Innovation and Structural Change in Complex Evolutionary Systems

Part V

Economic Development as the Interaction among Several Aspects of Structural Change

Tommaso Ciarli

SPRU, University of Sussex

t.ciarli@sussex.ac.uk

XIX Escuela de Verano de la CEPAL Sobre Economías Latinoamericanas

División de Desarrollo Productivo y Empresarial, CEPAL

Santiago, August 13-17, 2018

Plan for the next four of days

Part I: discuss some **evidence** and **main properties** of *innovation* (as an evolutionary process)

Part II: discuss some **evidence** and **main properties** of *complex systems*

Part III: introduce the use of ABM to study complex economic systems – taster of ACE

Part IV: modelling micro aspects of innovation

- The basic evolutionary process: replicator dynamics
- Search: NK Model
- Path dependency: technological choice

⇒ **Part V: model growth and structural change as an evolutionary complex dynamic**

Growth and structural change

Part V:
Modelling growth and structural change as an evolutionary complex dynamic (micro-macro)

Plan for part V

- Basic evidence on the relevance of *innovation* for economic growth and development
- Evolutionary growth theories: Nelson and Winter (1982) and some developments
- Basic evidence on on the relevance of *structural changes* economic growth, development
- A model of interrelated structural changes
  - Empirical evidence
  - Model and properties
  - Which variety?
  - Which structural change?
  - The relation between institutional and structural determinants (growth regimes)
  - Role of consumer preferences
  - The different roles of market concentration

Main references: Evolutionary/ABM Macro

- Nelson, R. & Winter, S. (1982), An Evolutionary Theory of Economic Change, Harvard University Press, Cambridge, MA. Ch 12 & 14
- Colander, D.; Howitt, P.; Kirman, A.; Leijonhufvud, A. & Mehrling, P. (2008), 'Beyond DSGE models: toward an empirically based macroeconomics', American Economic Review 98(2), 236–240.
- Dosi, G.; Fagiolo, G. & Roventini, A. (2010), 'Schumpeter Meeting Keynes: A Policy Friendly Model of Endogenous Growth and Business Cycles', Journal of Economic Dynamics and Control 34, 1748-1767.

Main references: ABM growth

- Silverberg, G. & Verspagen, B. (2005) Evolutionary Theorizing on Economic Growth in Dopfer, K. (ed.) The Evolutionary Foundations of Economics, Cambridge University Press, 506-539
- Verspagen, B. (2006), Innovation and Economic Growth, in Jan Fagerberg; David C. Mowery & Richard R. Nelson, ed., The Oxford Handbook of Innovation, Oxford University Press, Oxford, pp. 487-513.

Main references: growth and structural change

- Ciarli, T, A Lorentz, M Savona, and M Valente (2010). "The Effect of Consumption and Production Structure on Growth and Distribution. A Micro to Macro Model." *Metroeconomica* 61(1): 180-218
- Ciarli, T, and A Lorentz (2011) "Product Variety and Economic Growth. Trade off between Supply and Demand Dynamics". Working Paper, Max Planck Institute, Jena.
- Ciarli, T. (20120 "Structural Interactions and Long Run Growth: An Application of Experimental Design to Agent Based Models." Revue de l'OFCE, Debates and policies 124: 295-345.
- Lorentz, A, T Ciarli, M Savona, and M Valente (2015). "The Effect of Demand-Driven Structural Transformations on Growth and Technological Change." *Journal of Evolutionary Economics* 26(1): 219-246.
- Ciarli, Tommaso, and Marco Valente (2016) The Complex Interactions between Economic Growth and Market Concentration in a Model of Structural Change. *Structural Change and Economic Dynamics* 38 (May): 38-54.
- Ciarli, Tommaso, André Lorentz, Marco Valente, and Maria Savona (2018). Structural Changes and Growth Regimes. *Journal of Evolutionary*

Innovation and economic development

Innovation and economic development: some stylised facts about the great divergence

Long term income

Table: GDP per capita – World regions 1000–2001 (US$ PPP constant 1990)

	1000	1500	1820	1870	1913	1950	1973	2001
Western Europe	400	771	1 204	1,960	3,458	4,579	11,416	19,256
Western Offshoots	400	400	1,202	2,419	5,233	9,268	16,179	26,943
Japan	425	500	669	737	1,387	1,921	11,434	20,683
West	405	702	1,109	1,882	3,672	5,649	13,082	22,509
Asia (excluding Japan)	450	572	577	550	658	634	1,226	3,256
Latin America	400	416	692	681	1,481	2,506	4,504	5,811
Eastern Europe & f. USSR	400	498	686	941	1,558	2,602	5,731	5,038
Africa	425	414	420	500	637	894	1,410	1,489
Rest	441	538	578	606	860	1,091	2,072	3,372
World	436	566	667	875	1,525	2, 111	4,091	6,049
Interregional Spread	1.1:1	1.9:1	2.9:1	4.8:1	8.2:1	14.6:1	13.2:1	18.1:1
West/Rest Spread	0.9:1	1.3:1	1.9:1	3.1:1	4.3:1	5.2:1	6.3.1	6.7:1

Source: Maddison (2001)

Global technological outputs: patents

Year	Patent applications	Patents granted	Share of patents granted (%)		
			Foreign patents	Developing country patents	Developing countries excl. S.Korea
1870	19,171	12,157			
1900	39,673	24,656			
1913	68,117	33,915			
1950	67,264	43,039			
1973	103,695	74,139			
1990		99,220	46.6	1.5	0.5
1991		106,842	45.9	1.7	0.5
1992		107,511	45.3	1.8	0.4
1993		109,890	44.3	2.2	0.5
1994		113,704	43.4	2.5	0.5
1995		113,955	43.4	2.8	0.5
1996		121,805	43.0	3.1	0.5
1997		124,146	43.7	3.8	0.6
1998		163,209	44.4	4.7	0.6
1999		169,146	44.4	5.0	0.6
2000		176,084	44.9	4.8	0.7
2001		184,051	46.4	5.2	0.8

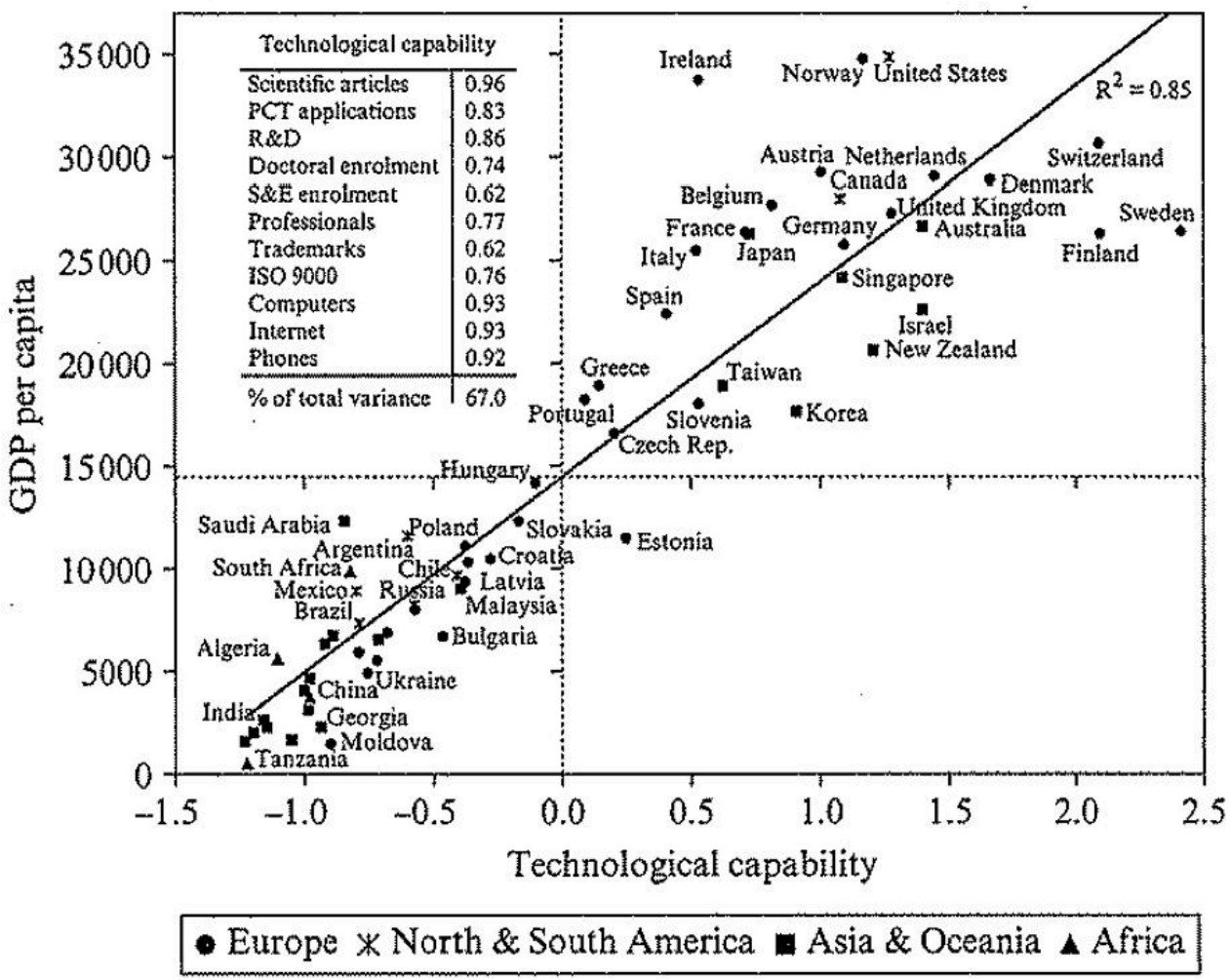
Source: Szirmai (2005)

Formal research and development

	R&D as % of GDP 1987–97[a]	R&D per capita PPP internat. $ 1987–97	Scientists and engineers per 100,000 1987–97
Bangladesh	0.3	2.9	52
China	0.5	13.0	454
India	0.8	9.9	149
Indonesia	0.1	2.8	182
Malaysia	0.3	18.0	93
Pakistan	1.1	9.6	72
Philippines	0.2	6.2	157
South Korea	2.9	285.0	2,193
Sri Lanka	0.2	1.8	191
Taiwan	2.1		544
Thailand	0.1	8.4	103
Turkey	0.4	21.6	291
Argentina	0.4	33.9	660
Brazil	0.7	34.9	168
Chile	0.7	74.9	445
Colombia	0.1	3.7	37
Mexico	0.3	23.4	214
Peru	0.6	24.2	233
Venezuela	0.5	41.2	209
Egypt	0.5	11.1	459
Nigeria	0.1	0.6	15
South Africa	0.7	43.1	1,031
Average Asian countries	0.8	31.6	328.1
Average Latin American countries	0.5	33.7	280.9
Average developing countries	0.6	30.5	336.7
Average OECD countries[a]	2.1	438.2	2,912

Source: Szirmai (2005)

GDP per capita and production & technological capabilities



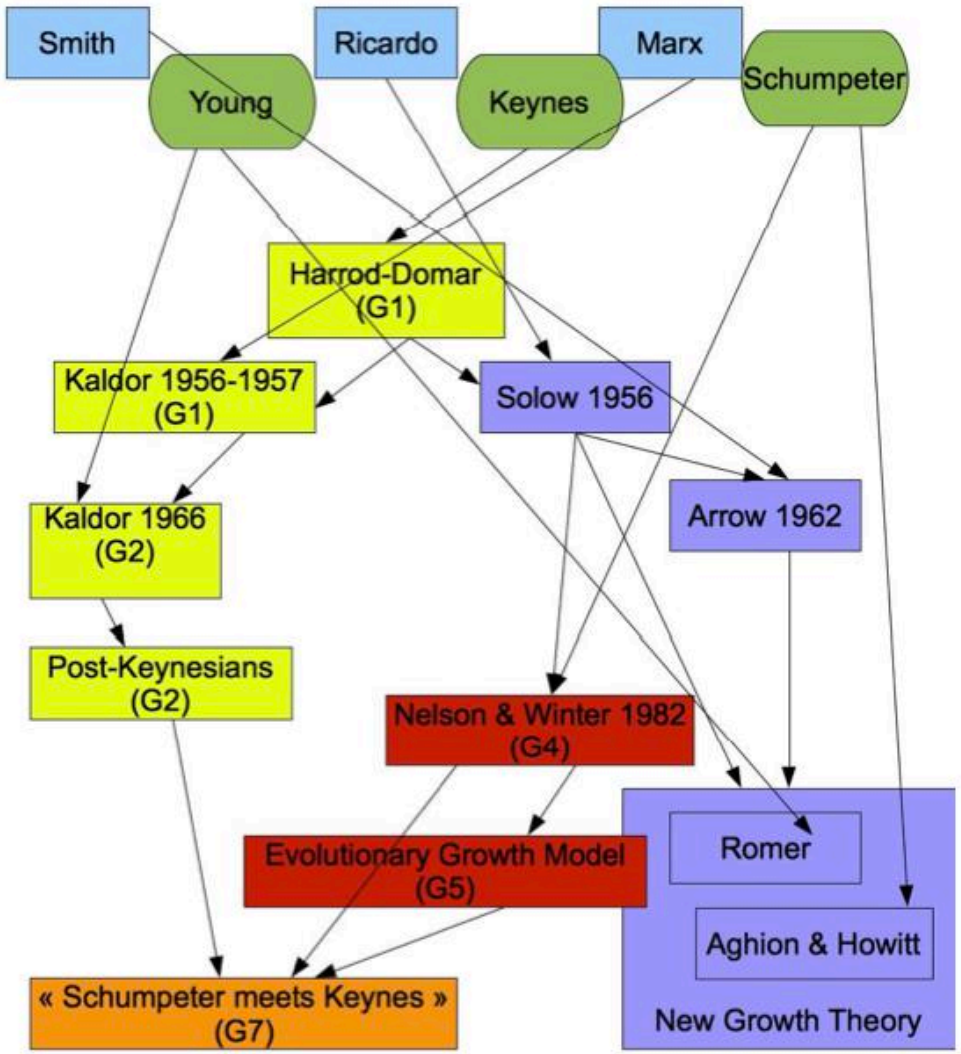
Source: Fagerberg and Srholec (2010)

Research base, Advanced training (absorptive), and Innovation exploitation (production/marketing)

Evo Growth Theories

The evolutionary growth modelling legacy:
NW and followers

Stylising growth theories



Source: André Lorentz

Nelson and Winter (1982): Model features

Population of heterogeneous firms

Fixed coefficient production function: complementary inputs

Technologies are drawn from a given and finite pool of existing techniques: paradigm

- Technological knowledge is localised, and specific to firms: no public good

Innovation is not always successful and needs profit investment (Schumpeter Mark II)

Firms are price takers: selection on *process* technology

Supply side model: demand is given

Main dynamics

Innovation drives firm selection through K innovation/investment

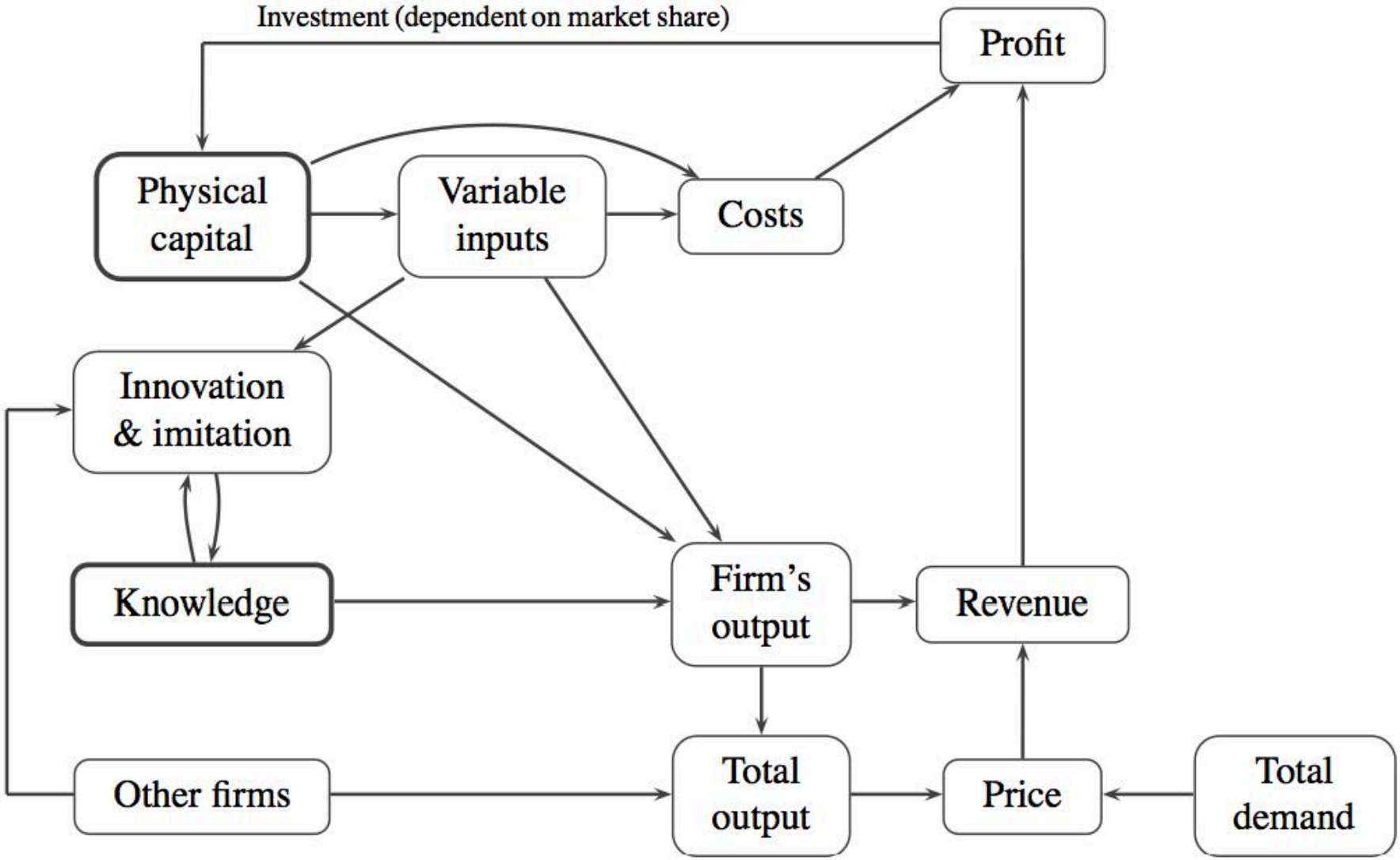
- Capital accumulation decreases when market share increases

