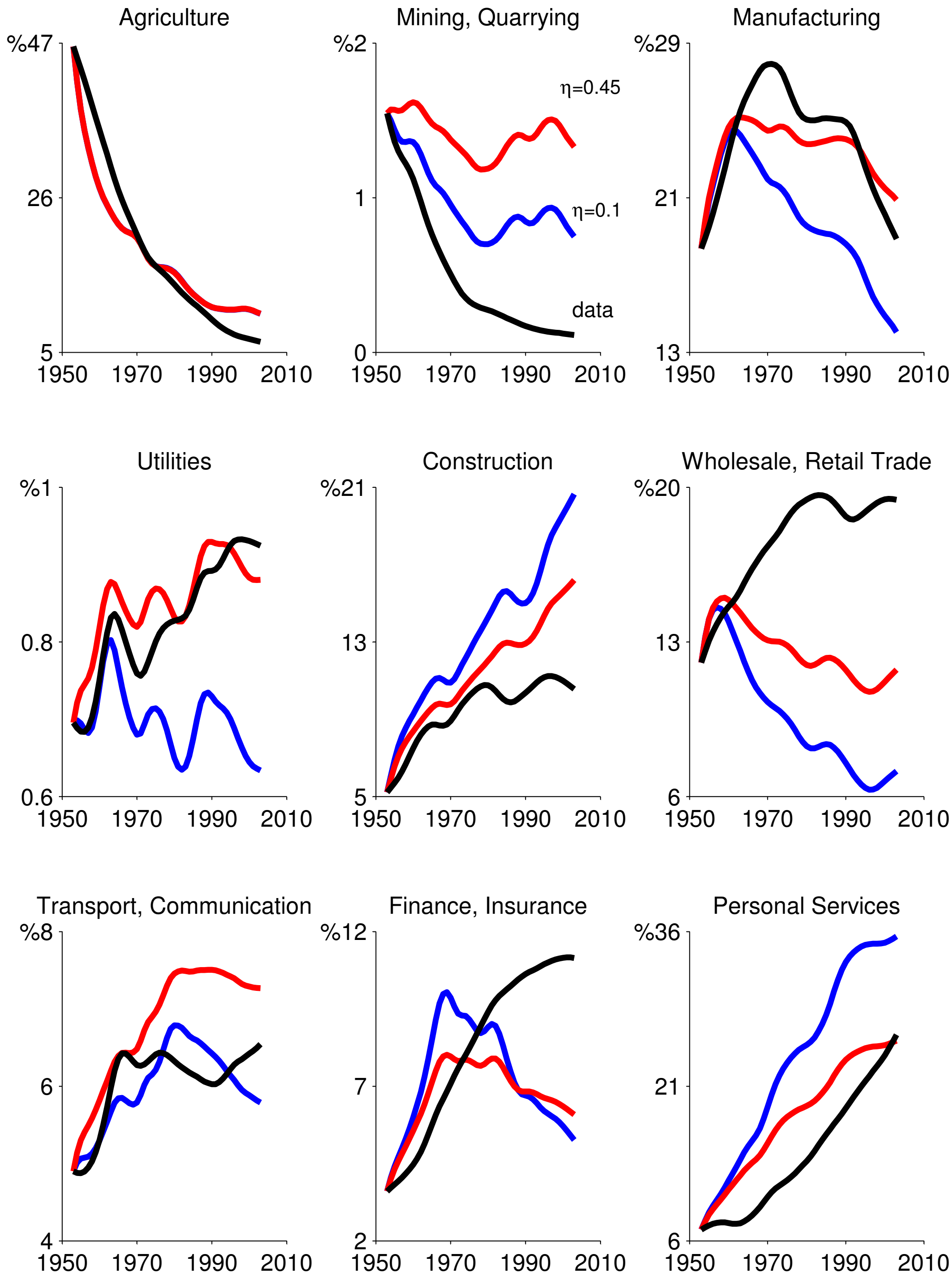

Figure 3: Sectoral Employment Shares, Data versus Model, Japan: 1953-2003

