A North-South agent based model of segmented labour markets. The role of education and trade asymmetries

Lucrezia Fanti[a]
Marcelo C. Pereira[b]
Maria Enrica Virgillito[a,c]

[a]Università Cattolica del Sacro Cuore [b]Unicamp
[c]Scuola Superiore Sant'Anna

Technology-Gap, Development Asymmetries and Market Concentration[1]

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Motivation

- Education and trade have been at the core of economic growth theory in the latest forty years, with special attention devoted to human capital accumulation and trade-oriented growth strategies.

- A consolidated tradition in evolutionary economics has put forward the role of international trade, and particularly the role of the composition of the exported bundles of products in affecting growth trajectories.

- Less attention has been devoted to the interaction of education and trade mechanisms in determining long-term growth, particularly in ABMs.

Why education and trade should affect the growth patterns of countries

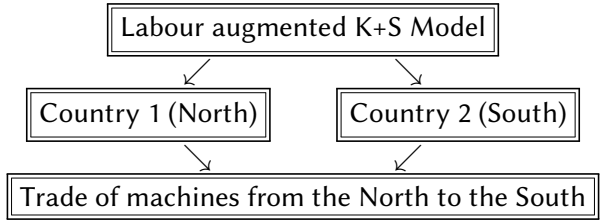
- If countries are differentiated in the amount of education they are able to ensure, this will impact upon the labour force they are able to train, and on the role workers serve in the labour market.
- Education might impact upon growth patterns via the probability to innovate, also affecting the type of products the country is able to produce.
- A leader-country will be able to produce more advanced goods, as well as machine and intermediate inputs to serve the demand of the laggard country.
- Trade flows might therefore accelerate crystallization in initial asymmetries driven by a different education rate.

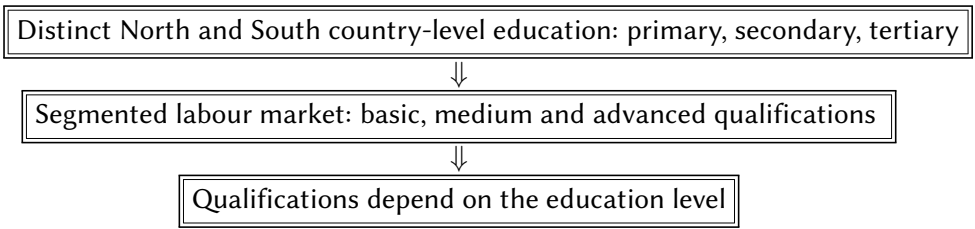
Objective of the paper

A two-country North-South ABM, wherein a laggard- and a leader-country are confronted in terms of asymmetries in their performance levels and macroeconomic dynamics.
Focus on:

- Education attainments and labour productivity
- Labour search-and-match process
- International trade and technical change

Strategy of implementation: trade and education





The North-South model description

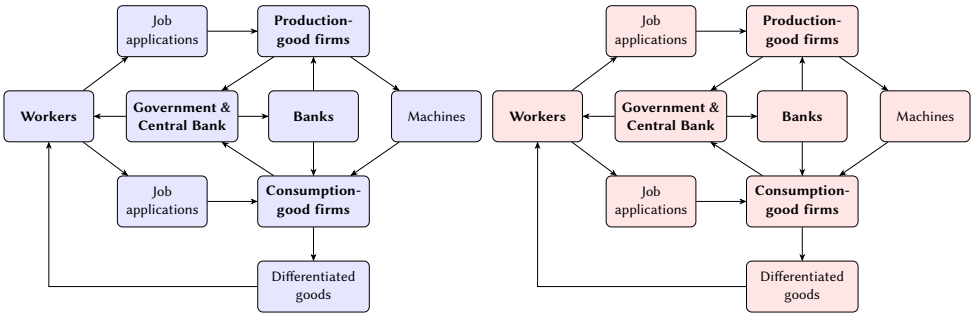
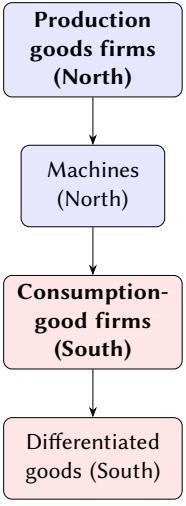


Figure: The North (blue $\epsilon_{ed} = 0.05$), the South (red $\epsilon_{ed} = 0.04$)