Market clearing price (for total output)

When capital falls below a given level: firm exit

Description of the dynamic process

Model details



Source: Andersen (2004)

R&D Investment and Economic growth

Chiaromonte and Dosi (1993); Dosi et al. (1994); Castaldi (2002); Fagiolo and Dosi (2003)

Multiple sectors

Multiple countries and no convergence

Persistence of firms differences

Refined R&D process

Capital accumulation and Economic growth

Silverberg and Lehnert (1994); Silverberg and Verspagen (1994b,a)

Focus on embodied capital innovation: techniques

Vintage capital models

More developed macroeconomic framework

Learning in innovation and imitation routines

Study long waves and short cycles of technological change

Schumpeter meeting Keynes

Dosi et al. (2015, 2013, 2010, 2006)

Combine Schumpeterian innovation dynamics (at the firm level) and Keynesian macro policies

Effect of different innovation regimes on macro variables

Two way relations between innovation and demand

Economic fluctuations and growth

Financial sector

Paradigm alternative to DSGE more than growth/development models

Post Keynesian flavour

Financial instability: Chiarella and Di Guilmi (2011); Delli Gatti et al. (2010); Russo et al. (2007); Delli Gatti et al. (2005)

SFC: Caiani et al. (2016); Riccetti et al. (2015); Seppecher and Salle (2015)

Whole economy models

Deissenberg et al. (2008)

Fine tuned micro behaviour

Policy models: employment, fiscal, monetary, industrial policies

Paradigm alternative to DSGE more than growth/development models

Generation of variety

Aoki and Yoshikawa (2002); Saviotti and Pyka (2008b,a, 2004)

- More focus on the demand side: Engel curves (escaping satiation)
- Product innovation: new sectors with monopolistic profits
- New firms enter the new market depending on financial availability, competition, mergers: saturation
- Endogenous growth depends on the creation of variety

Microfoundation of movements over the product space (Hidalgo et al., 2007): Desmarchelier et al. (2018)

Internaitonal trade and endogenous product specialisation: Dosi et al. (2017)

Structural change

Structural change (?)

Long term income

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Source: Maddison (2001)

Long term changes in production and employment structure

	Employment			Value Added		
Years	Agriculture	Industry	Services	Agriculture	Industry	Services
Average OECD						
1870	49	27	24	39	26	35
1900	38	25	31	28	31	41
1950	25	36	39	15	41	44
1980	6	30	64	4	37	59
Average Latin America						
1950	50	22	28	23	30	47
1980	29	26	45	12	37	51
Average Asia						
1950	73	8	19	49	15	36
1980	57	17	26	28	34	41

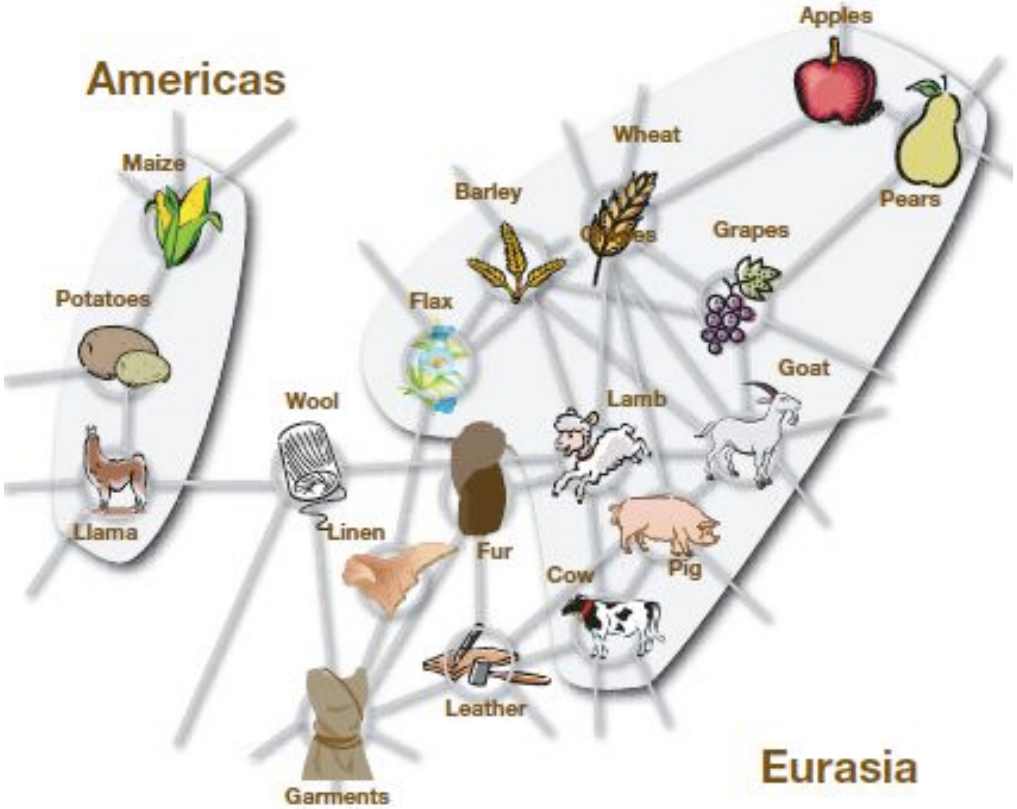
Source: Maddison (1989)

Structure of British Gross Domestic Expenditure, 1688 and 1996

	1688 *England and Wales*	*1996* *United Kingdom*
Food	25.7	6.5
Beverages and Tobacco	13.6	5.9
Clothing and Footwear	19.2	3.7
Light, Fuel and Power	3.7	2.2
Furniture, Furnishings and Household Equipment	9.3	4.0
Personal Services	3.0	1.2
Sub-total	**74.5**	**23.5**
Rent and Imputed Rent	4.1	10.0
Education	1.4	5.4
Health	0.7	6.7
Recreation and Entertainment	0.9	5.7
Transport and Communication	0.8	10.6
Other	1.9	11.5
Sub-total	**9.8**	**49.9**
Total Private Consumption (Total Items 1-12)	84.2	73.4
Government Consumption (except education and health)	9.0	10.9
Gross Capital Formation	6.8	15.8
Total Gross Domestic Expenditure	**100.0**	**100.0**
Level of Per Capita GDP (in 1990 international dollars)	1 411	17 891

Source: Maddison (2003)

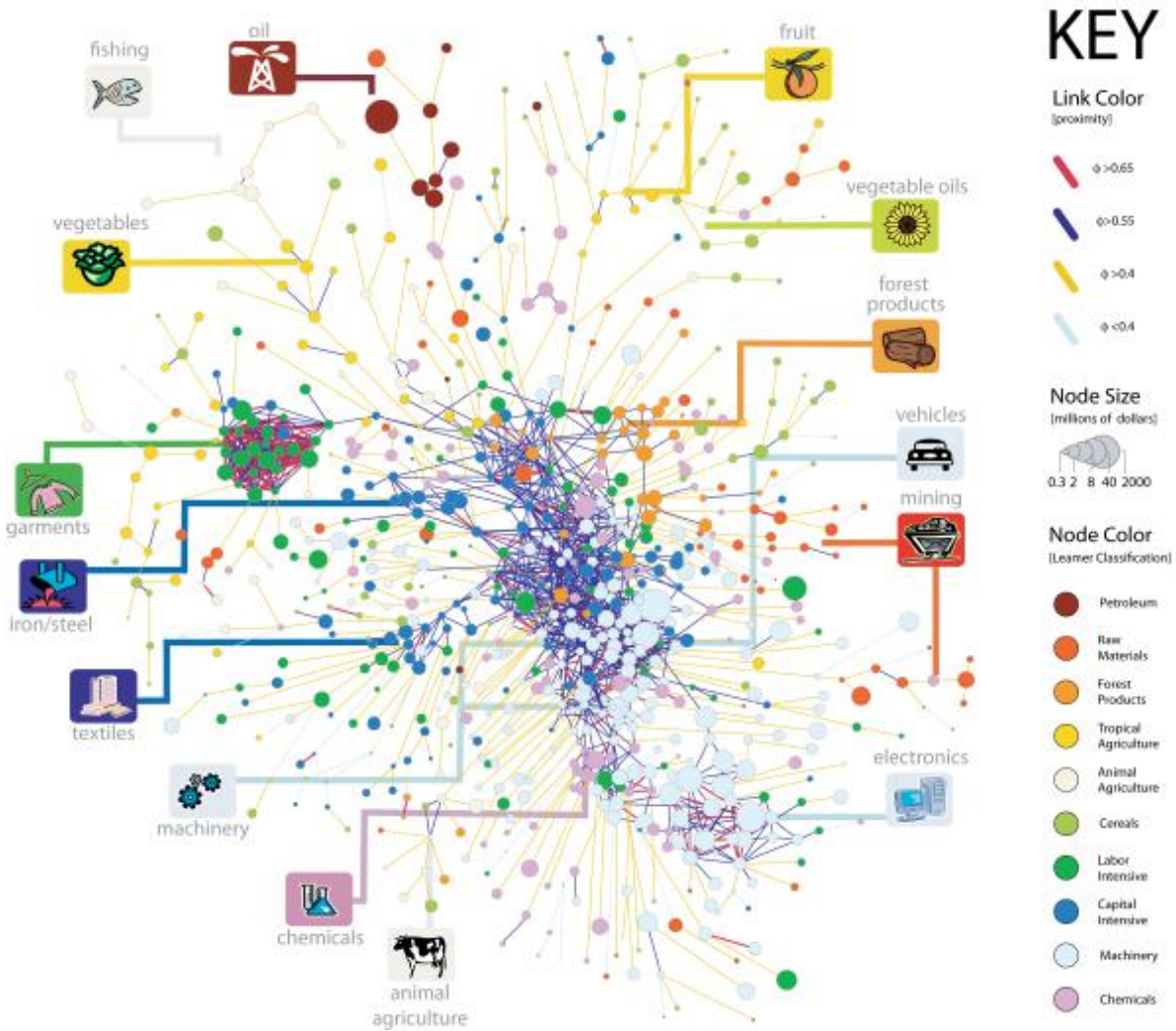
Product space and the long term geography of development



Source: Hidalgo and Hausmann (2008)

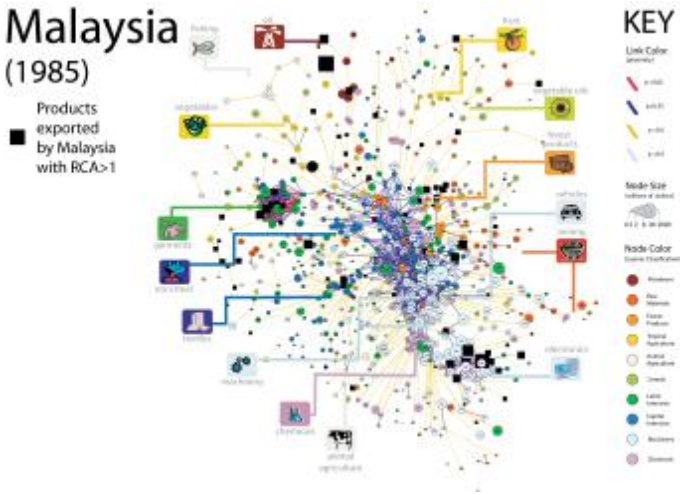
Civilizations grew by discovering products, that is, domesticating plants and animals. [...] allowed them to create more complex products, such as garments, tools, and weapons.

Product space, export and development prospects

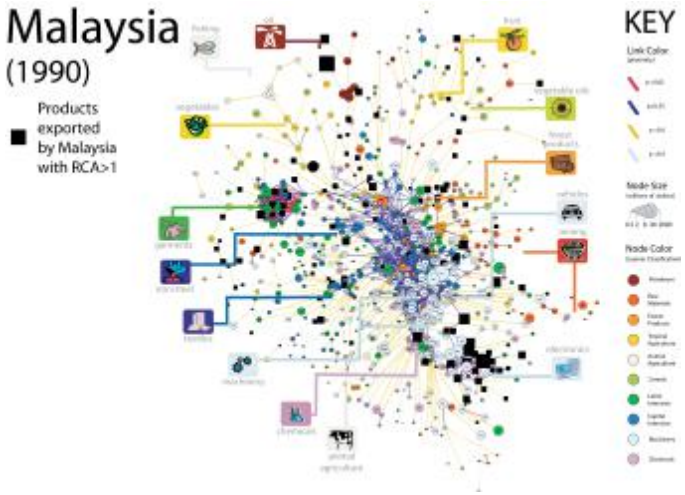


Source: Hidalgo et al. (2007)

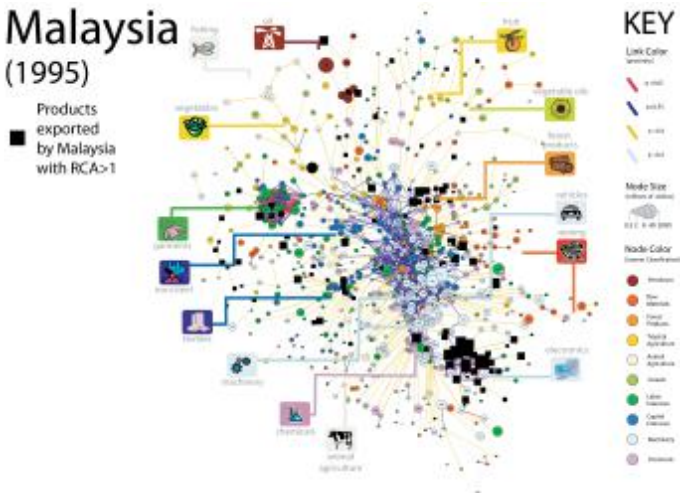
Evolution of industrial export in Malaysia – 1985-2000



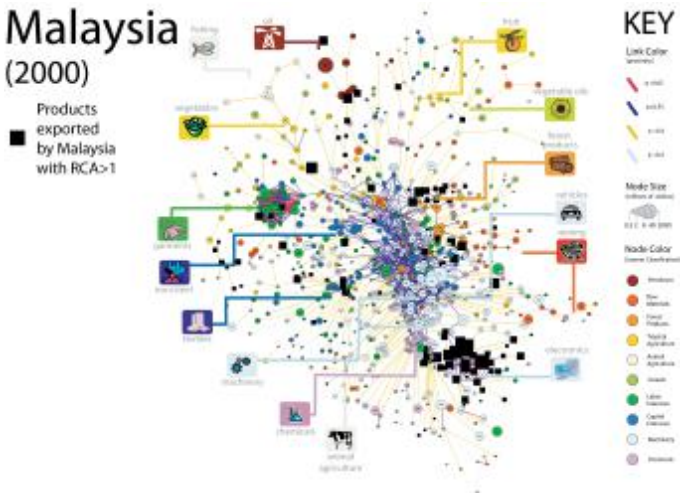
(a) 1985



(b) 1990



(c) 1995



(d) 2000

Structural change leads to transformations of economies and societies: e.g. after the industrial revolution in England

Concentration in large capital intensive firms & firm size growth (Desmet and Parente, 2009);

Increase in the number of goods available for final consumption (Berg, 2002);

Closer involvement of science in technological change (Mokyr, 2002);

Increased use of capital in agriculture and manufacturing and improvement in the technology embedded in machines and overall increases in productivity (Kuznets, 1973);

Urbanisation, income inequality and changes in social class composition (McCloskey, 2009)...