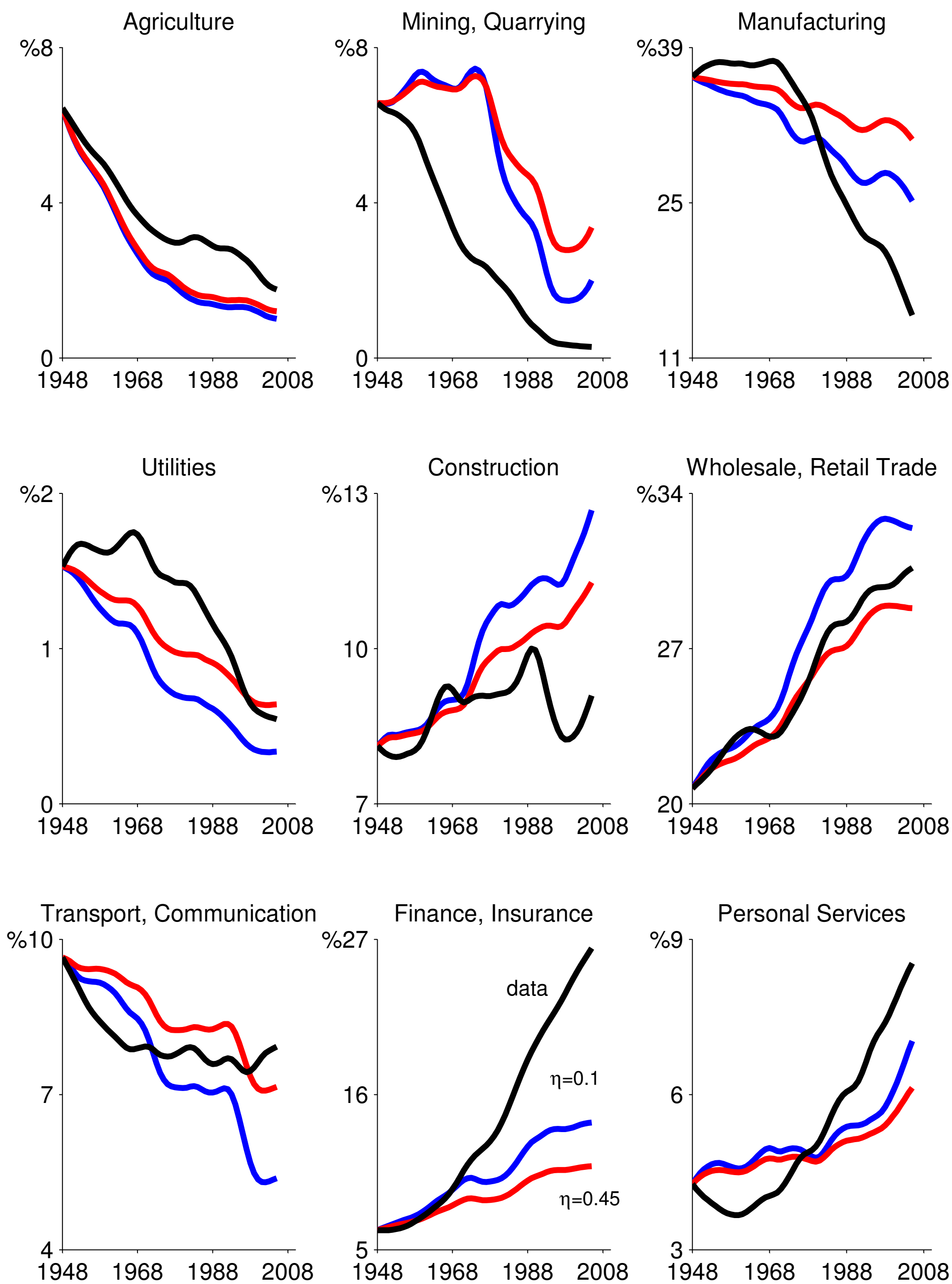

Figure 4: Sectoral Employment Shares, Data versus Model, United Kingdom: 1948-2005

