The dynamics of the World Income Inequality in the Unified Growth Theory Model without Scale Effect

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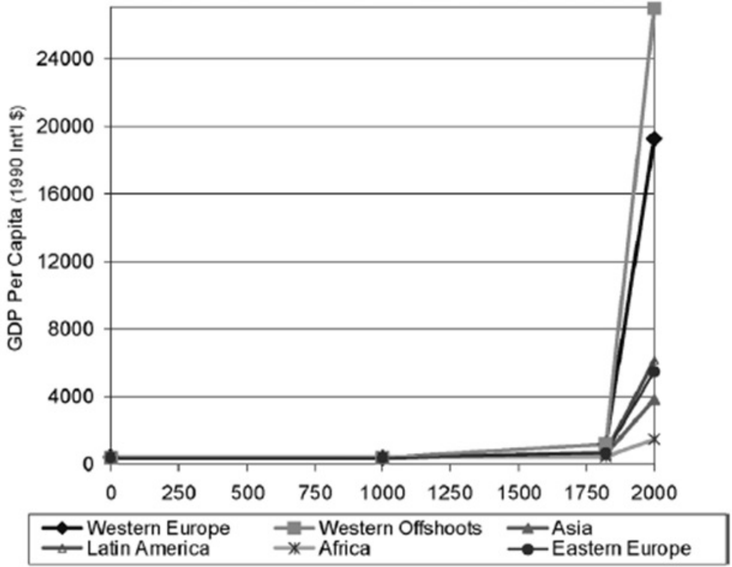
Motivation

- To understand the current distribution of incomes per capita between countries we need to take into account "the Greate Divergence" process: the increase of the gap between the rich and the poor countries after the industrial revolution.
- The unified growth theory (UGT) models are capable to explain the take-off from the Malthusian stagnation to the Modern growth regime
- UGT models underline the role of the scale effect that is the effect of the size of population on the innovation rate in the transition process.
  - the role of specialization and the division of labor
  - noncompetitive properties of innovations

Motivation-2

- The scale effect models seems to be important for analysis the world economy as a whole, but failed to explain the experience of individual countries
  - The pre-industrial England in XVII had 3 times smaller population than France
  - The early development of North Italian cities and Netherlands
- To explain these examples we provide the UGT model, which underlines the role of institutions as the major cause of economic growth

The great divergence



Related literature

- The UGT models of transition from Malthusian stagnation to the modern growth regimes: Kremer (1993), Goodfriend and McDermott (1995), Galor and Weil (2000), Galor and Moav (2002), Jones (2001), Kőgel and Prskawetz (2001), Lucas (2002), Tamura (2002), Strulik, Weisdord (2008).
- Schumpeterian growth models: Aghion, Howitt (1992,1995) Howitt, Mayer-Foulke (2002,2005)
- Politico-economic explanations of take-off: Galor et al. (2009), Acemoglu, Robinson (2006,2008,2012)

The first look on the model

- Two sectors: agricultural and manufacturing
- The technological progress is the result of creative destruction process in manufacturing. There are spillovers to the agricultural sector
- Agents belongs to three groups: landowners, industrialists and simply workers. Workers differ in their talents
- The technological progress is influenced by the institutional quality parameter, which is determined in the political process.
- The agents have different interests, relative to the quality of institutions, and their political power depends on the economic structure

outline

- The basic set-up
- Dynamics and steady-state in the model with exogenous institutions
- Calibration for the British economy
- The model with endogenous institutions
- The implication to the dynamics of incomes

1. The definition of preferences

The economy is inhabited by the overlapping generations of agents. Agents live two periods, childhood and adulthood, and make economic decisions only in the second period of time. Following Strulik, Weiddorf (2008) each agent maximizes

$$U_j(t) = \rho \ln n_j(t) + c_{m,j}(t), \quad (1)$$

where ρ is constant parameter, measuring the preferences for children, n_j is the number of children for adult j and $c_{m,j}$ is the consumption of manufacturing goods for adult j.

The budjet constraint is

$$y_j(t) = p(t)n_j(t) + c_{m,j}(t), \quad (2)$$

where $y_j(t)$ is the income of the agent j, $p(t)$ - is the relative price of food

$$n(t) = \rho/p(t). \quad (3)$$

Agricultural sector

The production in the agricultural sector is described by the Cobb-Douglas production function

$$Y_p(t) = A(t)^{\xi} T^{\beta} L_p(t)^{1-\beta}, \tag{4}$$

where T is the fixed quantity of land, $L_p(t)$ is the employment in agriculture.