Some changes precede income growth, others unfold as a consequence of income growth

Structural change

Structural change involves many aspects of the economy

> *"[...] complementary changes in various aspects of the economy, such as the sector compositions of output and employment, the organization of industry, the financial system, income and wealth distribution, demography, political institutions, and even the society's value system" (Matsuyama, 2008)*

> *"[...] a change in the structure of the economic system, that is, in its components and in their interactions. Components are [...] particular goods or services, and other activities and institutions, such as technologies, types of knowledge, organizational forms etc. What does it mean for a system to be in equilibrium when its composition keeps changing due to the emergence of qualitatively different entities? " (Saviotti and Gaffard, 2008)*

Modelling structural change

A basic model of innovation, growth and interaction between different aspects of structural change

Modelling structural change

(Agent-based) Model of complementary changes in various aspects of the structure of an economy (Ciarli, 2012; Ciarli et al., 2012; Ciarli and Lorentz, 2011; Ciarli et al., 2010)

S–1 **Organisation of production** [structure of labour, firm size, and earnings disparities]

S–2 **Technology of production** [speed of change in capital innovation, the share of R&D, and its success]

S–3 **Composition of production** [exploration of new sectors, quality of new products, and share of R&D]

D–1 **Income distribution** [profits, and labour compensation]

D–2 **Consumption patterns** [change in consumption shares and changes in consumer preferences]

All aspects are interrelated

Non-traditional assumptions

All decisions are taken out of equilibrium

Agents are **not** fully rational, they adapt their behaviour as response to previous events [time]

- E.g. consumers: limited ability to choose the best product, when facing multiple features

Preferences are non-homothetic

Capital builds through *time*

Firms have a hierarchical structure (partially mapped into tasks): skilled/unskilled dichotomies provide only a partial view of the distribution of wages

Main model assumptions

- Two populations of firms: final and capital sectors
- New markets emerge as an outcome of firms' innovation
- A firm has several layers of employees, each earning a different wage

$\Rightarrow$ Different consumption classes: demand different varieties of goods

- More organisational layers $\Rightarrow$ higher income differences
- Income growth
  - increases labour force level, and modify organisations
  - $\Rightarrow$ increases the level of demand and its heterogeneity

$\Rightarrow$ modifies both the class composition and their consumption shares

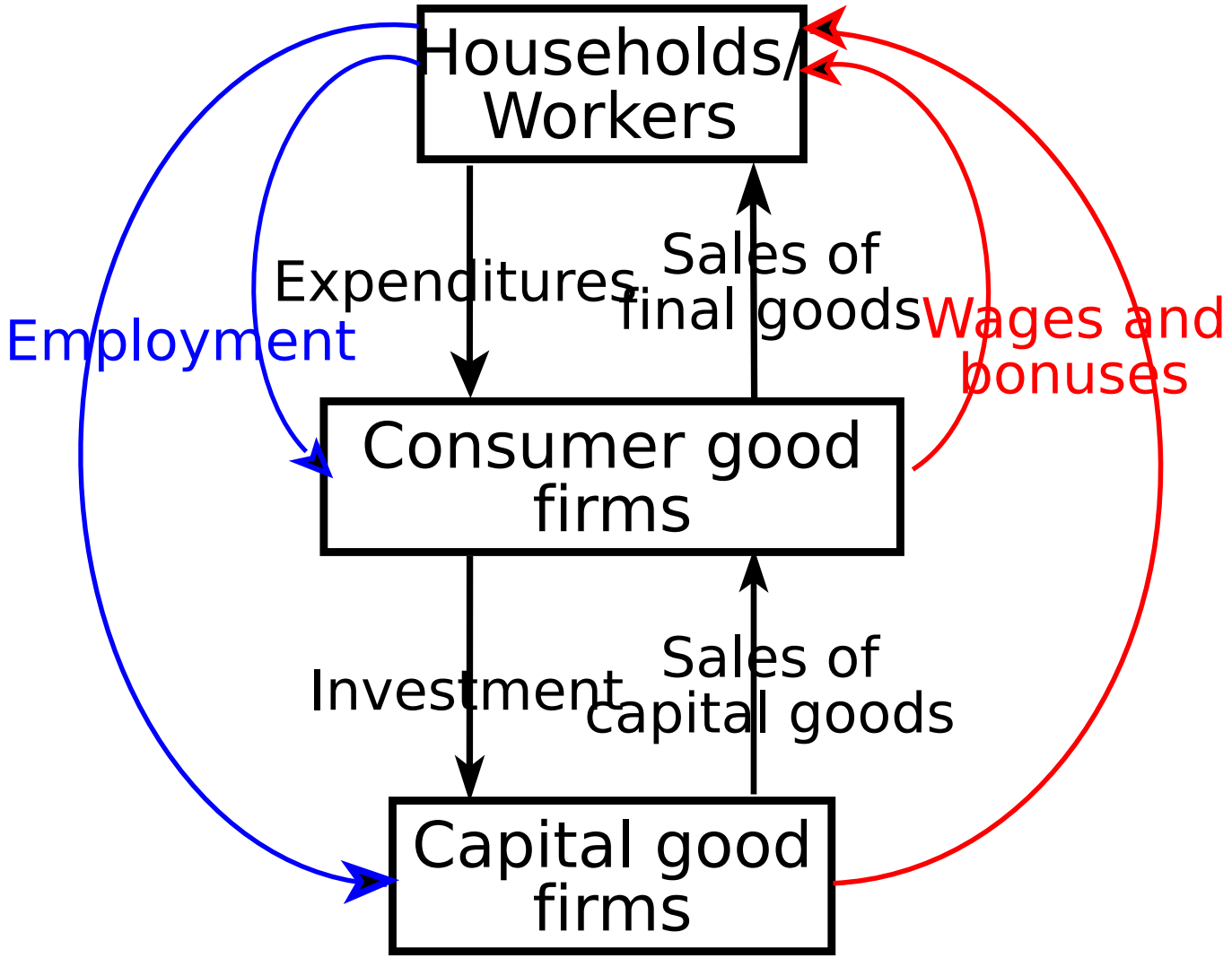
- Composition of demand affects firm's
  - product innovation
  - competitiveness
  - organisation
- Capital investment unconstrained

Basic setup

- **Manufacturing firms**: product technology, process technology, labour organisation, R&D $\Longrightarrow$ product innovation
- **Capital suppliers**: R&D $\Longrightarrow$ capital vintage, labour organisation
- **Consumers**: preferences, consumer classes, expenditure shares
- **Wages setting**: min wage (macro), labour hierarchies, bonuses

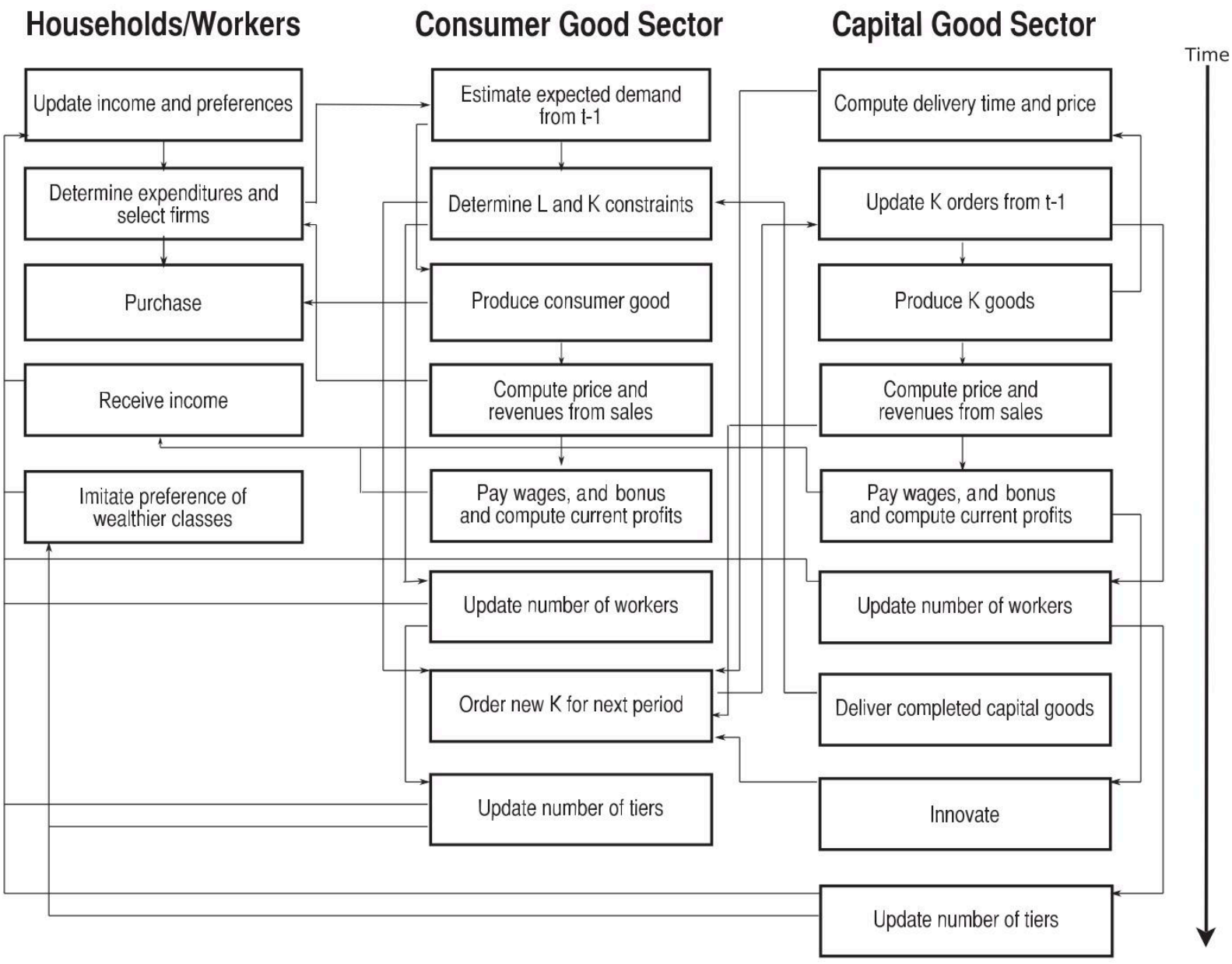
▸ Model details

Overall structure of the model and flow of goods and money



▸ Model details

Schedule of the operations performed during a time step



General results

Comparing different aspects of variety

Comparing the relevance of different sources of structural change

Product variety, demand and economic growth

"Growth and development typically involve the creation of new economic activities." (Burgess and Venables, 2004, p. 3)

- Product variety relative to the US is correlated with relative per capita income (Funke and Ruhwedel, 2001)
- Related export variety (within sectors) predicts short run growth (OECD) (Saviotti and Frenken, 2008)
- Growth is related to moving to the core of sophisticated products and to export complexity (Hidalgo and Hausmann, 2009; Hidalgo et al., 2007; Felipe et al., 2011)
- But also, most economies grow successfully concentrating in a small number of products (sectors) (Hausmann and Rodrik, 2003)

1. What variety?

Qualify (and possibly quantify) the variety-growth thesis in a closed economy

- How relevant is the dynamics of product innovation for growth? Is the relation linear?

Which aspect of product innovation is more relevant?

- firm's capacity to explore consumer needs / sectors
- firm's capacity to improve the quality of goods
- the frequency at which new products are marketed

Which role for demand: changes in consumer tastes, needs and shares?

2. Comparing sources of structural change

Which aspects of structural change are more relevant (for growth)?

Do the different aspects interact? If yes to which extent?

Control for model parametrisation

Initial conditions: benchmark

100 manufacturing firms initially differ only with respect to quality

2 Manufacturing sectors/needs, 10 overall needs

2 Income classes: craftsmen/micro firms/farms

Untested parameters reflects empirical observation Table

Asymptotic consumption share: UK top income centile Figure

Initial consumption share: symmetric Figure

Averages over multiple runs controls for random effects (200 / 20)

Validation

Long term endogenous growth in output with a transition from linear growth to exponential growth (Maddison, 2001; Galor, 2010)

Kuznets curve

S-shaped curve of growth in sectoral output from birth to diffusion

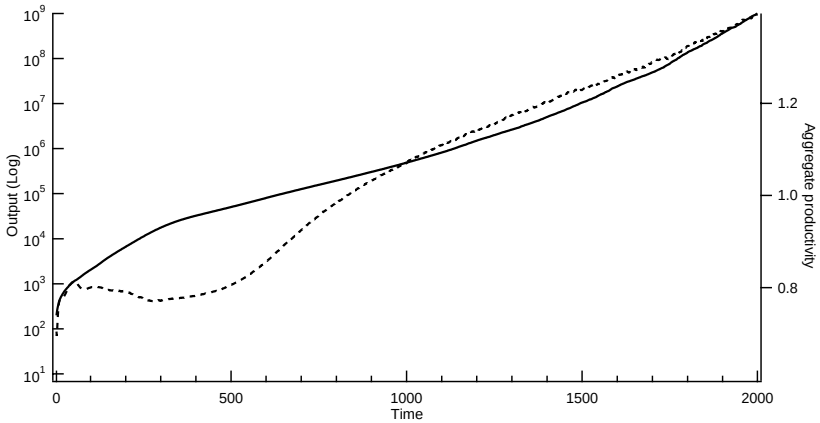
Kaldor-Verdoorn law: output growth and labour productivity growth

Capital deepening

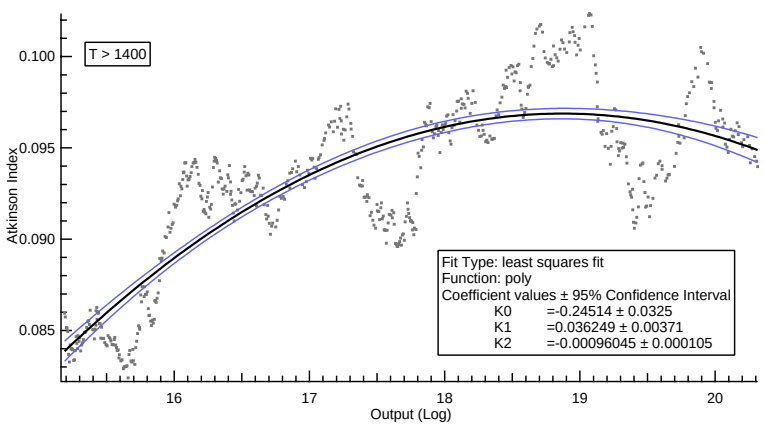
Autocatalytic productivity

Price short run fluctuations

Macro: Output, productivity & Inequality



(e) Output and productivity

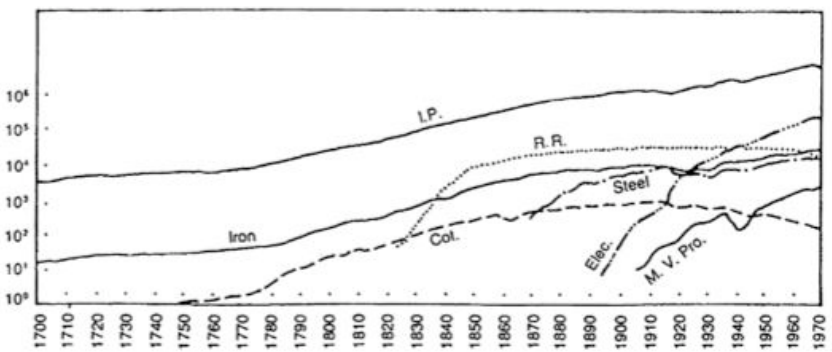


(f) Kuznets curve (1400-2000)

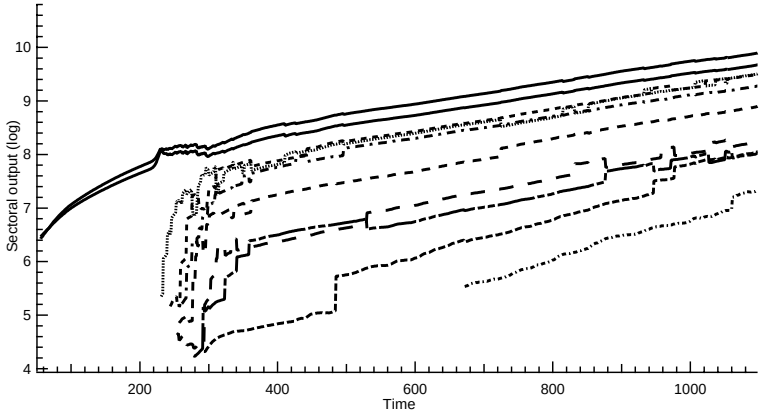
Take off and its effect on inequality

(1) Long term endogenous growth in output with a transition from linear growth to exponential growth (Maddison, 2001; Galor, 2010)
(2) Post take-off: Cumulative causation: ↑ Prod, ↓ Price, ↑ D, ↑ Investment, ↑ Firm size, ↑ Population & Consumer heterogeneity.

Meso: Emergence and diffusion of sectors



(a) Observed



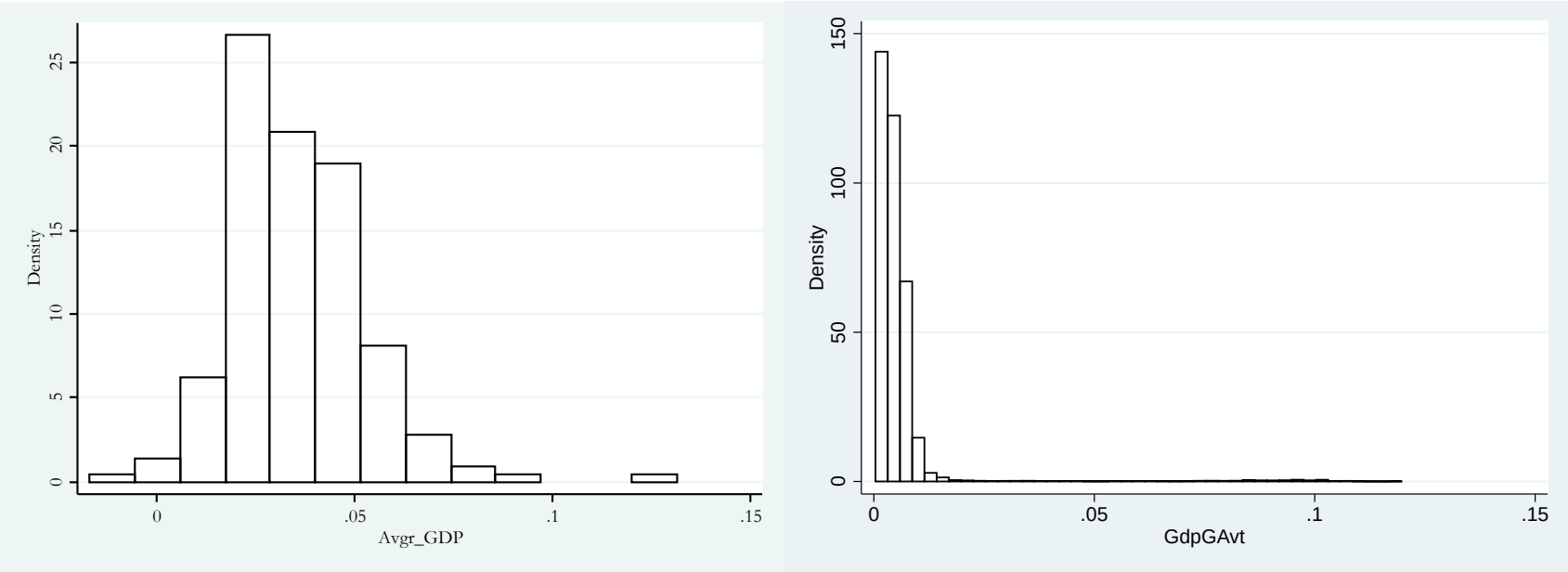
(b) Simulated

S-shaped curve of growth in sectoral output from birth to diffusion

(1) Emergence of new sector is concentrated in a relatively short time span

(2) Convergence across sectors, and some overlapping

Income growth distributions – world Vs simulation



(a) Observed (1980-2010) (b) Simulated (1-2000) – all factors

Source: IMF & simulations

The simulated distribution is definitely more skewed

(1) We look at 2000 periods, including long periods of stagnation

(2) Extreme values of the parameters Density > 36

(3) Overlapping distributions from ≠ data generation processes Figure

Product and demand variety: summary of results (Ciarli and Lorentz, 2011)