Model description: the North-South trade in machines



Education attainment and labour productivity I

- The individual attainment is measured in terms of years of schooling $ed_\ell \in [0, 16]$ distinct in: (1) primary ($ed_\ell \leq 8$), (2) secondary ($8 < ed_\ell \leq 12$), and (3) tertiary ($ed_\ell > 12$).
- Education is publicly provided by the government which allocates G_t^{ed} for education:

$$G_t^{ed} = \epsilon_{ed} Y_{t-1}, \tag{1}$$

  $\epsilon_{ed} \in [0, 1]$ is a parameter, and Y_t, the nominal GDP.
- the education level is drawn from a beta distribution:

$$ed_\ell \sim 16 \text{ beta}\left(g\,\alpha_{ed}, \beta_{ed}/g\right), \qquad g = \left(\frac{\epsilon_{ed}}{\epsilon_{ad}}\right)^{\vartheta_{ed}}, \tag{2}$$

  where $(\alpha_{ed}, \beta_{ed}) \in \mathbb{R}_+^2$ define the beta PDF that proxy the educational attainment distribution of an advanced country ($g = 1$), mapped to the $[0, 16]$ support.
- To obtain an educational attainment profile equivalent to an advanced country, the government must spend a share equal to ϵ_{ad} (a parameter in $[0, 1]$) every year
- $\vartheta_{ed} \in \mathbb{R}_+$ is the sensitivity of the distribution shape when $\epsilon_{ed} \neq \epsilon_{ad}$.

Education attainment and labour productivity II

Country R&D performance is influenced by the education expenditure, which modulates the probability of firm i obtaining access to innovation ($\theta^{in}_{i,t}$) and to imitation ($\theta^{im}_{i,t}$) in t:

$$\theta^{in}_{i,t} = 1 - e^{-\zeta_1 \, g \, IN'_{i,t}}, \tag{3}$$

$$\theta^{im}_{i,t} = 1 - e^{-\zeta_2 \, g \, IM'_{i,t}}. \tag{4}$$

$(\zeta_1, \zeta_2) \in \mathbb{R}^2_+$ are parameters, and $(IN'_{i,t}, IM'_{i,t})$ are the standardized share of workers allocated to innovative and imitative R&D activities, respectively.

Education attainment and labour productivity III

The technology of capital-good firm i is defined by (A_i^τ, B_i^τ). That is, the notional labour productivity of the manufactured machine-tool and the labour productivity to produce the machine.

Worker ℓ individual education level ed_ℓ drives consumption-good firm productivity and, together with current (learning-by-doing) skills $s_{\ell,t}$, defines his individual labour productivity:

$$A_{\ell,t} = \frac{s_{\ell,t}}{\bar{s}_t} A_i^\tau \left(\frac{ed_\ell}{\overline{ed}_{ad}} \right)^{\tau_{ed}}, \tag{5}$$

Capital-good sector productivity is affected by labour force education as well:

$$B_{i,t} = B_i^\tau \left(\frac{ed_{t-1}^1}{\overline{ed}_{ad}} \right)^{\tau_{ed}}, \tag{6}$$

$\tau_{ed} \in \mathbb{R}_+$ a scaling parameter defining the intensity of a deviation from the expected education level (Beta distribution) of an advanced country $\overline{ed}_{ad} = 16\,\alpha_{ed}/\left(\alpha_{ed} + \beta_{ed}\right)$, as defined in Eq. 2.

ed_t^1, the average education level of workers in capital-good sector.

Labour search-and-match I

Workers are grouped in three categories $c = 1, 2, 3$, according to the levels of education. Accordingly, firm labour demand $L^d_{j,t}$ in both sectors is segmented:

$$L^{d,1}_{j,t} = (1 - \theta_2 - \theta_3)\, L^d_{j,t}, \qquad L^{d,2}_{j,t} = \theta_2 L^d_{j,t}, \qquad L^{d,3}_{j,t} = \theta_3 L^d_{j,t}, \tag{7}$$

being $\theta_2, \theta_3 \in [0, 1]$, $\theta_2 + \theta_3 \leq 1$, parameters, $L^{d,c}_{j,t}$, $c = 1, 2, 3$, the labour demand of firm j at time t for primary-, secondary-, and tertiary-level workers, respectively.
R&D labour demand in capital-good sector consists of tertiary-level ($c = 3$) workers only.