Spillover effect

The technological level in agriculture equals to the technological level in manufacturing due to technological spillovers from manufacturing to agricultural sector.

On the demand side the subsistence constraint should hold, such that the quantity, produced in the agricultural sector, equals the demand for food

$$Y_p(t) = L(t+1) = n(t)L(t). \tag{5}$$

Manufacturing sector

The production function:

$$Y_m(t) = (L_m(t)/N(t))^{1-\alpha} \sum_{0}^{N(t)} A(i,t)^{\epsilon(1-\alpha)} x(i,t)^{\alpha} di, \tag{6}$$

where $N(t)$ is a number of intermediate inputs, $L_m(t)$ - employment in manufacturing, $A(i,t)$ and $x(i,t)$ is the quality and quantity of the intermediate input i.

- Each variety of intermediate inputs is produced by a single monopolistic firm with a simple one-for-one production function.
- Solving the monopolist problem, we obtain the equilibrium output of the general good

$$Y_m(t) = \alpha^{\frac{2\alpha}{1-\alpha}} A(t)^{\epsilon} L_m(t), \tag{7}$$

where

$$A(t) = \sum_{0}^{N} A(i,t) \tag{8}$$

Intratemporal equilibrium

- the labor market is competitive and so wages in both sectors in units of manufacturing products should be equal

$$w_p(t)p(t) = w(t) \tag{9}$$

- Let define the share of employment in agriculture as $\theta(t) = L_p(t)/L(t)$.

Definition

For given $L(t), A(t)$ the intratemporal equlibrium is the sequence of $\{n(t), Y_p(t), Y_m(t), \theta(t)\}$, such that all adults solve their problem (1) given the constraint (2), each firms maximize their profits, wages in both sectors equalise and market clearing conditions hold

Solving the model we get

$$\theta(t) = \rho\kappa / A(t)^{\epsilon} \tag{10}$$

where $\kappa = (1-\beta)/(1-\alpha)\alpha^{\frac{2\alpha}{1-\alpha}}$ The increase in $A(t)$ increases the productivity in the manufacturing and agriculture, the demand for food limits by the substistence constraint. Therefore, labor switch from the agriculture to the manufacturing
The gross fertility rate equals

$$n(t) = \rho^{1-\beta}\kappa^{1-\beta} T^{\beta} A(t)^{\xi-\epsilon(1-\beta)} / L(t)^{\beta}. \tag{11}$$

- The increase of the size of population decrease the gross reproduction rate through the effect on agricultural prices
- The relationship between $A(t)$ and $n(t)$ is monotonic. For $\xi =$ is positive.

Income per capita and employment in the agricultural sector

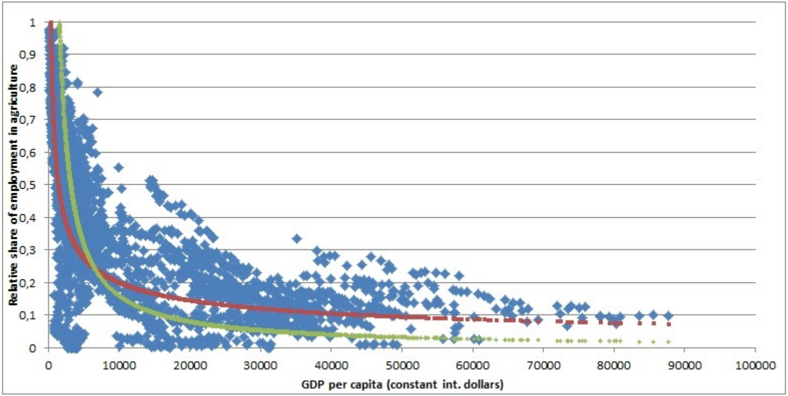


Figure : Data from World Development Indicators 1960-2012, all countries, all years, on the vertical axe the ratio of employment in agriculture to the total sum of employment in agriculture and manufacturing sector

Innovation process and scale effect

- A share $s(t)$ of labor force (adults) called potential innovators with a given probability λ create an idea of innovation that is increasing the quality of one of the intermediate inputs by a given size γ in a random sector.
- With a probability $B(t)$ each of them is capable to implement this idea into the successful project
- The number of varieties of intermediate inputs is proportional to the size of population.

$$N(t) = \chi L(t). \tag{12}$$

- Technological progress as the number of innovations per intermediate input sector will equal

$$g_a(t) = \Delta A(t)/A(t) = \gamma B(t)\lambda s(t)/\chi. \tag{13}$$

The technological progress depends only on the share of potential innovators in total population as well as the probability of successful implementation.