Variety as exploration of new markets/needs, and introduction of new goods, has a significant positive effect on growth Figure and Figure

Variety in innovation result (product quality) has a negligible positive effect on Output Figures

Rate of convergence to expenditure shares concentrated on luxury 'needs' has a negative effect on Output Figures

- Demand and Supply distribute across markets ↓ firm concentration Figure and Figure
- ⇒ No time for development (K accumulation) of industry

Experimental design (Ciarli, 2012)

2^k full factorial design: analysis of k factors at two levels (**H**igh and **L**ow), simulating all possible combinations (Montgomery, 2001; Kleijnen et al., 2005)

- identify the factors that are more influential
- study a large number of interactions of different orders between factors
- minimise the number of simulation runs

Analyse the 10 factors defining the **initial structure** and the scale of **structural changes** through time: extreme values

$\Rightarrow y_{ijlt}$ observations

- i factor responses: output and other modal variables (Inequality, Productivity, Concentration, Prices,...)
- j designs: 1024
- l replicates: 20
- t periods: 2000

Factors = parameters

Factors (parameters) measuring structural change (Values)

S–1 **Organisation of production**: change distribution and consumption

- ν ↓ number of workers per managers
- b ↑ wage differential among tiers

S–2 **Technology of production**

- σ^a ↑ change in vintage productivity
- ζ ↑ probability of successful innovation
- ρ^k ↑ K firm R&D

S–3 **Composition of production**

- ι ↑ discovery of new sectors
- ϑ ↑ product quality
- ρ ↑ Final firm R&D

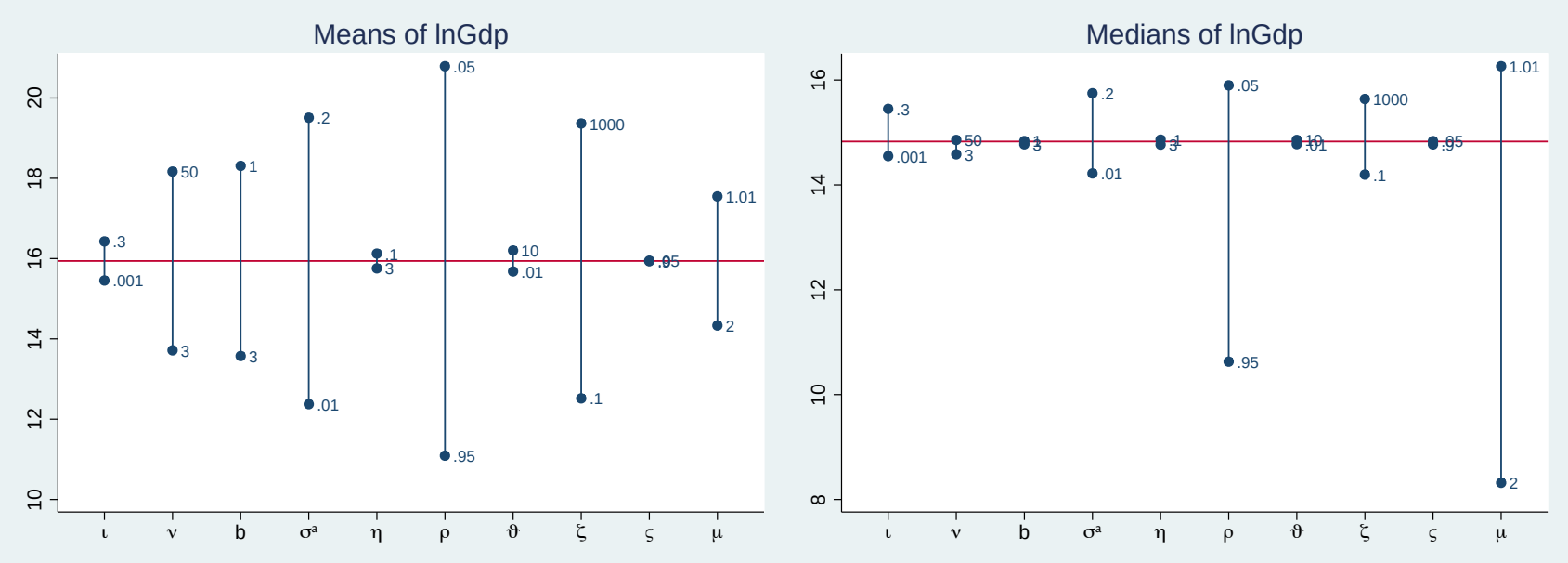
D–1 **Income distribution**

- $\mu = \mu^K$ ↑ Profits

D–2 **Consumption patterns**

- η ↑ change in consumption shares
- ς ↑ preferences differences across classes

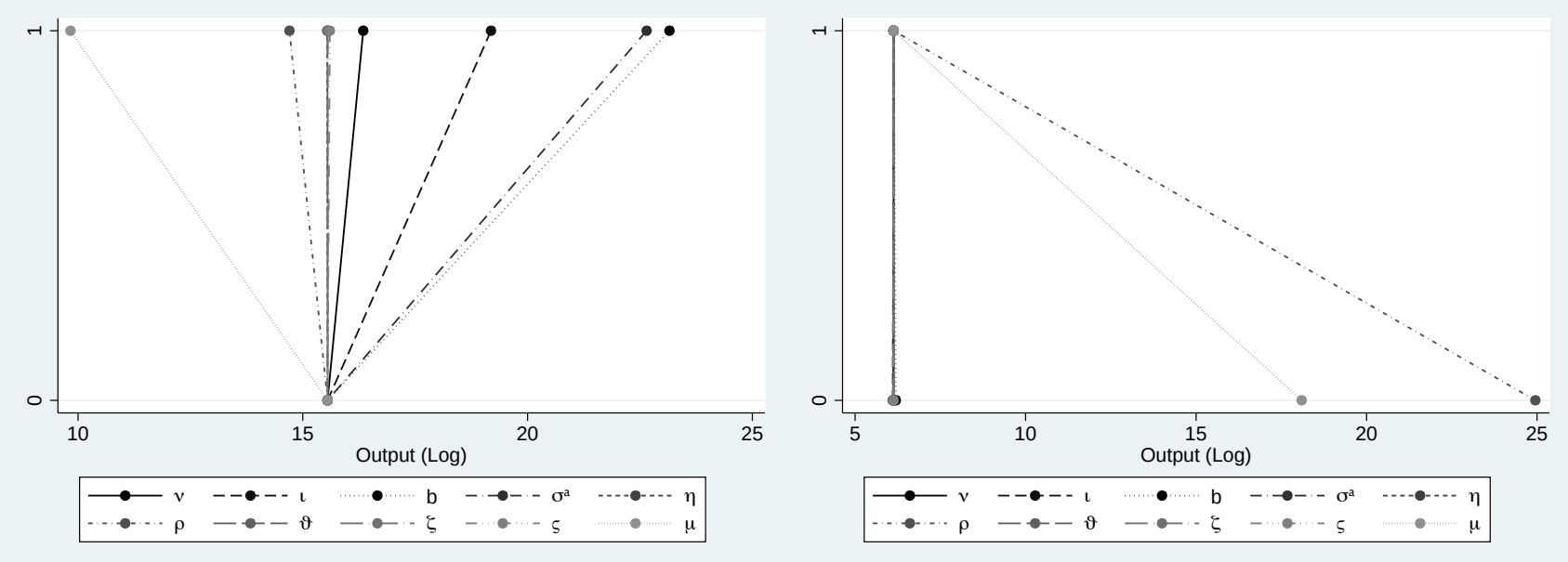
Mean and median differences in output for different factors



(a) Mean (b) Median

Effect of each factor in the last simulation step, for any value of the other parameters

Main effect of factors for High (a) and Low (b) values of all other factors



(a) All factors Low

(b) All factors High

(1) With no structural change: strong effect of most factors
(2) With strong structural change: no effect of most factors

ANOVA: Mostly significant factors

Source	Partial SS	df	MS	F	Prob>F
Model	1.258e+06	9	139790	414.1	0.00
ι	4840	1	4840	14.34	0.00
ν	101546	1	101546	300.8	0.00
b	114912	1	114912	340.4	0.00
σ^a	260782	1	260782	772.6	0.00
η	691	1	691	2.05	0.15
ρ	481609	1	481609	1427	0.00
ϑ	1399	1	1399	4.150	0.04
ζ	240068	1	240068	711.2	0.00
ς	0.821	1	0.821	0	0.96
μ	52954	1	52954	156.9	0.00
Residual	6.909e+06	20469	337.5		
Total	8.168e+06	20479	398.8		

1. Speed of convergence of the expenditure shares and of the change in the preferences (consumption): **not significant**
2. **All others are significant**

How about the interactions between factors?

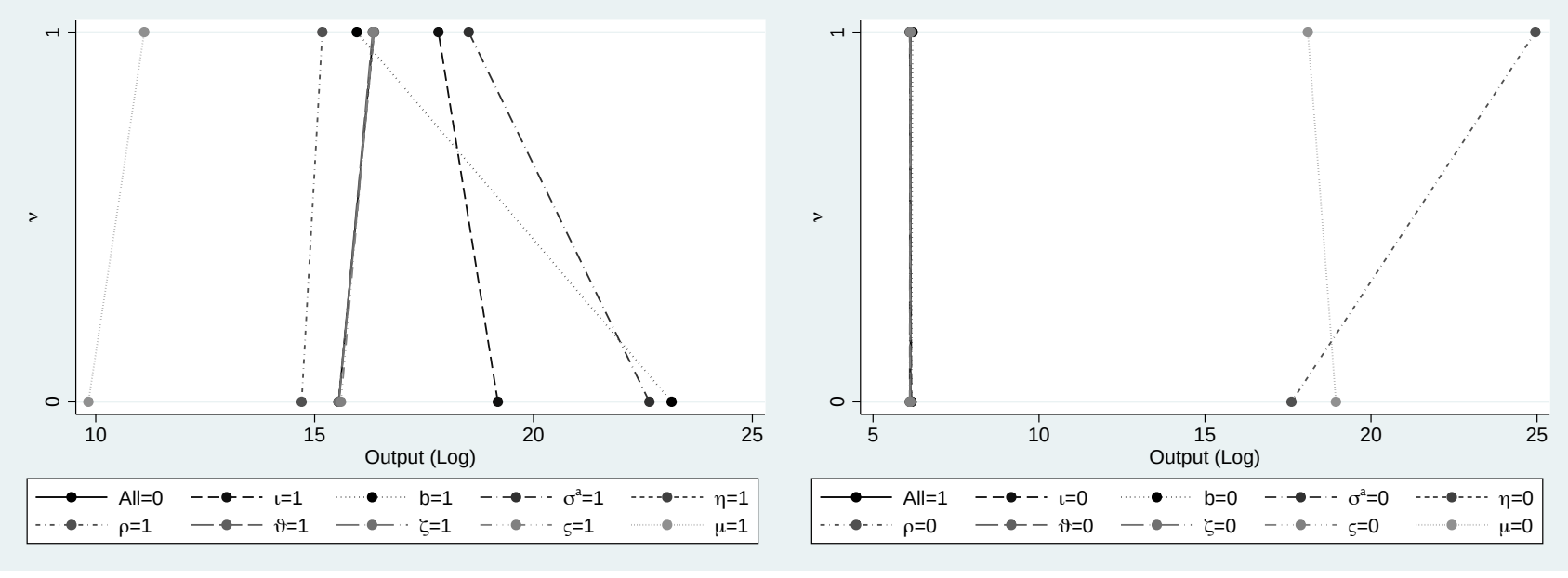
	(1) ι	(2) ν	(3) b	(4) σ^a	(5) η	(6) ρ	(7) ϑ	(8) ζ	(9) ς	(10) μ
ι	0									
ν	**	***								
b	***	***	***							
σ^a	0	***	***	***						
η	**	0	0	0	0					
ρ	***	***	***	***	0	***				
ϑ	0	0	0	0	0	**	0			
ζ	**	***	***	***	0	***	0	***		
ς	0	***	*	0	0	0	*	0	0	
μ	**	***	***	***	0	***	0	***	**	***

Note: Values on the diagonal refer to the factor main effect.

The effect of most factors is non-monotonous across designs

⇒ Not enough to analyse the role of specific structural conditions

Cross effects of parameters on output ν



(a) All factors Low

(b) All factors High

Sectors wages and productive change the sign of the effect of an increase in ν

First order interactions: examples

Complexity of the organisational structure (ν):

- ι, b, and σ^a change the sign of its effect
  - when **L**ow, $\uparrow \nu \Rightarrow \uparrow Y$; when **H**igh, $\uparrow \nu \Rightarrow \downarrow Y$

$\Rightarrow$ Complex organisations $\uparrow Y$ when

- New sectors emerge quickly
- Organisational costs are compensated by productivity growth
- Wages differ between organisational layers

Higher opportunities for R&D in the capital sector (σ^a)

- Positive impact on output, **depending on**
  - the organisation (ν, b)
  - the share of profits invested in R&D and its effectiveness (ρ, ζ)
- **Independent from**
  - the introduction of product variety in the consumer market (ι, ϑ)
  - the structure of demand for more variety (η, ς)

Relative impact of factors and main variables on output

Variables	(1) Factors	(2) Contr Var	(3) F & CV
ι	0.692***		1.063***
ν	0.009***		-0.012***
b	0.107***		-0.061***
σ^{α}	3.242***		0.966***
η	-0.023***		-0.016***
ρ	-4.900***		-3.947***
ϑ	0.013***		0.003**
ζ	0.001***		0.000***
ς	0.040**		0.021*
μ	-9.330***		-9.510***
A		1.201***	2.900***
AT		-3.809***	3.523***
σp		0.119*	-0.092***
σq		0.001	0.000***
R		0.779***	
Observations	20,480	20,480	20,480
Pseudo R^2	0.43	0.09	0.48

*** p<0.01, ** p<0.05, * p<0.1

Relative impact of factors and main variables on output

Labour productivity (A) and R&D expenditure (R) positively related

Product variety is significant only when not controlling for A (it's determinant): growth through selection

Inequality ($\mathcal{A}T$) has an overall negative relation

However, the effect of all model variables depends on the factors of structural change Figure

Impact of factors and main variables on output

ρ and μ determine structural changes with the strongest (negative) effect on output

σ^{α}, ι and b large positive

However, controlling for main model variables

- Inequality index negative
- R&D expenditure positive
- ν negative: reduces the pace at which firms grow in size and diversify: slower increase in the aggregate demand and its variety
- b negative: increased inequality

Relative impact of factors and first order interactions

	(1) ι	(2) ν	(3) b	(4) σ^{α}	(5) η	(6) ρ	(7) ϑ	(8) ζ	(9) ς	(10) μ
ι	1.51	0.16	-0.09	-0.31	-0.01	-0.55	0.03	-0.18	0.04	-0.97
ν	1.38 0.28	0.33	-0.95	0.69	0.23	-0.56	-0.08	0.62	0.12	0.20
b	-0.10	-0.81 -0.16	1.14	-0.24	-0.15	0.11	-0.05	-0.34	-0.28	0.10
σ^{α}	-0.37	0.68	0.10 -0.34	1.51	0.00	-1.58	0.09	2.26	-0.12	-0.73
η	0.04	0.28	-0.21	1.39 -0.03	-0.18	0.00	-0.02	-0.04	0.08	0.10
ρ	-0.52	-0.35	0.31	-1.00	-0.26 0.00	-0.56	-0.57	-1.42	0.01	-2.51
ϑ	-0.05	0.01	-0.08	0.18	0.00	-0.98 -0.61	0.55	0.10	0.20	-0.17
ζ	-0.14	0.42	-0.34	1.18	0.03	-0.88	0.58 0.08	1.24	-0.14	-0.39
ς	0.05	0.23	-0.20	-0.03	0.11	-0.06	0.20	1.05 -0.12	0.17	-0.37
μ	-0.98	-0.24	0.37	-1.27	0.12	-1.61	-0.56	-0.96	0.10 -0.31	-6.06 -6.22

Note: Values on the diagonal refer to the factor main effect. Standard errors computed with 400 bootstraps. Reference case is the low value of factors.

p<0.01 p<0.05 p<0.1

Question and contribution

Why regions with similar levels of output grow so differently?

The initial differences that determine growth divergence are those that define the structure of an economy and the way in which this evolves through time

Different aspects of structural change: organisation, product, production, consumption, distribution

The relevance of interacting different structural change aspects

Full factorial DOE: scenarios. Probability of outcomes depends on assumptions.

$\Rightarrow$ 2^{10} economies starting from the same initial conditions except for one of the aspects of structural change: negligible structural changes VS large structural changes in all economic aspects

Summary of results

Most aspects of structural change are significant determinants of output, but magnitude varies substantially

- 1. Income distribution, 2. rate of change in production technology, 3. Emergence of new sectors, 4. Organisation of production, 5. Consumption patterns (barely significant)

Most relevant factors are determinant even with negligible structural changes in all other economic aspects

But economies experiencing large structural changes in most aspects, are not affected if one is negligible.