Labour search-and-match II

Firms organize the candidate queue into three sub-queues, according to the worker category c. Considering the set of workers in the sub-queues $\{\ell_{j,t}^{s,c}\}$, each firm selects the subsets of desired workers $\{\ell_{j,t}^{d,c}\}$ to make a job (wage) offer:

$$\{\ell_{j,t}^{d,c}\} = \{\ell_{j,t} \in \{\ell_{j,t}^{s,c}\} : w_{\ell,t}^{r} \leq w_{j,t}^{o,c}\}, \quad c = 1, 2, 3. \tag{8}$$

Firms in consumption-good sector target workers that would accept the wage offer $w_{j,t}^{o,c}$ correponding to the worker category, considering the wage $w_{\ell,t}^{r}$ requested by workers, if any. In the capital-good sector, firms top the wages offered by the consuption-good sector ($w_{i,t}^{o,c} = \max_j w_{j,t}^{o,c}$).

Labour search-and-match III

- The hiring process takes place one category at the time, from higher to lower education levels (i.e., $c = 3, 2, 1$).
- Remaining open positions in level $c + 1$ are transferred to the labour demand $L_{j,t}^{d,c}$ of the level c immediately below, if any.
- Firms may hire a set of workers with lower education than desired, to reduce the production losses associated to an open position. However, worker productivity $A_{\ell,t}$ is reduced, in comparison to the desired labour segmentation.
- Firm j hires up to the total demand $L_{j,t}^{d,c}$ for each category or up to all workers in each sub-queue is reached, whichever is lower. The total number of workers $L_{j,t} = \sum_{c=1}^{3} L_{j,t}^{c}$ the firm will employ in t, given the current workforce $L_{j,t-1}$, is bounded by:

$$0 \leq L_{j,t}^{c} \leq L_{j,t}^{d,c} \leq L_{j,t}^{s,c}, \qquad L_{j,t}^{z,c} = L_{j,t-1}^{c} + \#\{\ell_{j,t}^{z,c}\}, \qquad z = d, s, \quad c = 1, 2, 3. \quad (9)$$

International trade and technical change I

- The North and South countries trade only capital goods (machines). Countries share the same currency, so no exchange rate is required, and there are no import tariffs (same currency area set-up). Consumption-good exports are not possible.
- Capital-good suppliers send brochures to clients (potentially) domestically and abroad to advertise machines. They contact existing $HC_{i,t}$ clients, and a number $\gamma HC_{i,t}$ of new clients, irrespective of the country. $\gamma \in \mathbb{R}_+^*$ is a fixed parameter.
- Machine exports X_t^1, by capital-good firms, and imports Im_t^2, by consumption-good ones, define the country balance of trade $X_t^{net} = X_t^1 - Im_t^2$ (or net exports). As the model is stock-flow consistent at the world level, $\sum X_{c,t}^{net} = 0$, C is the number of countries.

International trade and technical change II

- The technology of capital-good firms evolves in an international set-up. Firms may try to imitate machines developed in the other country.
- The success probability of imitation is inversely proportional to the technological gap $\mathcal{D}_t^{m,n}$ between imitating and imitated firms. This gap is based on the technological coordinates (A_i^τ, B_i^τ).
- The gap is measured as the Euclidean distance – in the (c^2, p^1) normalized space – of the machines currently produced by the imitator m and the imitated firm n:

$$\mathcal{D}_t^{m,n} = \sqrt{\left(\frac{c_{n,t}^2 - c_{m,t}^2}{\bar{c}_t^{2w}}\right)^2 + \left(\frac{p_{n,t}^1 - p_{m,t}^1}{\bar{p}_t^{1w}}\right)^2}, \tag{10}$$

where $c_{i,t}^2$ is the unit cost of a (client) consumption-good firm when using the machine manufactured by firm i, and $p_{i,t}^1$ is the price of such machine. $\bar{c}_t^{2w}$ and $\bar{p}_t^{1w}$ are the respective world average values.

International trade and technical change III

Once firm i succeeds in imitating foreign firm h, the different education expenditures between the host countries imply distinct absorptive capacities:

$$A_{i,t}^{im} = \frac{g_i}{g_h} A_{h,t-1}, \tag{11}$$

$$B_{i,t}^{im} = \frac{g_i}{g_h} B_{h,t-1}. \tag{12}$$

$(A_{i,t}^{im}, B_{i,t}^{im})$ are the productivities achieved by firm i when imitating firm h machines defined by $(A_{h,t-1}, B_{h,t-1})$. (g_i, g_h) are the adjusted relative government expenditures g of the countries where firms i and h are established.