Education and economic growth

- The costs of becoming innovators $c_j w(t)$ is proportional to the wage rate in the manufacturing sector and differ across population.
- The costs are distributed independently, the distribution function is given, $F(c)$.
- If the agent becomes innovator, he has an opportunity to innovate in a random sector and get $\nu\gamma\pi\lambda B(t)$, where ν is the share of profits, belongs to the innovator
- If the distribution function of innovation costs equals $F(c) = \psi s(t)^{\eta}$, from the research arbitrage equation we get

$$s(t) = (\nu\alpha(1-\theta(t))\lambda\gamma B(t)/\psi\chi)^{1/\eta}. \tag{14}$$

- Therefore, the technological progress in the manufacturing sector equals

$$g_a(t) = (\nu\alpha(1-\theta(t))/\psi)^{1/\eta}(B(t)\gamma\lambda/\chi)^{1+1/\eta} \tag{15}$$

The determinants of the technological progress

$$g_a(t) = (\nu\alpha(1-\theta(t))/\psi)^{1/\eta}(B(t)\gamma\lambda/\chi)^{1+1/\eta} \quad (16)$$

- The relative employment in manufacturing $(1-\theta(t))$
- The probability of implementation for new ideas $B(t)$
- The size of innovations, γ
- The individual probability of innovation λ
- The share of innovator in total profits ν
- The quantity of intermediate inputs per adult χ
- The relative costs of education ψ and the shape of education costs curve η

2. Model dynamics with exogenous institutions

The model can be rewritten in the form of two dynamic equations

$$A(t+1) = A(t)(1+\vartheta(t)(1-\rho\kappa/A(t)^{\epsilon})^{1/\eta} \quad (17)$$

and

$$L(t+1) = L(t)^{1-\beta}\rho^{1-\beta}\kappa^{1-\beta}A(t)^{\xi-\epsilon(1-\beta)}. \quad (18)$$

ϑ is the combination of exogenous variables

$$\vartheta(t) = (\nu\alpha/\psi)^{1/\eta}(B(t)\gamma\lambda/\chi)^{1+1/\eta}, \quad (19)$$

Steady state

For $B > 0$ the growth rate of technological progress (g_a) and the population growth ($n(t)$) will converge to the steady-state level.
The share of employment in the agriculture tends to zero. In this case the share of innovators as well as the technological progress in the manufacturing converges to the maximum level

$$\overline{s} = (\nu\alpha\gamma\lambda B/\psi\chi)^{1/\eta} \tag{20}$$

and

$$\overline{g_a} = (\nu\alpha/\psi)^{1/\eta}(B\gamma\lambda/\chi)^{1+1/\eta}. \tag{21}$$

The population growth converge the maximum level

$$\overline{n} \approx \overline{g_a}(\xi/\beta - \epsilon/\beta + \epsilon) \tag{22}$$

3. Calibration

The periods are divided on 25 years subperiods from 1550 to 2100.

Values	Explanations
$\alpha = 0.5$	the share of profits in value added 1/3
$\beta = 0.2$	the share of rent in agricultural output
$\theta(1550) = 0.95$	initial economic structure
$n(0) = 1.00025^{25}$	from Kremer (1993) dataset
$A(0)$, T	is obtained exogenously from (10) (11)
$\rho = 0.15$	best data fit
$\vartheta = 0.91$	maxumum gr.rates 2.3% per year
$\epsilon = 0.5, \xi = 0.55, \eta = 1$	best fit of the data

The example of British industrial revolution

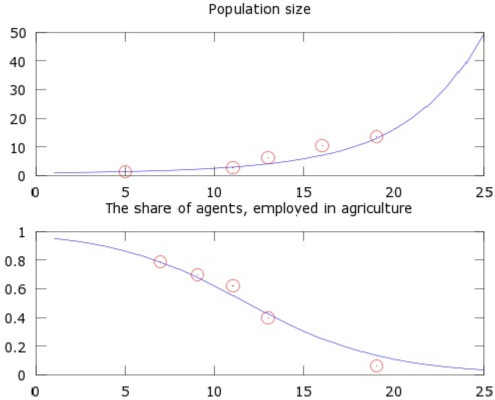


Figure : Transitional dynamics. 1550-2100. The points show the real data and the curves represent the calibrated model dynamics. The data of relative employment in agriculture in manufacturing and population size of Clark (1985), Voiglénder, Vothe(2006), British demographic surveys