Most aspects strongly interact: implications

- Account for a large number of economic aspects to understand long term patterns of divergence
- Study micro interactions: some aspects may be relevant for some economies

Growth regimes

Fordist vs post-Fordist growth regimes: relation between income distribution and growth mediated by structural changes

Post 1980s regularities

Increasing income inequality (Atkinson, 2015; Atkinson and Morelli, 2014; Piketty, 2014)

- Increased share of wealth concentrated in the top 10% and 1% (Alvaredo et al., 2013; Atkinson and Morelli, 2014)

Decreasing labour compensation and contribution

- Decline of labour shares (over GDP) since the 1970's (Karabarbounis and Neiman, 2013; Summers, 2013)
- Wage growth and productivity growth diverge (Lazonick, 2014)
- Robotisation: innovation increasingly labour saving (Brynjolfsson and McAfee, 2014; Karabarbounis and Neiman, 2013)
- Hollowing of the middle class (Acemoglu and Autor, 2011)
- Superstar firms (Autor et al., 2017)

Post 1980s regularities

Wage differences contribute substantially to raising inequality

- Increased compensations of top classes of workers: wages, bonuses, profit shares (Atkinson et al., 2011) and stock options (Frydman and Jenter, 2010)
- Increased firm size (Poschke, 2015; Mueller et al., 2015) and market concentration (The Economist, 2016)
    - wage dispersion (Mueller et al., 2015) and CEO pay rise (Frydman and Jenter, 2010)

Rate of return on capital higher than growth rate (Piketty, 2014)

- Increased financialisation of economies and firms (Lazonick, 2014; Lazonick and Mazzucato, 2013; Stockhammer, 2012)

Inequality and demand

Changes in the labour market are related to the composition of **consumption and consumer** (preferences) (Manning, 2004; Autor and Dorn, 2013; Mazzolari and Ragusa, 2013)

Engel law: consumption baskets and preference change with income

- Middle income classes change consumption shares faster than lower income classes (Lavaughn, 2014)

Saving rates increase first linearly and then exponentially with income (Dynan et al., 2004)

Research question

Relation between **income growth and distribution**, mediated by **structural change**, for distinct ▸ growth regimes (Boyer, 1988; Petit, 1999; Coriat and Dosi, 2000)

- **Labour relations**: compensation, profit shares, and the elasticity of wages with respect to productivity and inflation
- Norms of **competition**: entry barriers and market selection
- Income related norms of **consumption**: consumption shares and consumer preferences

RQ1: How do **exogenous institutional features** affect output growth, income distribution, and their relation?

RQ2: How do **endogenous structural features** affect output growth income distribution, and their relation ?

Fordist (1) vs. Post-Fordist Regime (2)

Regime component	**Regime 1**	**Regime 2**
Labour relations		
Wage differences	Lower	Higher
Profit shares	Lower	Higher
Minimum wage elasticity to price and productivity	Higher	Lower
Norms of competition		
Entry barriers	Lower	Higher
Consumer selection	Lower	Higher
Norms of consumption		
Changes in consumption shares	Slower	Faster
Changes in consumer preferences across classes	Slower	Faster

Main findings

Post Fordist regime (2) exhibits significantly **higher inequality**, **lower output growth**, **higher unemployment**, and **lower productivity**

Institutional determinants

- Wage differences and distribution of bonuses to top managers, sharpened by capital income.
- Concentration of production magnifies the effect: competition
- Minimum wage not relevant

Structural determinants

- Firm organisation
- Structure of demand: demand distribution across sectors influences competition and market concentration.
  - Particularly relevant least wealthy classes

Institutional and structural determinants are tightly linked

Main differences in the model

Endogenous mark-up

Financial market

- Constrained investment in capital goods
- Savings

Savings increase with income, non linearly

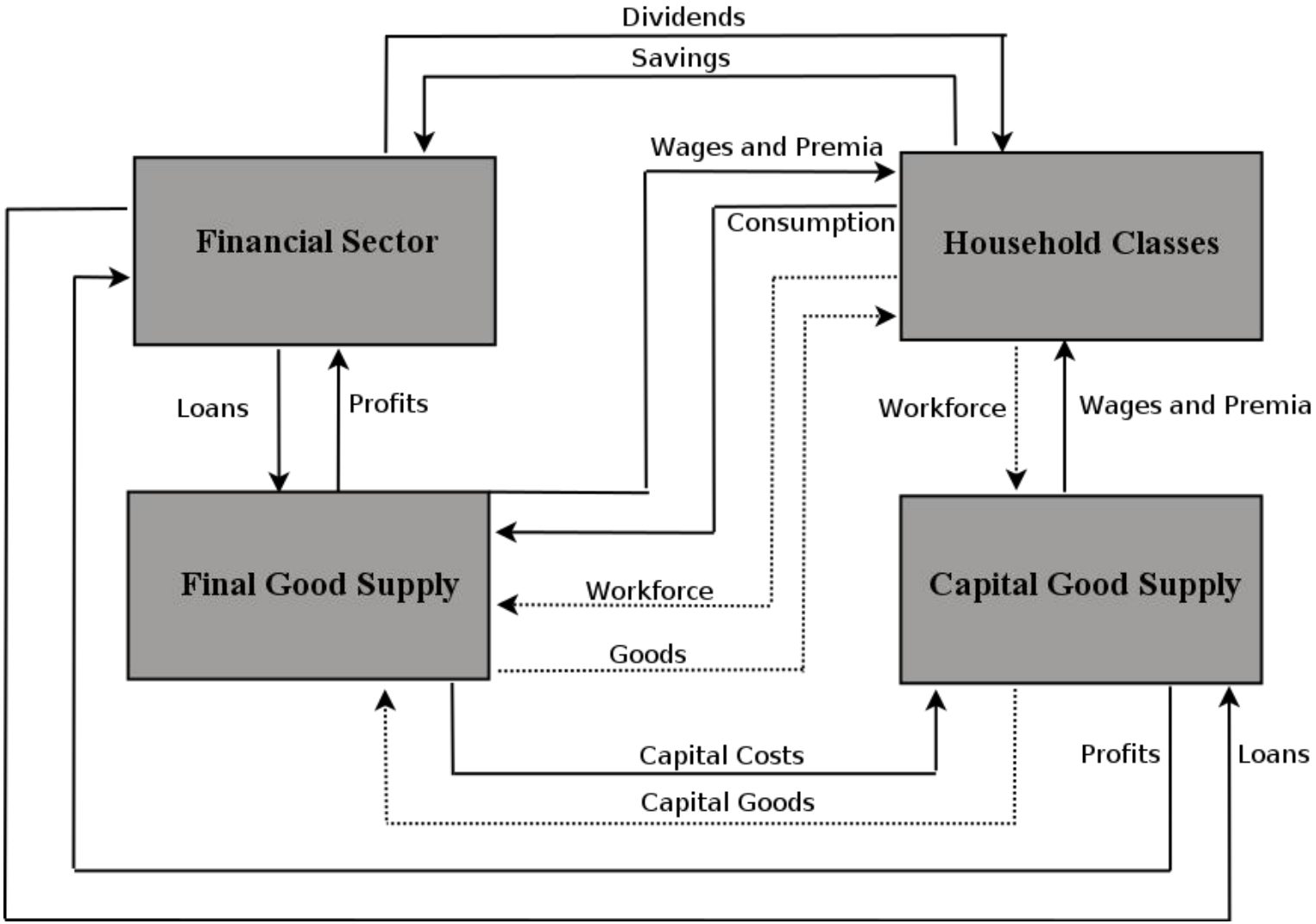
Firm entry and exit related to indebtedness

Product innovation within the sector

Study post-take-off

Flow diagram of the model

The model



Notes. Dashed lines represent goods or services exchanged between the agents and solid lines represent money flows.

Wage labour nexus I (▸ Model details)

Firms in all sectors hire different tiers of workers and 'executives'

Wages

- The wage of a class i is the sum of the wages paid by all firms to the employees in the corresponding organisational tier
- Firm hierarchical tier = consumer class: firm growth $\Rightarrow$ new, wealthier, class
- Wage in tier i is a multiple b of wage in $i-1$

Profit shares

- A share π of profits redistributed by firms to the managers

Dividends

- Workers also receive dividends proportional to savings ($\propto$ wages)
- Saving rate increase with income: $\uparrow$ dividends

Wage labour nexus II (▸ Model details)

Minimum wage

- Beveridge curve and Wage curve: ↓ unemployment
- Renegotiated following productivity and inflation: elasticity ϵ_A and ϵ_P

Parameter		Regime 1	Regime 2
Wage difference between tiers:	b	low	high
Profit shares distributed to executives:	π	low	high
Elasticity of the minimum wage to productivity:	ϵ^A	high	low
Elasticity of the minimum wage to prices:	ϵ^P	high	low

Norms of competition (▸ Model details)

Entry barriers

- Firms enter in each final good sector with a probability ϑ

Selection

- Mark-up ↑ when demand exceeds a firm's production capacity and ↓ when inventories exceed a desired ratio
- Firms innovate to improve the good's quality ($q_{n,f}(t)$)
- Consumers select goods with q above and p below $\lambda_{q,i}$ and $\lambda_{p,i}$

Parameter		**Regime 1**	**Regime 2**
Probability of entry:	ϑ	higher	lower
Consumer's selectivity with respect to price:	$\lambda_{p,1}$	lower	higher
Consumer's selectivity with respect to quality:	$\lambda_{q,1}$	lower	higher

Norms of consumption (▸ Model details)

Consumption shares

- Disposable income is spent on goods from all N sectors or saved
- Consumers from a class i allocate a share $c_{n,i}$ of expenditures to each final good sector
- Shares change with income classes from basic to luxury (η)

Preferences

- Consumers select goods with q above and p below a threshold
- Selection threshold on $q \uparrow$ and on $p \downarrow$ with income class (η_λ)

Parameter		**Regime 1**	**Regime 2**
Changes in consumer preferences:	η_λ	lower	higher
Changes in expenditure shares:	η	lower	higher

Initial conditions

100 final good firms initially differ only with respect to good's quality

10 K good firms

10 final good sectors/needs

Income classes: endogenous

Untested parameters reflects empirical observation Table

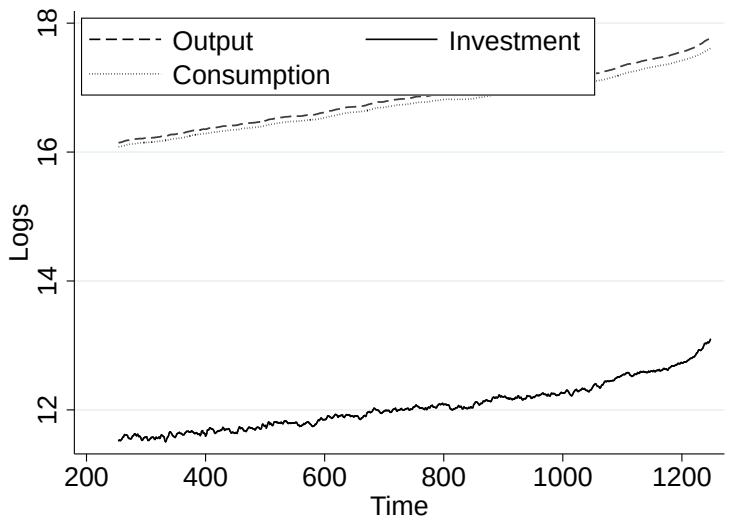
Asymptotic consumption share: UK top income centile
First class consumption share: bottom 10% figure

Averages over multiple runs controls for random effects

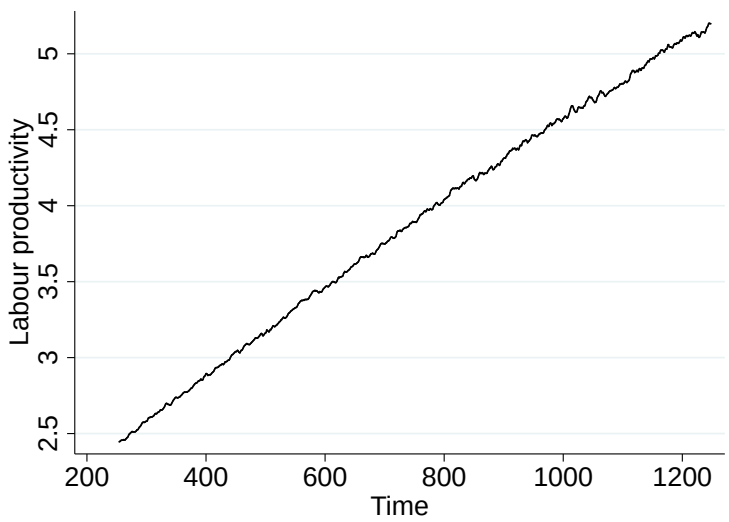
Main results outline

1. Model Properties
2. Growth regimes
3. Institutional determinants of economic growth and distribution
4. Structural determinants of economic growth and distribution

Main macro series and productivity



(a): Output, investment and consumption



(b): Aggregate labour productivity

The model accounts for many observable properties (appendix)

Empirical regularity	Figure/Table
Macro	
Endeogenous growth	
Business cycles	
Auto-correlations of key variables	
Cross-correlation of key variables	
Beveridge curve	
Wage curve	
Output growth distribution (fat tailed)	
Meso	
Firm size distribution (log normal)	
Firm growth distribution (skewed and fat tailed)	
Growth of average firm size	
Micro	
Productivity differences	
Capital stock investment (lumpiness)	

Parametrisation of the two Growth Regimes

Dimension	Parameter		Benchmark	Regime 1	Regime 2
Wage labour nexus	Wage difference between tiers:	b	1.6	1.4	1.8
	Profit shares distributed to executives:	π	0.15	0.1	0.35
	Elasticity of the minimum wage to productivity:	ϵ^A	1	1	0.8
	Elasticity of the minimum wage to inflation:	ϵ^P	1	1	0.8
Competition	Probability of entry:	ϑ	0.08	0.1	0.06
	Consumer's selectivity with respect to price:	$\lambda^a_{p,1}$	$0.\overline{9}$	$0.77\overline{5}$	$0.97\overline{5}$
	Consumer's selectivity with respect to quality:	$\lambda^b_{q,1}$	$0.\overline{1}$	$0.22\overline{5}$	$0.02\overline{5}$
Consumption	Changes in consumer preferences:	η_λ	0.25	0.2	0.3
	Changes in expenditure shares:	η	0.4	0.3	0.5

Main Macroeconomic Indicators for the Two Growth Regimes

	Regime 1 (Fordist)	Regime 2 (Post-Fordist)
Output (real)	4382302	2848252
Atkinson Index ($\mathcal{A}_{ind}$)	0.140	0.258
Unemployment Rate	4.624	4.804
Average Income Level	404.233	502.803
Average Profit Level	913257.72	1004774.08
Minimum Wage Level	222.850	206.559
Wage-Income Ratio ($\mathcal{W}$)	0.738	0.698
Premia-Income Ratio	0.025	0.021
Dividends-Income Ratio ($\mathcal{E}$)	0.236	0.281
Aggregate Productivity	2.032	1.993
Embodied Productivity	3.549	3.479
Capital-Labour Ratio	5.792	5.818
Value-Added Concentration	7.804	7.901
Employment Concentration	15.987	16.104
Inverse Herfindahl Index ($\mathcal{H}_Y$)	103.85	72.07
Consumption Concentration	6.952	7.088

Atkinson index vs. real output LAD estimates

		Real GDP	Const.
Regime 1:	Atkinson Index	6.707e-09**	0.166***
		(2.431e-09)	(0.003)
Regime 2:	Atkinson Index	2.140e-08**	0.196***
		(8.255e-099)	(0.023)

*** p<0.01, ** p<0.05, * p<0.1

Institutional determinants

Mainly defined by the regime

Higher inequality in regime two is a direct consequence of the difference in the wage multiplier between tiers of workers (b) [wage-income ratio]

Minimum wage [vs. average income]

Dividends (the functional distribution of income) [dividends-income ratio; profits; saving rates]

Market concentration [linked to structure]

- Probability of firm entry and consumer selectivity
- Most concentrated sectors are those producing luxury goods

Institutional determinants (▸ Tables)

Dimension	Parameter		Regime 1	Regime 2
Wage labour nexus	Wage difference between tiers:	b	A-; Y+	A+; Y-
	Profit shares distributed to executives:	π	A-; Y+	A+; Y-
	Elasticity of the minimum wage to productivity:	ϵ^A	Υ+	Υ-
	Elasticity of the minimum wage to inflation:	ϵ^P	Υ+	Υ-
Competition	Probability of entry:	ϑ	A-; Y+	A+; Y-
	Consumer's selectivity with respect to price:	$\lambda_{p,1}$	A+; –	A-; –
	Consumer's selectivity with respect to quality:	$\lambda_{q,1}$	A+; –	A-; –
Consumption	Changes in consumer preferences:	η_λ	–	–
	Changes in expenditure shares:	η	–	–

Structural determinants

Supply side concentration: the sheer emergence of large firms explain part of the raising inequality

Concentration varies by sector: the higher the demand from low income classes, the lower the concentration

Competition: sectors representing high shares of the less wealthy consumers expenditures experience a significantly higher demand, from consumers that are very selective with respect to price: lower profits

Productivity gains in post-Fordist regime do not translate in demand

Conclusions

Most OECD countries have experienced a sharp increase in income inequality, mainly due to the raise in top incomes

Accompanied by growth slow down and stagnation

Accompanied by changes in consumption, decreasing labor shares, de-linked dynamics of productivity and wages, increased mechanisation, increased rents, increased bonuses, and concentration of production in fewer larger firms

We study these differences as the result of growth regimes: institutional and structural differences

Conclusions

Post Fordist regime (2) exhibits significantly **higher inequality**, **lower output growth**, **higher unemployment**, and **lower productivity**

Institutional determinants

- Wage differences, accompanied by capital income, and the distribution of bonuses to top managers.
- Concentration of production magnifies the effect: competition
- Minimum wage not relevant

Structural determinants

- Firm organisation
- Structure of demand: demand distribution across sectors influences competition and market concentration.
  - Particularly relevant least wealthy classes

Institutional and structural determinants are tightly linked

Policy implications

Breaking the vicious cycle between the institutional and the structural determinants that in post-Fordist regime induces a more unequal distribution of income, lower output, and higher unemployment.