Gap variables to detect cross-countries asymmetries

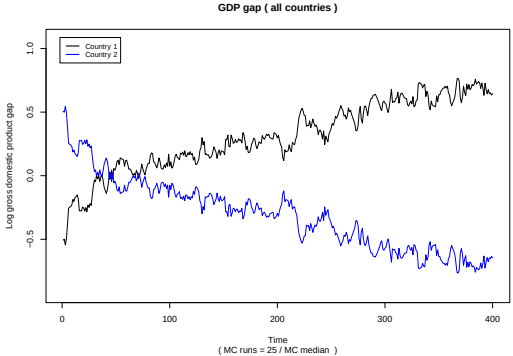
- We choose to investigate the presence of asymmetric relations between the two countries by showing the gap in terms of some crucial macroeconomic outcome variables.
- Each gap variable is computed for both countries as follows:

$$\frac{(X_1 - X_2)}{X_1} \tag{13}$$

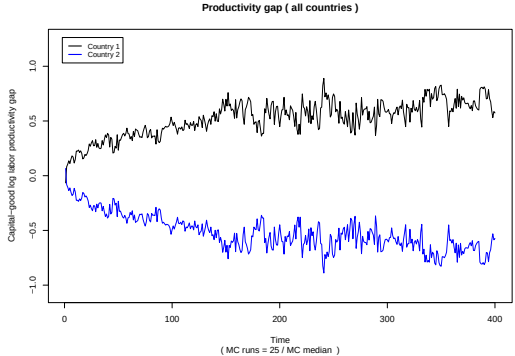
$$\frac{(X_2 - X_1)}{X_1} \tag{14}$$

- Thus each plot shows two specular artificial time series representing the gap in each country with respect to country 1, that is the leader.