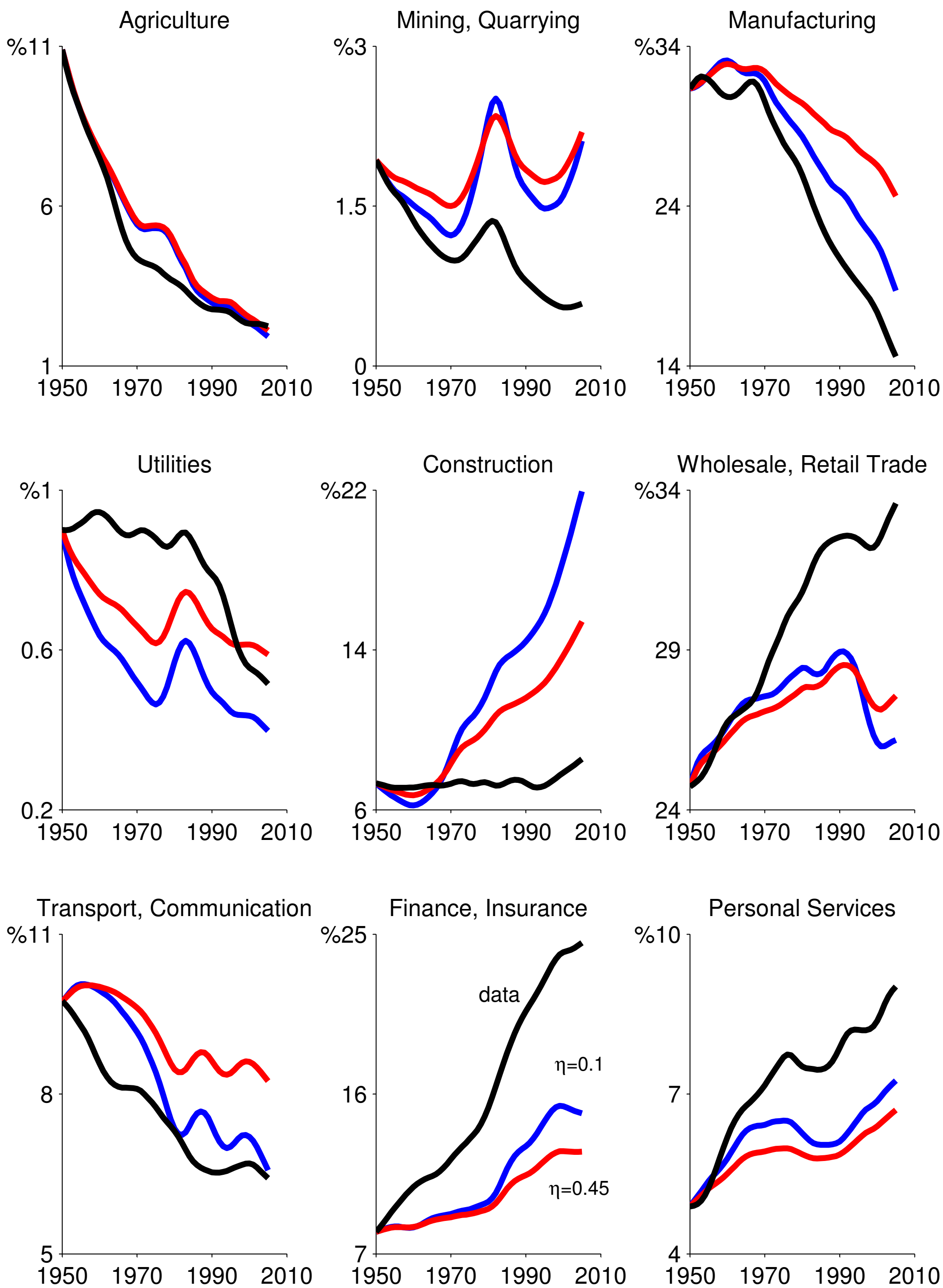

Figure 5: Sectoral Employment Shares, Data versus Model, United States: 1950-2005