Institutional determinants ease the burden of structural determinants of inequality (e.g. firm organisation)

- Wage difference caps
- Income distribution
- Barriers to entry
- Effect of redistributive policies on the demand composition

Consumption

Effect of the dynamics of consumption preferences on the dynamics of macro–economic growth

The relevance of consumption

Part of the current crises is demand driven

Demand is crucial in the relation between income distribution and growth (Föllmi and Zweimüller, 2008)

The emergence of new outputs (and demand for them) is crucial in fuelling economic growth (Aoki and Yoshikawa, 2002; Saviotti and Pyka, 2008b)

Changes in consumption needs explains escaping Engel curves (Witt, 2001)

Focussing on changes in consumption preferences as structural change

Analyse the effect of specific aspects of consumption micro-behaviour on the macro-dynamics of growth and labour productivity (Lorentz et al., 2016)

Consumption preferences (selectivity)

Model with no product innovation

Consumer behaviour

For each need, given the **perceived** characteristics of a good $i^*_{f_n,m} = N\left(i_{f_n,m}, \sigma^i i_{f_n,m}\right)$ (quality and price), a consumer selects all the firm**s** that offer a good with **equivalent** values and shares the demand

$$i^*_{f_n,m} \equiv i^*_{B_n,m} \Leftrightarrow |i^*_{f_n,m} - i^*_{B,m}| < (1 - \upsilon_{z,m}) \cdot i^*_{B,m}$$

$\upsilon_{z,m}$: selectivity

The selectivity with respect to *less–then–optimal* quality on each characteristic defines consumer class preferences: the percentage of difference from the value considered as the best in the market in a given period

Workers at the shop-floor level are not at all selective with respect to quality, but very selective with respect to price.

Opposite for the richest classes (emerging with firm growth): symmetric preferences.

Changes in consumer behaviour across classes

υ^{max}: selectivity of the shop-floor workers with respect to price and of top asymptotic managerial class with respect to quality.

υ^{min}: selectivity of the shop-floor workers with respect to quality and of top asymptotic managerial class with respect to price.

$$\upsilon_{p,z+1} = (1 - \delta_\varsigma)\upsilon_{z,p} + \delta_\varsigma \upsilon^{min}$$
$$\upsilon_{q,z+1} = (1 - \delta_\varsigma)\upsilon_{z,q} + \delta_\varsigma \upsilon^{max}$$

$\upsilon_{z,m}$: selectivity with respect of the characteristic $m = p, q$, price (p) and quality (q), z is the index for the class $\Rightarrow \upsilon_{z=1,p} = \upsilon^{max}$, and $\upsilon_{z=1,q} = \upsilon^{min}$.

When υ^{max} and υ^{min} are close, the classes differ marginally with respect to consumption patterns.

High selectivity has a large and significant impact on output

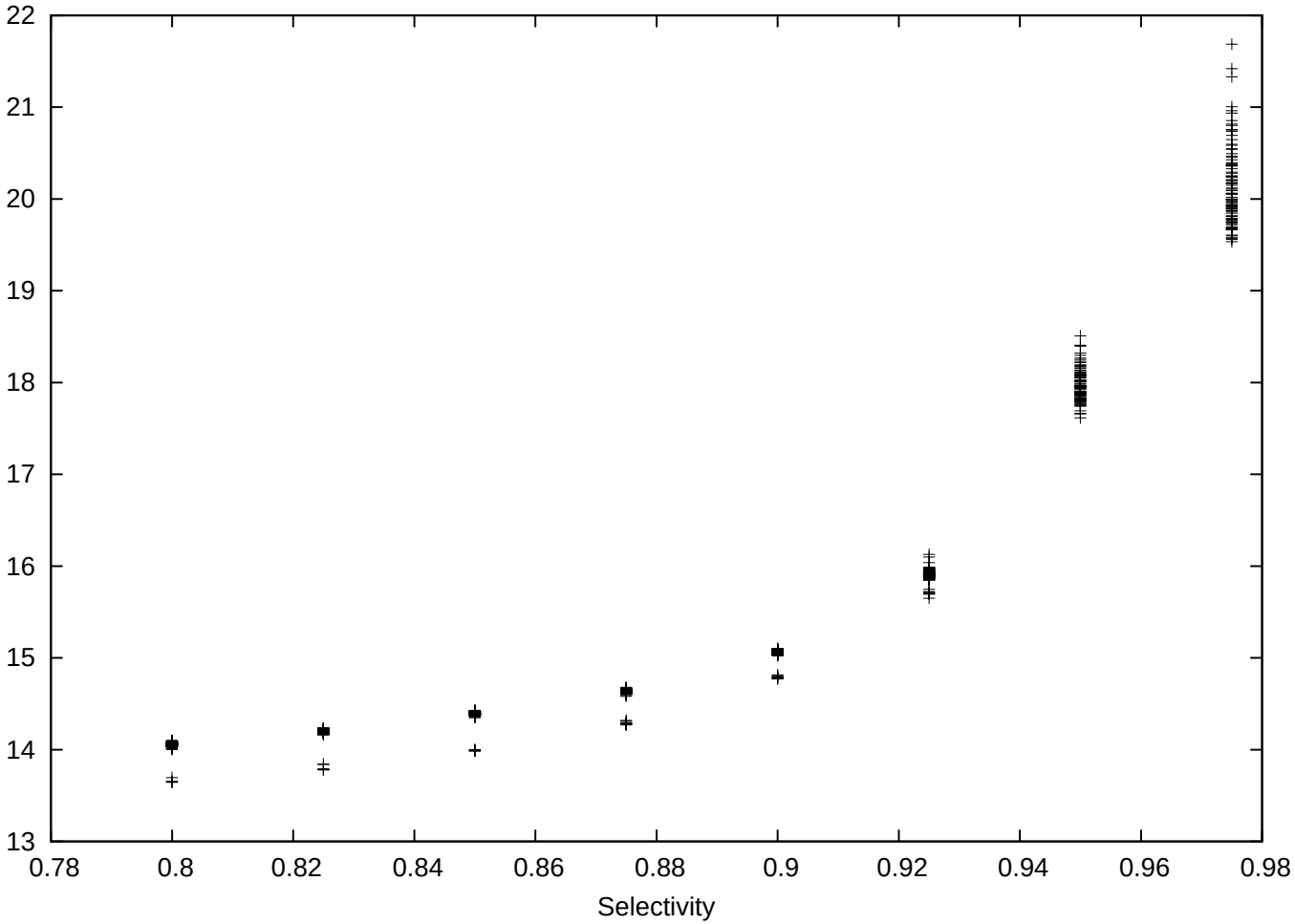


Figure: ***Log output vs*** v^{max}. *Data from 100 independent runs for each value of* v^{max} *at* $t = 2000$

High selectivity has a large and significant impact on output

For higher levels of selectivity, the volatility of structural change shocks is amplified (Figure): with low selectivity economies experience smooth transition phases and lower growth

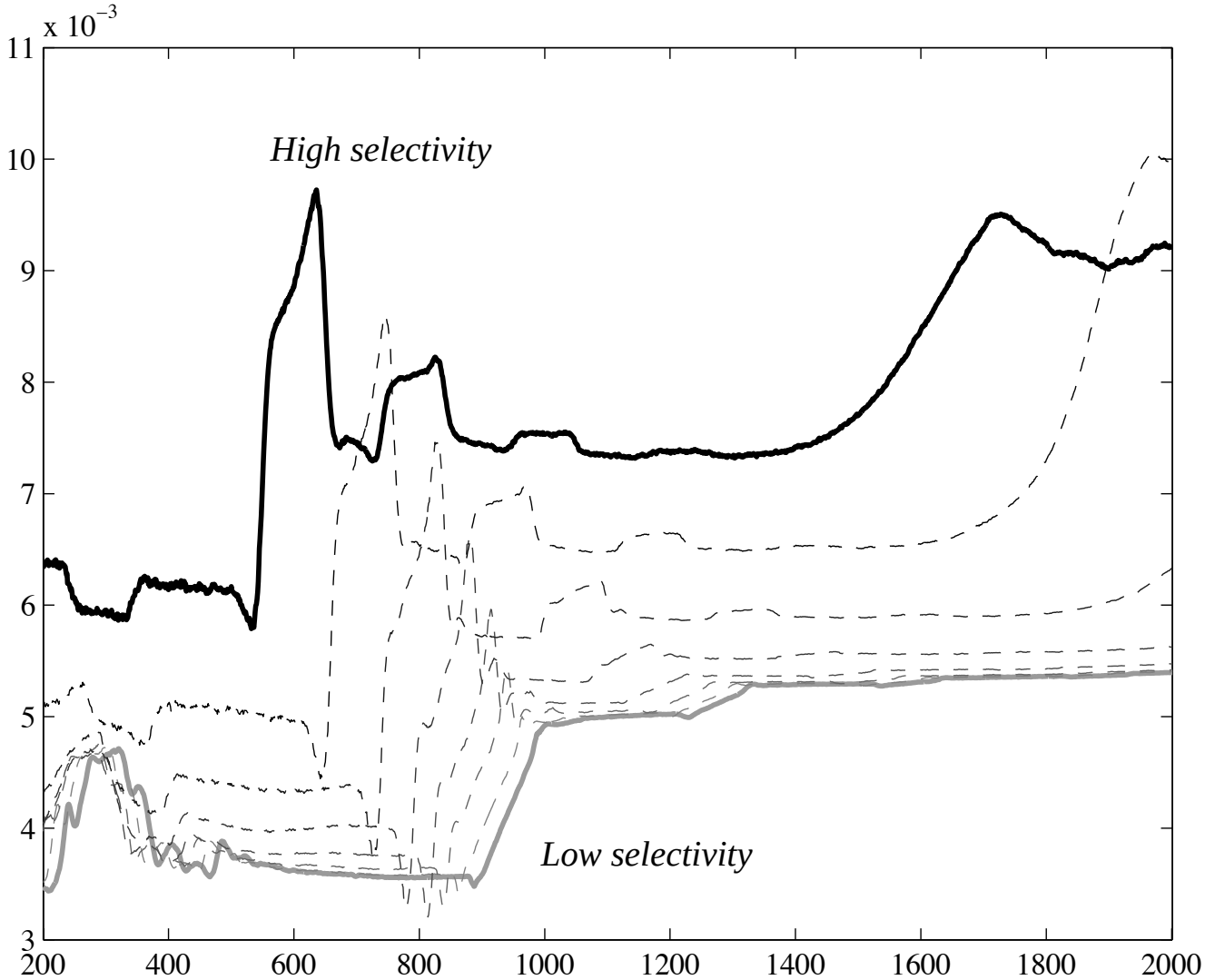
During the Malthusian phase, higher selectivity and output growth economies experience lower aggregate productivity (Figure)

- Growth through factor accumulation: ↑ concentration (Figure) ⇒ ↑ larger firms ⇒ ↑ costs

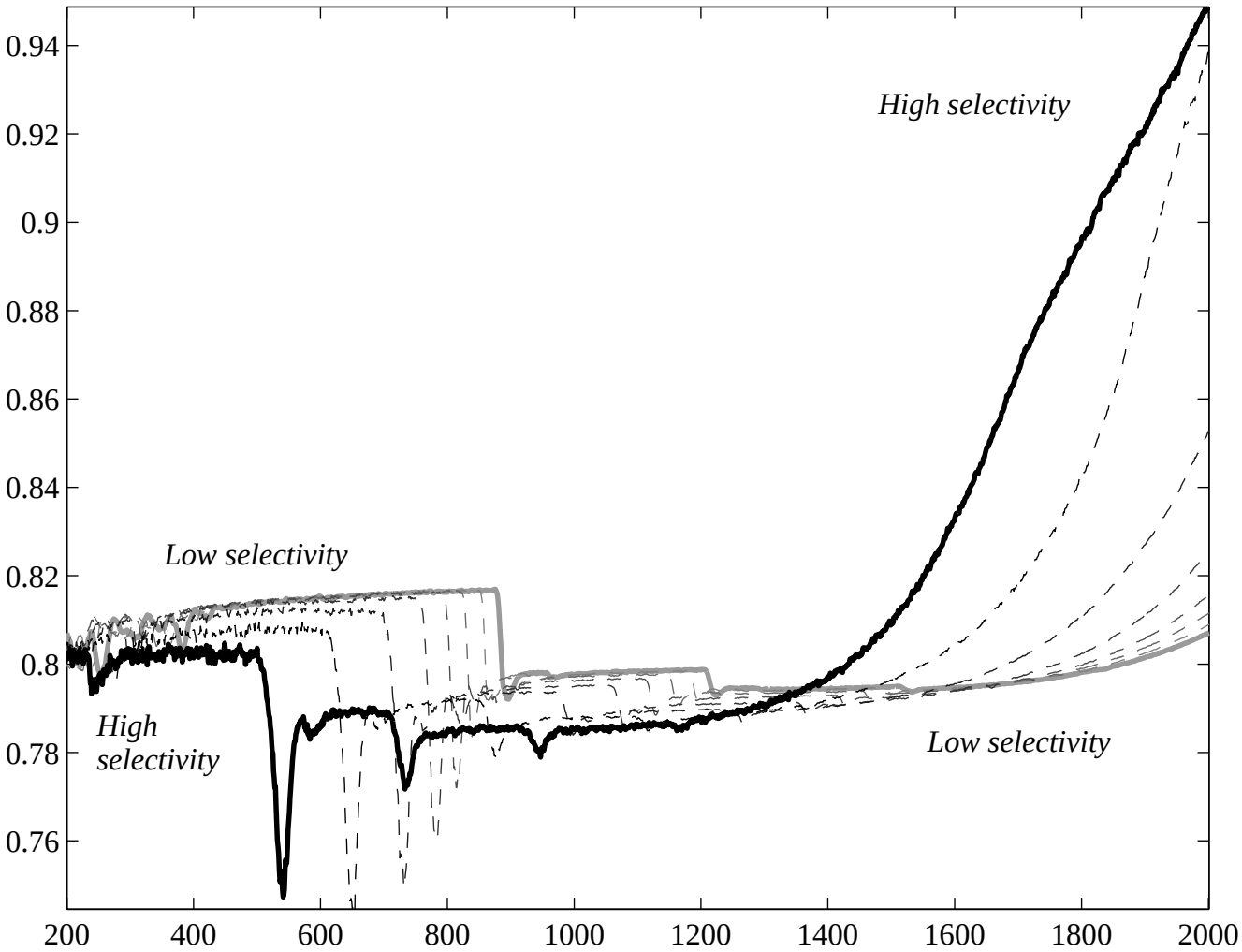
After take off higher selectivity induces higher growth as demand is accompanied by productivity enhancing innovations

- Higher market concentration implies higher investment in capital vintages

Time series of the output growth rate for different values of v^{max}

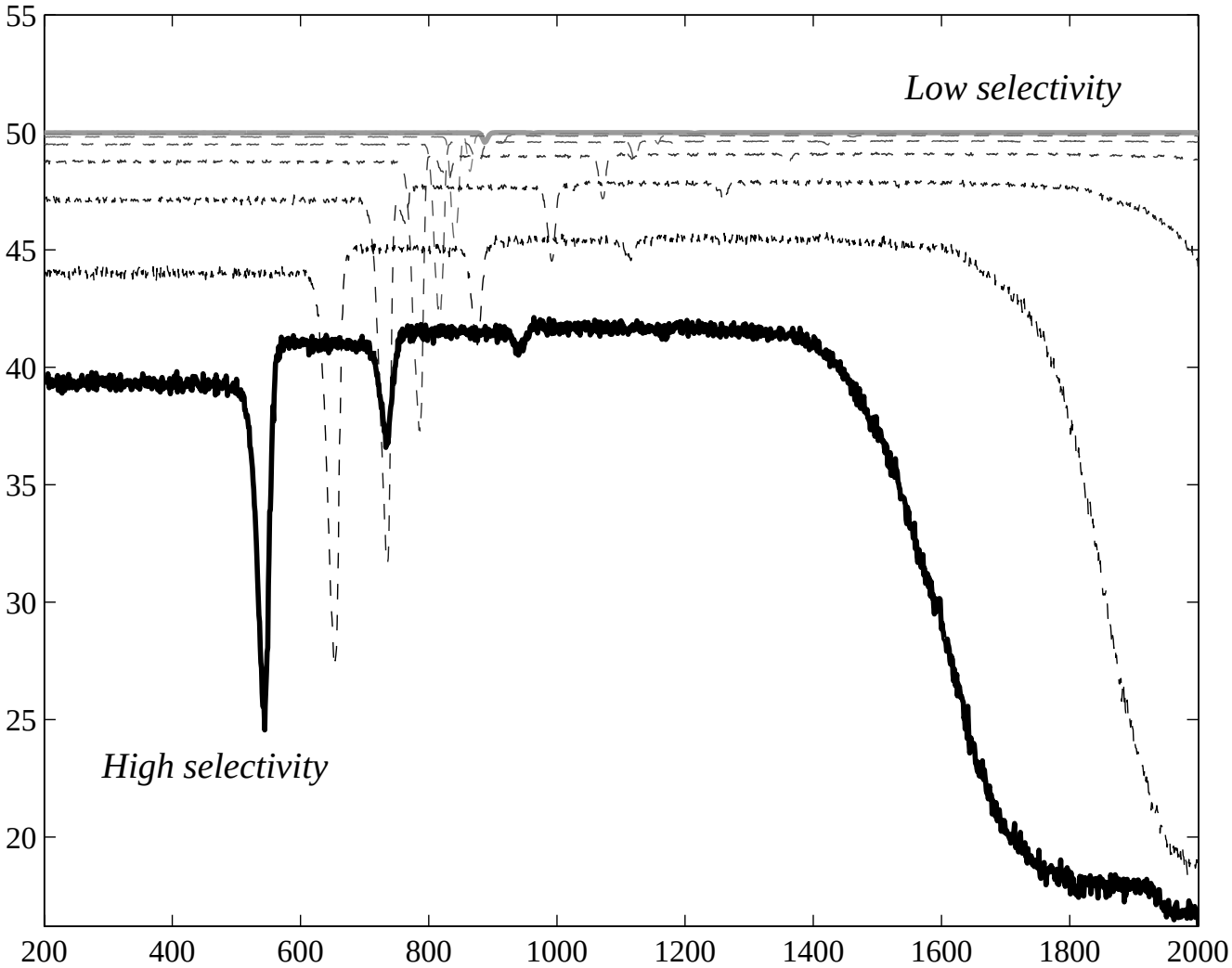


Time series of aggregate labour productivity for different values of v^{max}



Back

Time series of the market concentration for final good producers



Back

Market concentration

Dispersion (variety, S & D) $\Rightarrow$ market concentration $\Rightarrow$ Growth?