Income per capita: model and the real data

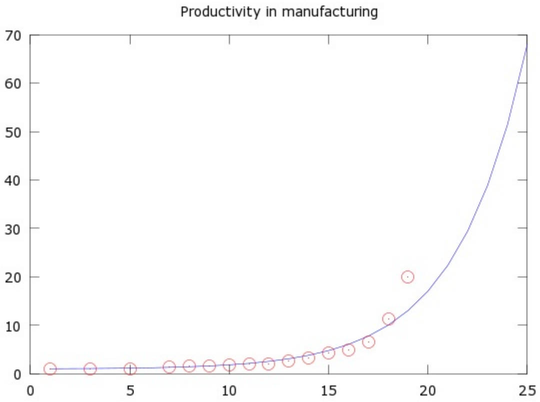


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Figure : The productivity in manufacturing -simulation (line) and income per capita (Madisson database)

Initial conditions and growth

In 1700 England was far more industrialised, than its neirbourgs. According to Voigtlnder N., Voth H.J. (2006) the relative employment in manufacturing in France was 16%, rather then 23% in England. In the East Europe the relative employment in manufacturing was even lower, 15% in 1700, according to Craft (1985). In Russia even in the late XIX century the agricultural sector provided employment for approximately 85 percent of the working-age Russian population.

4.The model with endogenous institutions

- In each period three types of agents coexist in the society: landowners, capitalists and workers.
- Only landowners and capitalists influence the political decision.
- The political power (p_j) of landowners and capitalists is proportional to their income flows
- The probability to win the political contest equals $p_j / \sum_0^1 p_s$ for each group of agents
- At the end of each period the winning group of agents chose the political regime from $B = [B_L; B_H]$
- All agents maximize their relative future income, which corresponds to their future political power

Political power

Landowners benefit for the rent from the natural resources as well as capitalists get the profit income from the production of intermediate inputs. From (2) the rent from the natural resources equals

$$R(t) = \beta p(t) Y_p(t), \tag{23}$$

or

$$R(t) = \beta \gamma L(t) \tag{24}$$

The rent from agriculture is proportional to population size. The total capitalists profit is determined as

$$\pi_c N = (1-\nu)(1-\alpha)\alpha^{\frac{1+\alpha}{1-\alpha}} A(t)^{\epsilon} L_m(t), \tag{25}$$

The ratio between capitalist profits and landowners rent equals

$$v(t) = (1-\nu)\alpha(1-\beta)(1-\theta(t))/(\beta\theta(t)) \tag{26}$$

Model dynamics with endogenous institutions

Each period $B = B_H$ with a probability $1/(1 + v(t))$ and $B = B_L$ with a probability $v(t)/(1 + v(t))$

In this case the model is capable to explain

- The long period of Malthusian stagnation before the industrial revolution
- The episodes of unstable take-off
- leap-frogging effect

Diffusion of knowledge

Suppose now that at some date T_0 due to the globalization process the technological spillovers appears from the rich and poor countries. Therefore, the size of innovations become an endogenous variable as it depends on the distance to technological frontier.

$$\gamma(t) = \gamma_1 + \gamma_2(A_L(t)/A(t)) \tag{27}$$

In this case the model is capable to explain

- The convergence process for a group of countries in modern period
- The volatility of growth rates in developing countries.

Extention: The change in fertility preferences

Assume that there is a change in fertility preferences. Adults agents, working in the manufacturing sector, always chose a fixed number of children n^*. Therefore

$$n_x(t) = \theta(t)n(t) + (1 - \theta(t))n^*(t) \tag{28}$$

In this case the model correctly fit the British demographic revolution

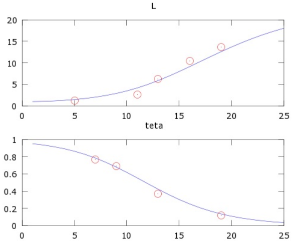

Figure : The employment structure and dynamics of population with demographic transition

Conclusion

- We propose two-sectors Schumpeterian model with alternative mechanism of take-off
- The gradual transition to the manufacturing sector influences the proportion of the power distribution between landowners and capitalists, and finally leads to the adoption of institutions, favoring the industrial development.
- The model also explains the basic facts about between-country income dynamics: the Malthusian stagnation, the great Divergence and the modern convergence club phenomenon.