Gaps in performance

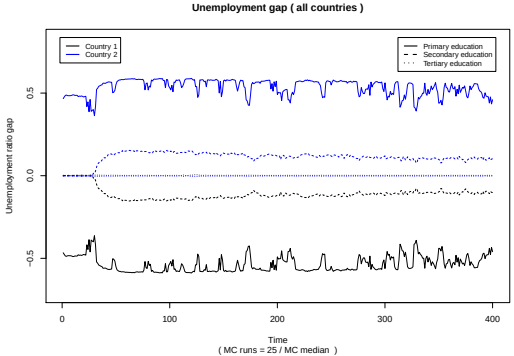


(a) GDP gap

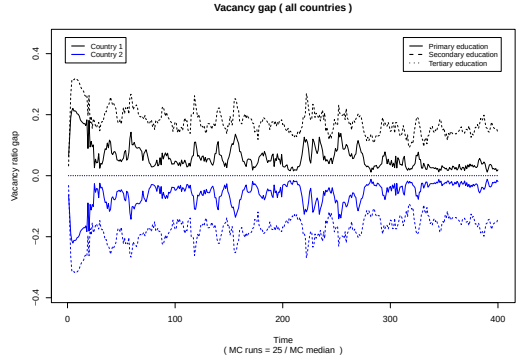


(b) Productivity gap

Gaps in labour markets

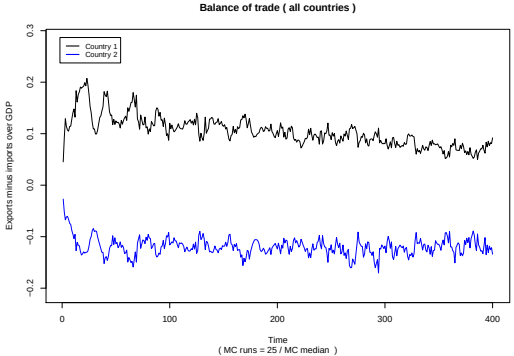


(c) Unemployment gap by qualification level

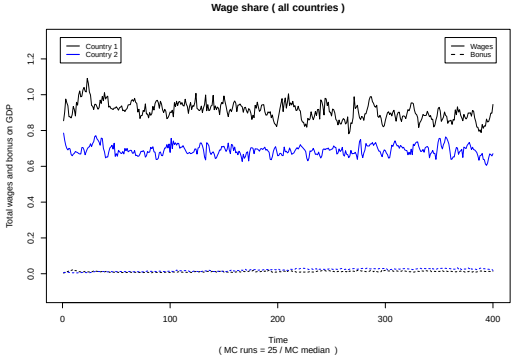


(d) Vacancy gap by qualification level

Gap in trade and wage share

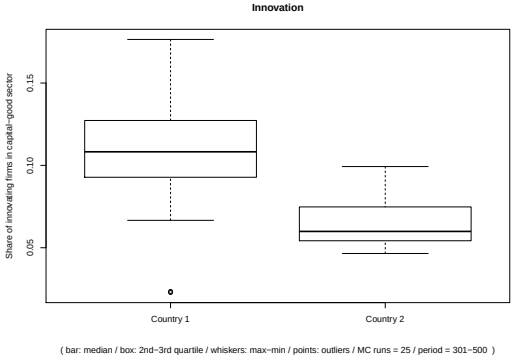


(e) Trade balance

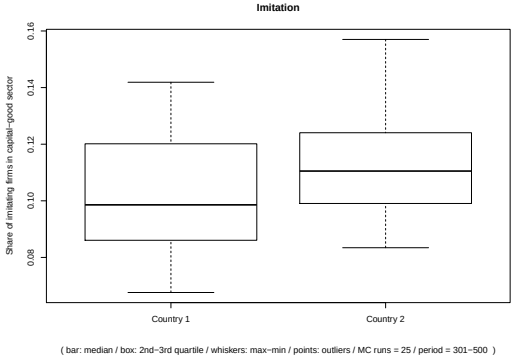


(f) Wage share

Gaps in technological advancement



(g) Innovation



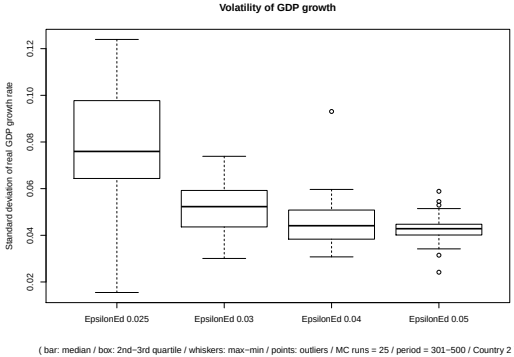
(h) Imitation

Wrap-up of main results

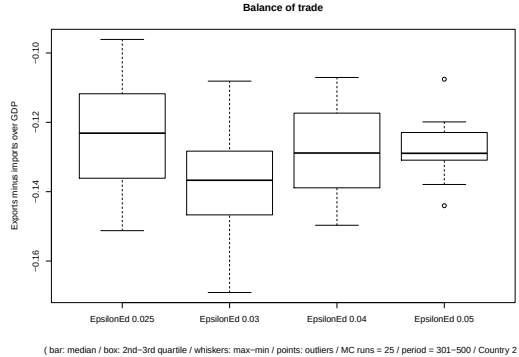
- Persistent asymmetries in performance indicators, e.g. GDP and productivity among the leader and the laggard country.
- Persistent asymmetries in technological advancements: note that higher imitation does not mean better imitation by firms in country 2.
- Segmented labour markets resulting into i) unemployment rate gap negative correlated with the education level and ii) vacancy rates gap particularly in medium level qualifications (secondary education).
- Balance of trade showing a persistent net North exporter (South importer) also recording higher (lower) wage share.

Note that all these results hold **just** decreasing the ϵ_{ed} parameter in the South regulating the total amount of expenditure in education.