Market concentration

Large number of our results are related to market concentration

$\Rightarrow$ Emergence of large firms with strong investment in new capital vintages and demand for R&D

$\Rightarrow$ Schumpeter Mark II

Is concentration relevant for economic growth?

We have noticed that income concentration is not always good for growth

Concentration of consumers in different niches, vs similar consumers

Concentration of goods quality and price vs dispersion of goods characteristics

Market concentration and structural change (Ciarli and Valente, 2016)

Three aspects of structural change that are correlated to both market concentration and economic growth

(i) product variety, measured as disparities among the quality of final goods;

(ii) firm differentiation based on mark-ups related to the quality of goods, which segments the access to high quality goods;

(iii) consumer preferences related to price and quality based on a process of imitation by less wealthy income classes of the preferences of wealthier income classes

RQ: Differences in the timing of concentration and whether it is induced by dispersion on the demand or supply side, might affect economic growth differently.

Final good quality

Firms in the consumables market produce a non-homogeneous good differing in terms of quality ($i_{2,f}$) and price ($i_{1,f}(t) = p_f(t)$)

Quality is assigned at the outset linearly increasingly with respect to firm index from $\underline{i_2}$ to $\overline{i_2}$.

Products with higher quality are more sophisticated and should be thought as luxury goods. Products with lower quality are less sophisticated and should be thought as satisfying basic needs.

Mark-up and quality

Price:

$$p_f(t) = i_{1,f}(t) = (1 + \mu_f(t))c_f(t)$$

The mark-up is proportional to quality, with the minimum mark-up $\underline{\mu}$ corresponding to the minimum quality $\underline{i_2}$, and the maximum mark-up $\overline{\mu}$ corresponding to the maximum quality $\overline{i_2}$

$$\mu_f = \frac{i_{2,f(t)} - \underline{i_2}}{\overline{i_2} - \underline{i_2}} \left(\overline{\mu} - \underline{\mu}\right) + \underline{\mu}$$

Homogenisation of preferences

As before

$$v_{p,z+1} = (1 - \delta_\varsigma)v_{p,z} + \delta_\varsigma v^{min}$$
$$v_{q,z+1} = (1 - \delta_\varsigma)v_{q,z} + \delta_\varsigma v^{max}$$

But when a new class emerge and adopts a new lifestyle, the poorer consumers imitate the preferences

$$v_{p,z<Z} = (1 - \alpha)v_{p,z} + \alpha v_{p,z+1}$$
$$v_{q,z<Z} = (1 - \alpha)v_{q,z} + \alpha v_{q,z+1}$$

Main findings

Market concentration ↑ economic growth ⇔ sufficiently large demand (Schumpeter Mark II (Malerba and Orsenigo, 1995))

If firms are highly differentiated (quality), less affluent consumers must converge towards the consumption of the more affluent classes.

Higher market power decrease market concentration by hindering the consumption of higher quality goods to lower income classes, and separating different consumer niches: lower investments & innovation

Results strongly influenced by different aspects of structural change

- changes in the behaviour (or income) of less wealthy classes
- investment in new capital vintages
- emergence of diverse income classes with heterogeneous consumption preferences

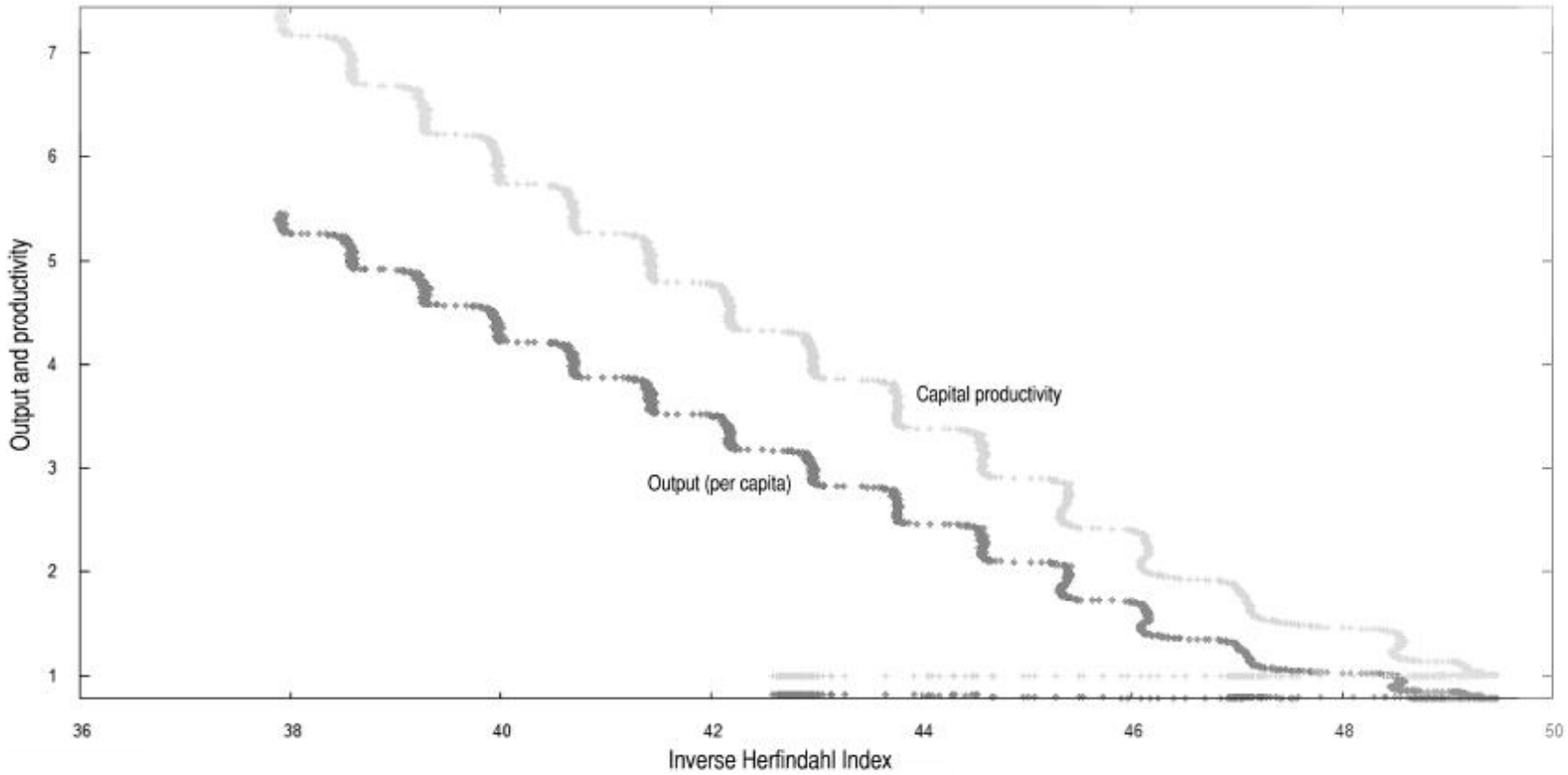
Supply side product variety, *cæteris paribus*, has no significant effect

Summary of results

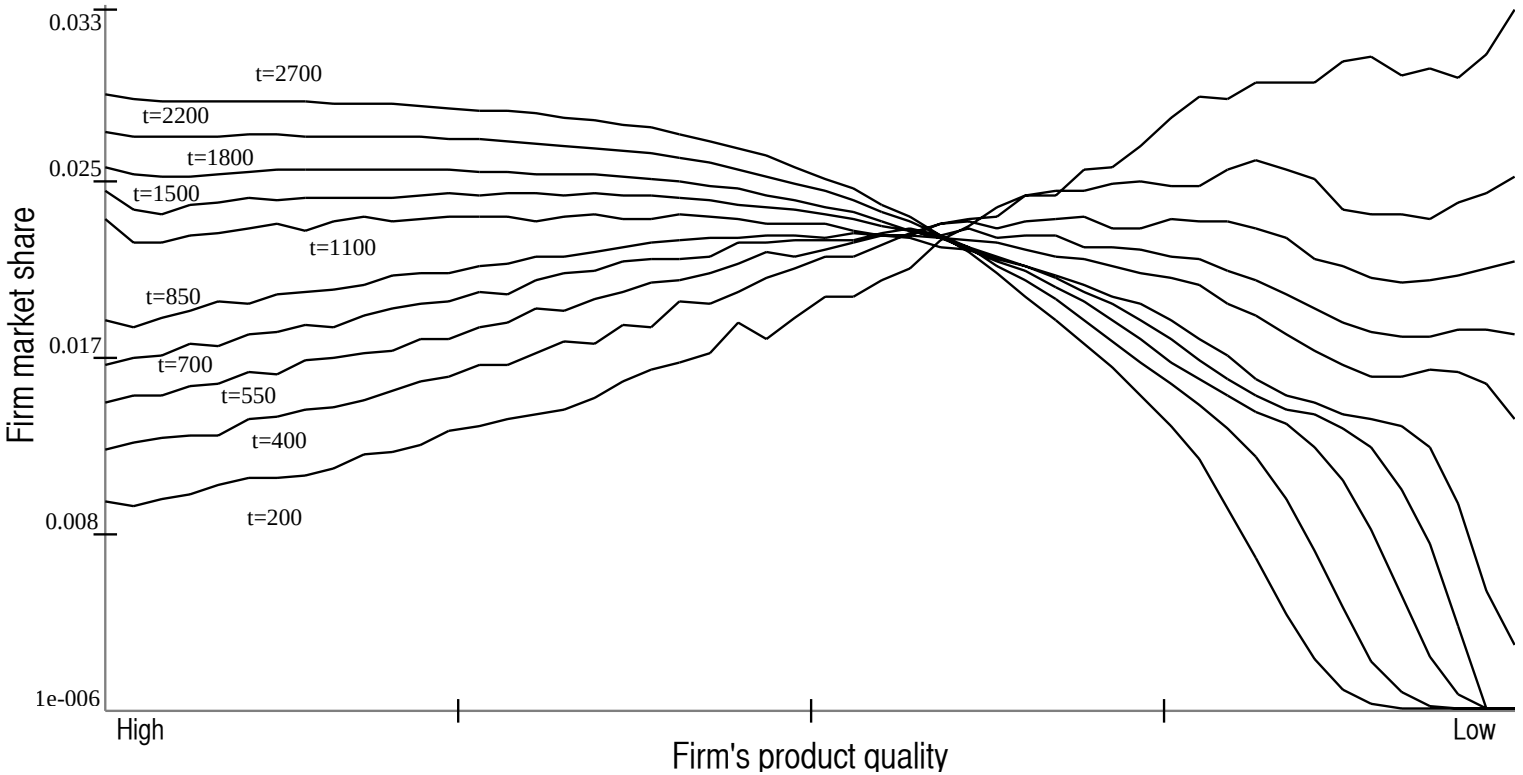
	Dispersion	Selection/Concentration[4]		Output
		Malthusian	Kaldorian	
Preferences	$\uparrow$[1]	$\uparrow/\uparrow$	$\downarrow/\downarrow$	$\downarrow$
Price	$\uparrow$[2]	$\uparrow/\uparrow$	$\uparrow/\downarrow$	$\downarrow$
Quality	$\uparrow$[3]	$\longleftrightarrow/\longleftrightarrow$	$\uparrow/\uparrow$	$\longleftrightarrow$

Footnote: [1]lower imitation of wealthier class preferences; [2]wider distribution of mark-up rates; [3]wider distribution of product quality; [4]we distinguish between the initial stage of development (Malthusian stagnation) and the final stage of development (Kaldorian sustained growth).

Concentration is generally associated with higher output

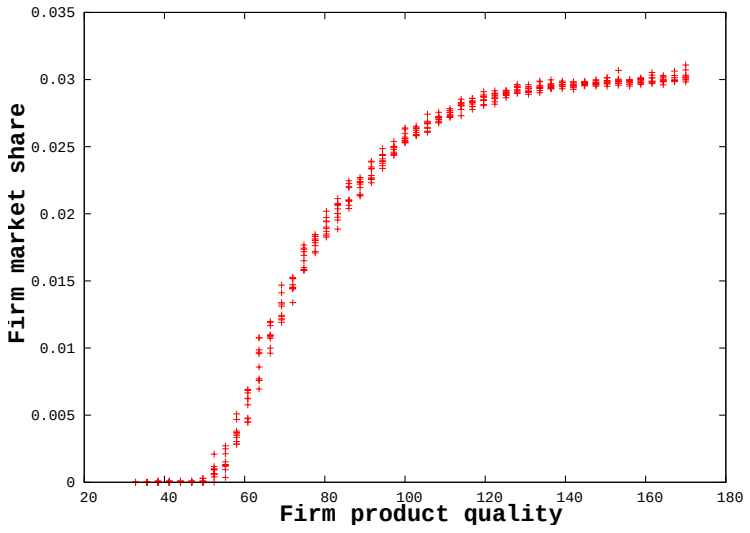


Firms market share shift through time: from price winners to quality winners

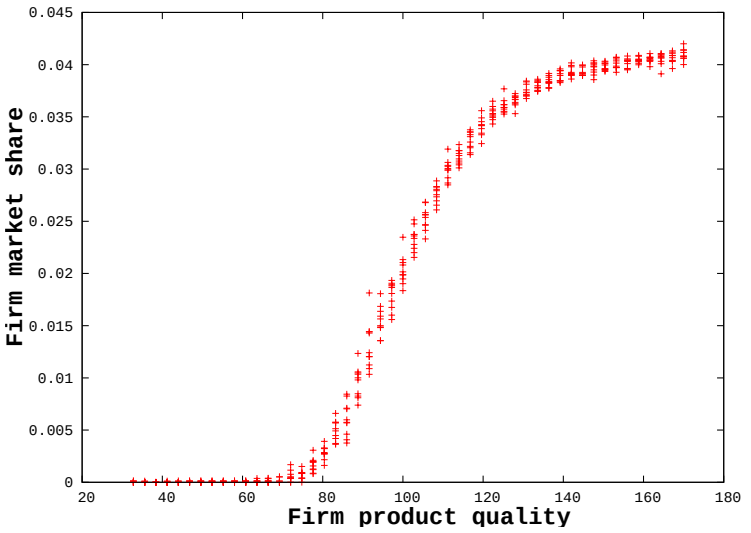


Firms ordered by product quality (x)

Faster imitation: distribution of firm size more skewed (more exits)