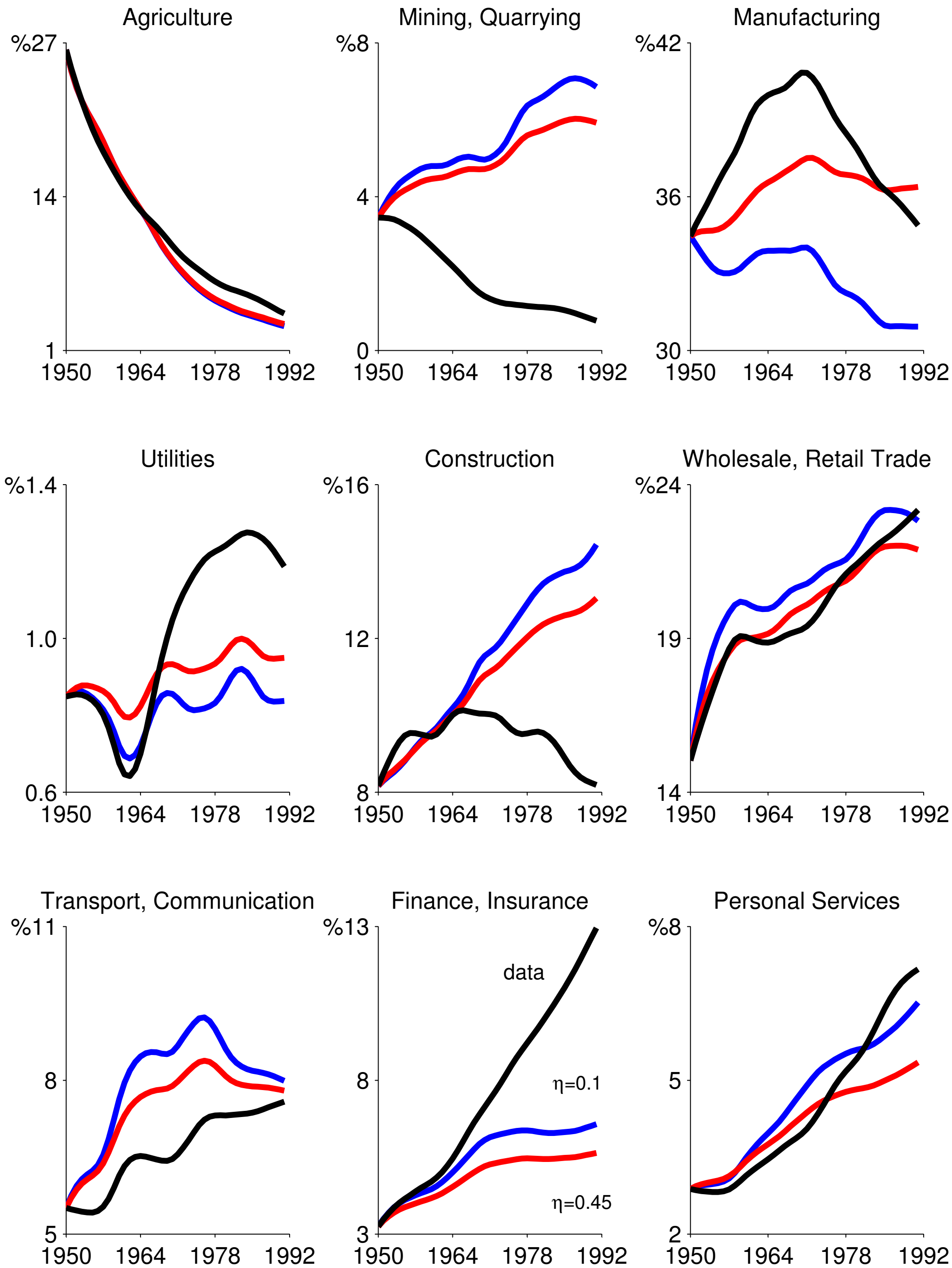

Figure 6: Sectoral Employment Shares, Data versus Model, West Germany: 1950-1991