The role of education: Laggard country with different levels of ϵ_{ed}

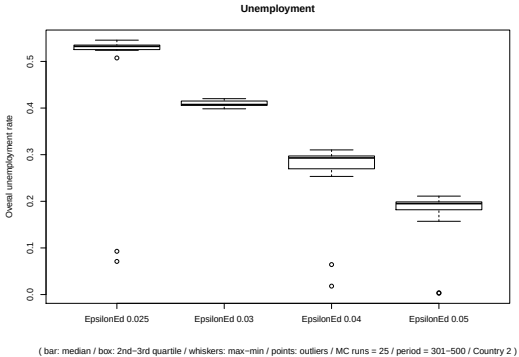


(i) Volatility of GDP

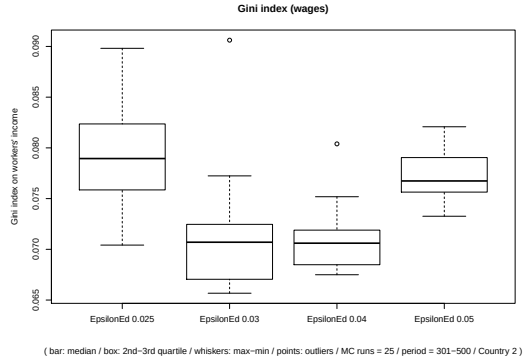


(j) Balance of trade

The role of education: Laggard country with different levels of education expenditure ϵ_{ed}



(k) Unemployment



(l) Gini Index

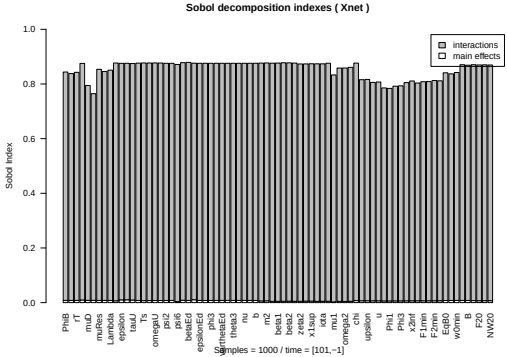
Wrap-up of main results of policy experiments on the role of education

- Volatility of GDP growth rates and unemployment *negatively correlated* with the education expenditure.
- Gini index showing a U-shape relationship with education.
- Balance of trade led more by idiosyncratic asymmetries rather than by differences in the education level in terms of average rates, while it is more affected in terms of volatility.

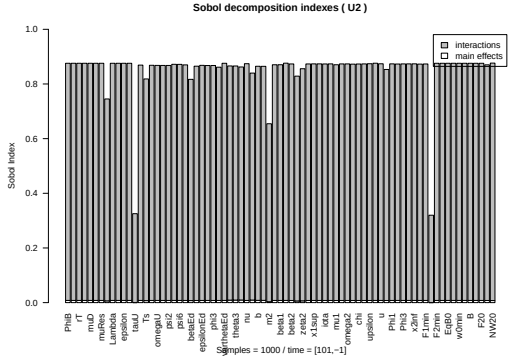
Conclusions

- One of the first ABM presenting a model of trade in capital goods and education in order to study patterns of convergence and divergence across countries (leader and laggard).
- Introduction of a segmented labour market leading to different dynamics in terms of labour market outcomes (unemployment and vacancy) by education (and qualification) level.
- We showed that differences in education levels persistently affect country performance, trade balance and labour markets. The channels of these feedback mechanisms go:
  - from education to innovation;
  - from education to labour markets;
  - from innovation to international trade;
  - from education and trade (via technology and labour markets) to country GDP and productivity growth.
- New developments will look at the role of convergence versus divergence policies (imitation and import tariff).

Kriging meta-modelling: ‘insensible’ variables to education

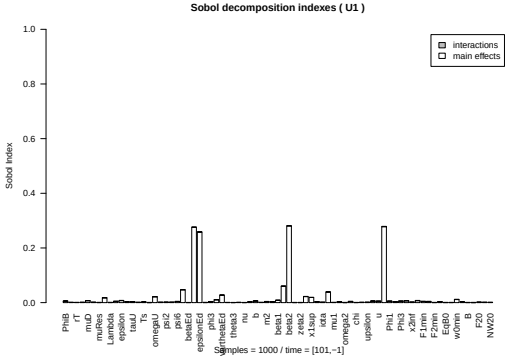


(m) Trade

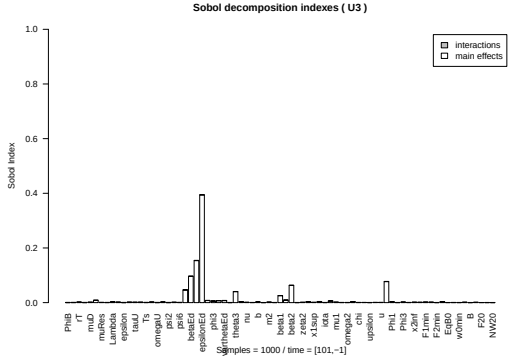


(n) Unemployment by secondary education

Kriging meta-modelling: ‘sensible’ variables to education



(o) Unemployment by primary education



(p) Unemployment by tertiary education

Innovation and R&D

- **Capital-good firms search for better machines and for more efficient production techniques**
  - $A_{i,t}$: productivity of machine manufactured by firm i
  - $B_{i,t}$: productivity of production technique of firm i
  - $A_{i,t}$ and $B_{i,t}$: determine the technology of firm i at time t

- **R&D**
  - R&D investment (RD) is a fraction of firm sales (S):

$$RD_{i,t} = \upsilon S_{i,t-1} \qquad \upsilon > 0$$

  - R&D is performed by workers devoted to this activity, whose demand is:

$$L_{i,t}^{R\&D} = \frac{RD_{i,t}}{w_{i,t}}$$

  - capital-good firms allocate R&D workers between innovation (IN) and imitation (IM):

$$IN_{i,t} = \xi L_{i,t}^{R\&D} \qquad IM_{i,t} = (1-\xi) L_{i,t}^{R\&D} \qquad \xi \in [0,1]$$

Investment

- **Expansionary investment**
  - demand expectations ($D^e_{j,t}$) determine the desired level of production ($Q^d_{j,t}$) and the desired capital stock ($K^d_{j,t}$)
  - firm invests ($EI_{j,t}$) if the desired capital stock is higher than the current capital stock ($K_{j,t}$):

$$EI_{j,t} = K^d_{j,t} - K_{j,t}$$

- **Replacement investment**
  - payback period routine
    - an incumbent machine is scrapped if

$$\frac{p^*}{c(\tau) - c^*} \leqslant b, \qquad b > 0$$

    - $c(\tau)$ unit labor cost of an incumbent machine;
    - p^*, c^* price and unit labor cost of new machines
  - also machine older than Λ periods are replaced

Labour Demand and Production

The labour demand is defined as

$$L^d_{j,t} = \frac{Q^d_{j,t}}{m_2 A_{j,t}} \tag{15}$$

where m_2 indicates the capital productivity and $A_{j,t}$ the expected average labour productivity.
Desired production is determined by expected demand, computed via a simple adaptive rule

$$D^e_{j,t} = f(D_{j,t-1}, D_{j,t-2}, D_{j,h-1}) \tag{16}$$

where $D_{j,t-1}$ is the demand actually faced by firm j at time $t-1$ (h positive integer)

Labour Demand and Production

The desired level of production Q_j^d depends on the expected demand as well as on the desired inventories N_j^d and the actual stock of inventories N_j

$$Q_{j,t}^d = D_{j,t}^e + N_{j,t}^d - N_{j,t-1} \tag{17}$$

Each firm j will have, in average, a fraction of the number of applicant workers ωL in its job queue, proportional to firm size f

$$L_{j,t}^s = \omega L f_{j,t-1} \tag{18}$$

where ω is a parameter and $f_{j,t-1}$ is the market share of firm j at time $t-1$

Hiring

In case of an increase in production, workers are hired

$$\text{if} \quad \Delta Q^d_{j,t} = Q^d_{j,t} - Q_{j,t-1} > 0 \quad \text{then} \quad \text{hire} \quad \Delta L^d_{j,t} = L^d_{j,t} - L_{j,t-1} \quad \text{workers} \tag{19}$$

The skills dynamics

The skill level $s_{\ell,t} > 0$ of each worker ℓ evolves over time as a multiplicative process:

$$s_{\ell,t} = \begin{cases} (1+\tau_T)s_{\ell,t-1} & \text{if employed in } t-1 \\ \dfrac{1}{1+\tau_U}s_{\ell,t-1} & \text{if unemployed in } t-1. \end{cases} \tag{20}$$

with $\tau \geq 0$ a parameter.

Wage indexation

$$w^o_{j,t} = w^o_{j,t-1}(1 + WP) \tag{21}$$

$$WP = \psi_2 \frac{\Delta A_t}{A_{t-1}} + \psi_4 \frac{\Delta A_{j,t}}{A_{j,t-1}} \tag{22}$$

$$\psi_2 + \psi_4 \leq 1 \tag{23}$$

Each firm can afford to pay a salary not bigger than a *break even salary*

$$w^{MAX}_{j,t} = p_{j,t-1} A_{j,t-1} \tag{24}$$