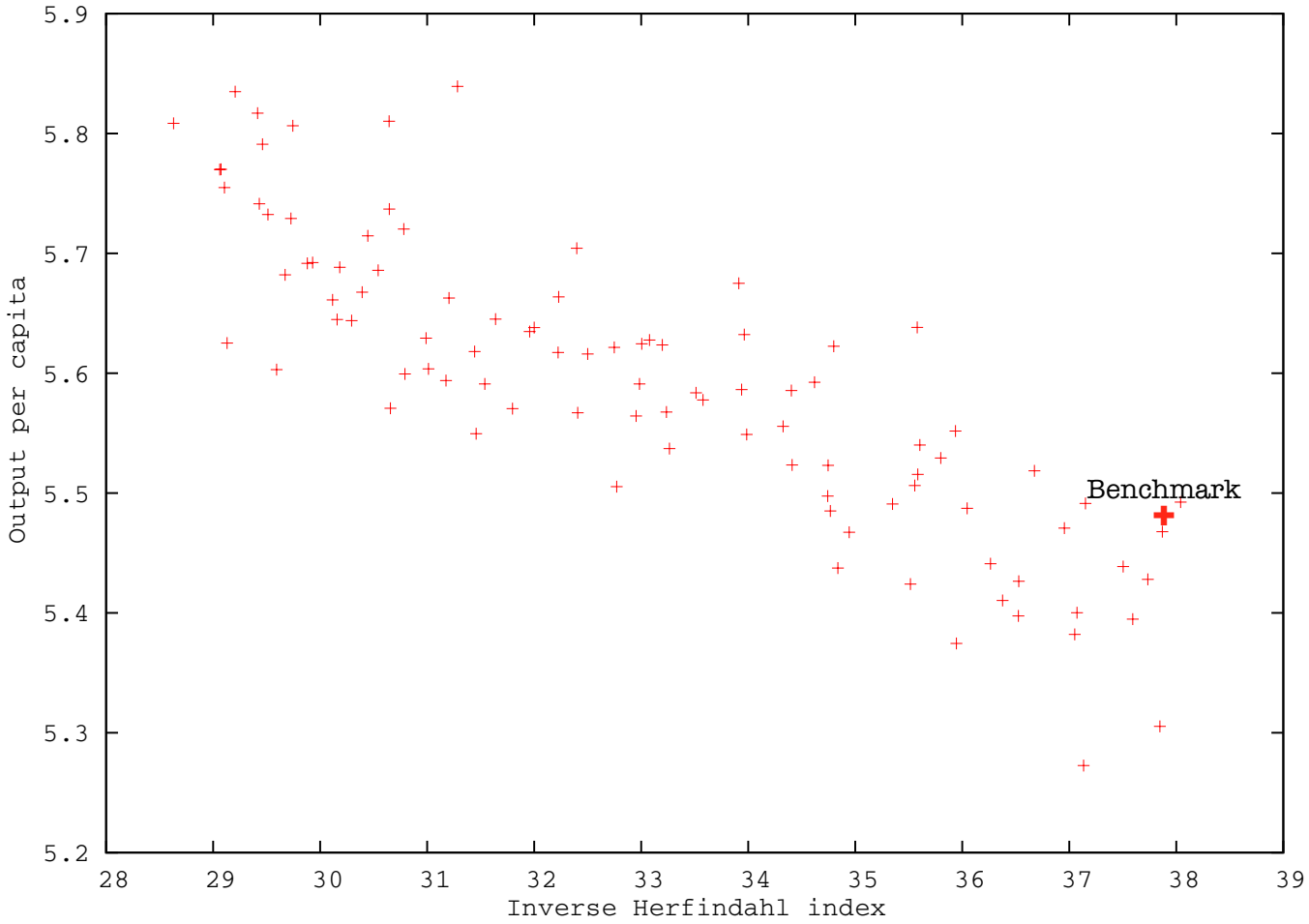


(a) $-\alpha = 0.1$



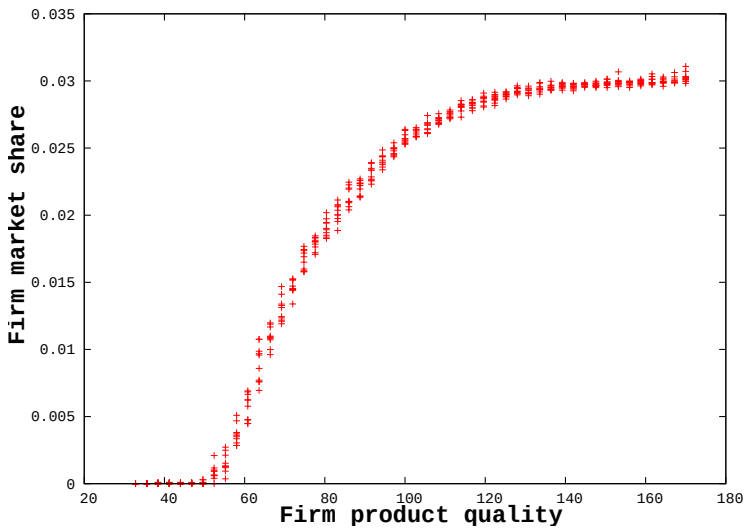
(b) $-\alpha = 0.2$

Faster imitation ⇒ ↑ concentration ⇒ ↑ income growth

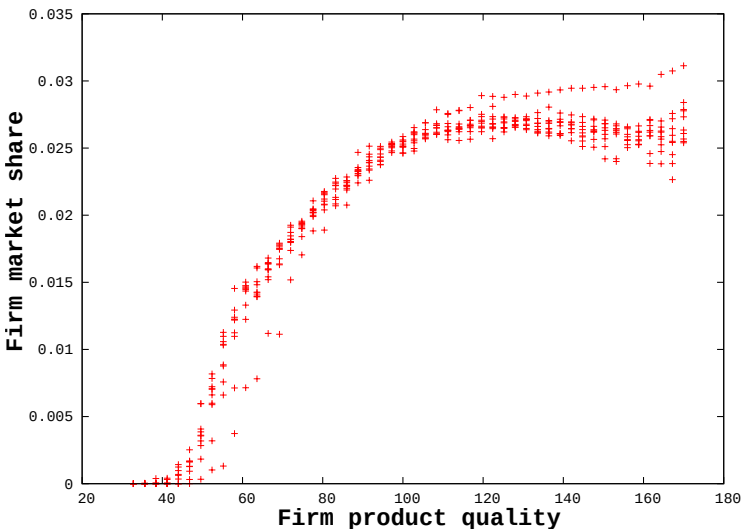


Higher demand and higher investment (concentration driven): societies where lower income classes, through redistribution and social

Higher average mark-up: lower sales of high quality and lower concentration

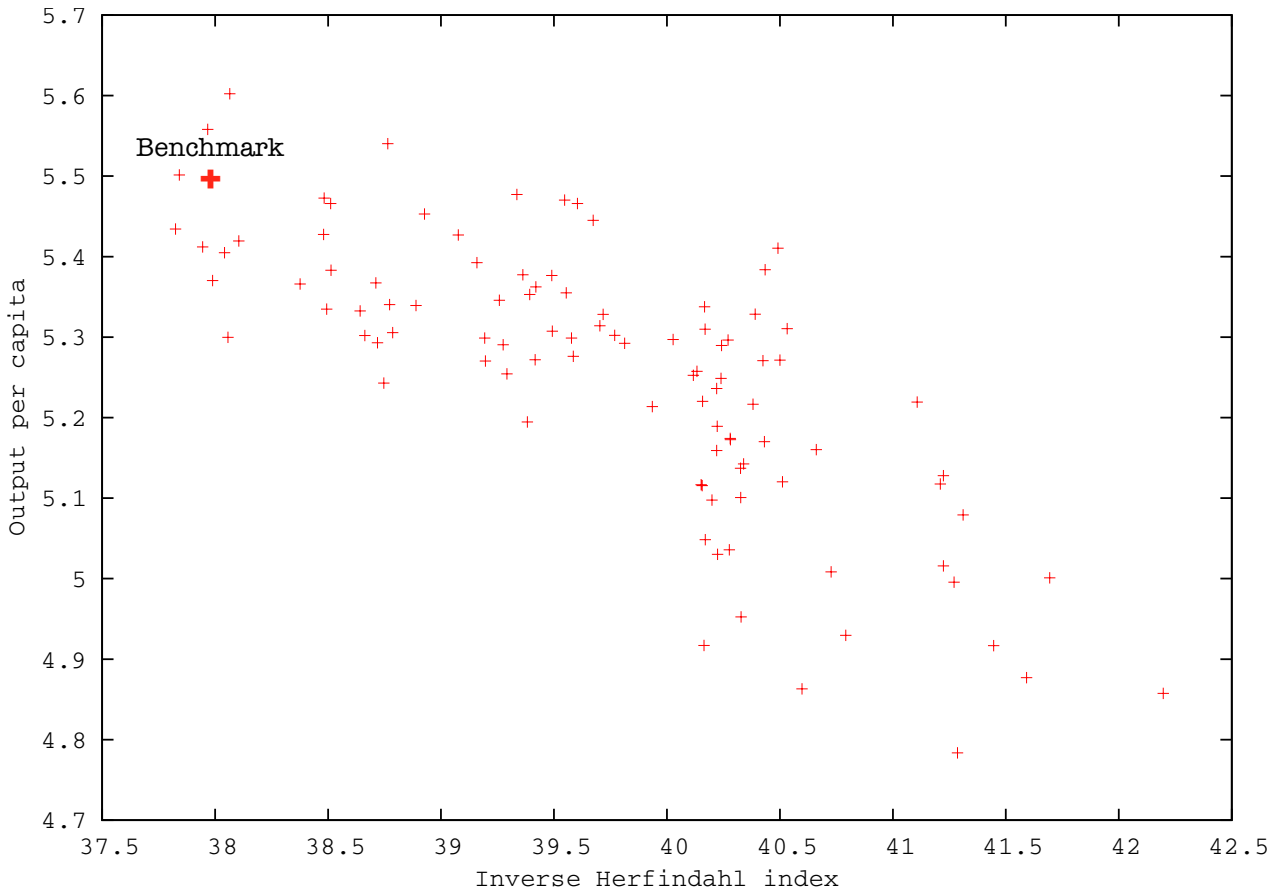


(a) – $\mu = 0.1$



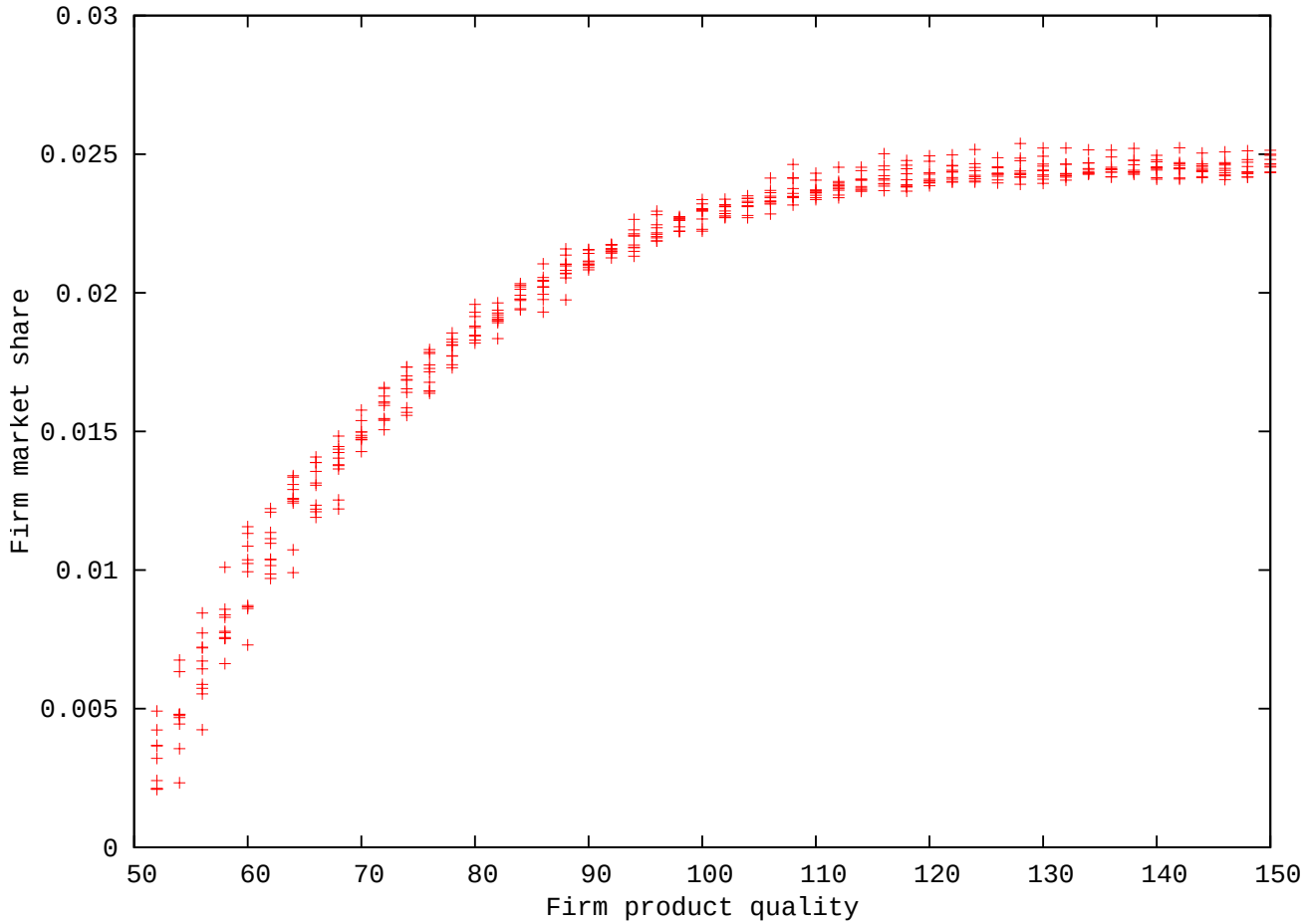
(b) $\mu = 0.3$

Higher mark-up ⇒ ↓ concentration ⇒ ↓ income growth



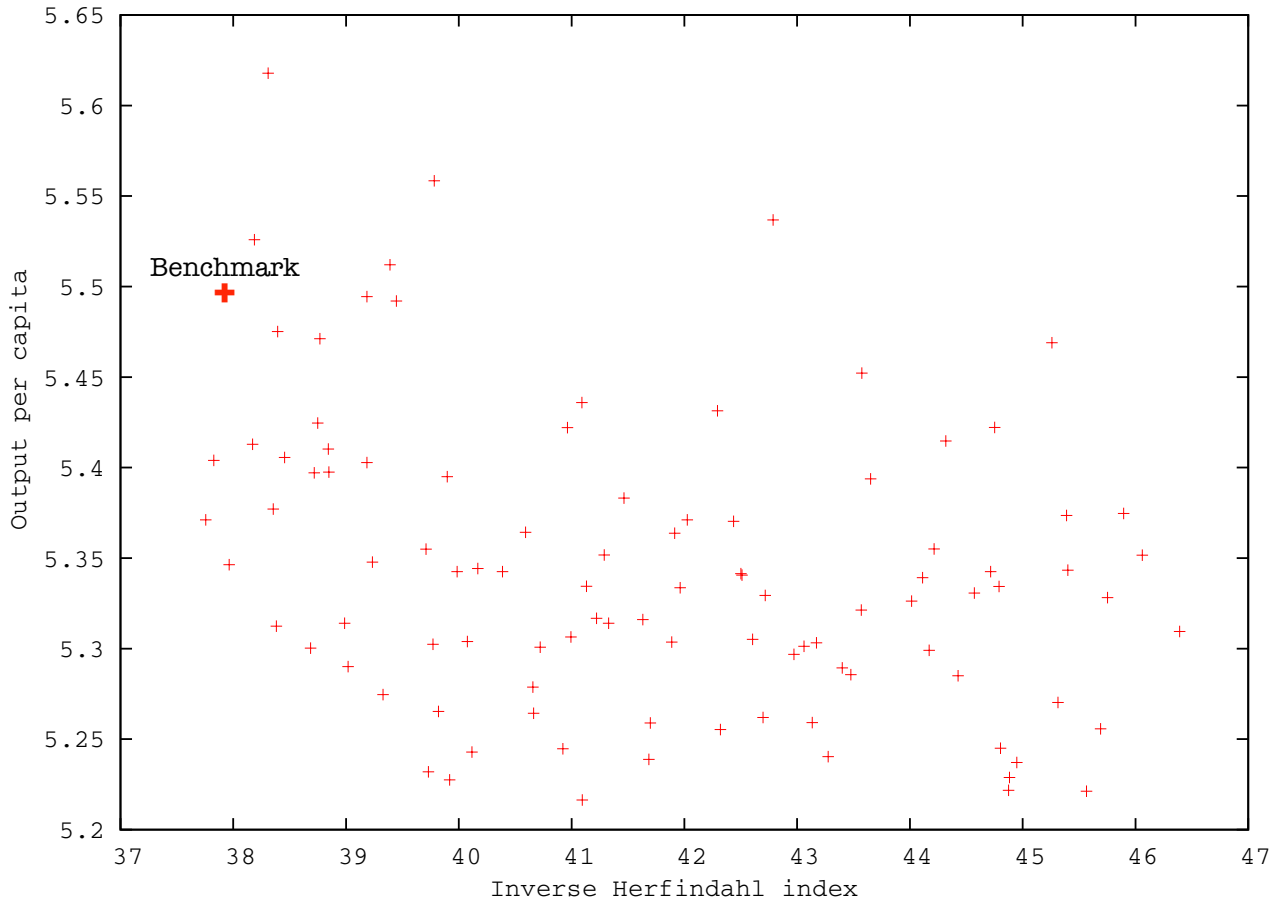
Higher prices depress demand and, therefore, per capita output: (i) directly, by reducing demand; (ii) indirectly, by reducing market concentration (K investment).

Lower product disparity: less concentrated distribution of market shares



No firm exit the market, and most selection occurs over price (which reduces as income grows, in last phases of dev.)

Higher product disparity ⇒ ↑ concentration ⇒ ↕ income growth



Higher disparity in quality has no effect on income growth through market concentration (without changes in prices and/or consumption)

Conclusions

Study the relation between market concentration through the process of economic development, as a function mainly of demand dynamics

- less well studied structural changes (consumer preferences, firm size, and capital vintages)

Different phases of development – initial Malthusian stagnation and Kaldorian sustained growth: different heterogeneities – preferences, price, and quality – different effect on economic growth.

- Societies where lower income classes have access to the basket of top classes may lead to stronger economic performance
- ↑ market power ↓ market concentration by hindering the consumption of higher quality goods to lower income classes, and separating different consumer niches: lower investments & innovation
- Market concentration ↑ for increasing product disparity, with no no effect on growth

Initial state of industry and firms

Back

An industry populated by n firms

Physical capital stock $(K_{i,t})$

Productivity of the capital $(A_{i,t})$

Both levels are result of firms' behaviour in $t-1$

Production and pricing

Production function: only capital with constant returns to scale:
$Q_{i,t} = A_{i,t} K_{i,t}$

- Unit invariable cost c to use capital

Total supply: $Q_t = \sum_n Q_{i,t} = \sum_n A_{i,t} K_{i,t}$

- Firms produce at full capacity (no strategic interaction on quantities)

Demand for homogeneous good with market clearing price:
$P_t = D(Q_t) = D/Q_t^{1/\eta}$

- where η: unit elasticity with respect to price

Profit rate: $pi_{i,t} = P_t A_{i,t} - c - r_{i,t}^{in} - r_{i,t}^{im}$

Total profits: $\Pi_{i,t} = pi_{i,t} K_{i,t}$

Technical progress

Technical progress occurs as a change in capital productivity:
$A_{i,t+1} \geq A_{i,t}$

Fixed rule of expenditure in both innovation $\left(r_{i,t}^{in}\right)$ and imitation $\left(r_{i,t}^{im}\right)$

Innovation

If the firm innovates, two stages stochastic process

Probability that an investment in innovation is successful:
$P\left[d^{in} = 1\right] = a^n r_{i,t}^{in} K_{i,t}$

- Where $r_{i,t}^{in} K_{i,t}$ is R&D expenditure; a^n a parameter

If $d^{in} = 1$, innovation result is again a random event normally distributed: $\tilde{A}_{i,t} \sim N\left(A_{i,t}^*, \sigma^2\right)$

- $A_{i,t}^*$: firm (cumulative) or market level (incremental) current productivity
- science based knowledge: exogenous increase of A

Imitation

If the firm imitates, two stages stochastic process

Probability that an investment in imitation is successful:
$P\left[d^{im} = 1\right] = a^m r_{i,t}^{im} K_{i,t}$

- Where $r_{i,t}^{im} K_{i,t}$ is imitation expenditure; a^m a parameter

If successful, the firms imitate the best $\hat{A}$ or the mean $\bar{A}$ productivity in the market in the current period

The final productivity is the maximum between $A_{i,t}$, $\tilde{A}$, $\bar{A}$ and $\hat{A}$.

Capital investment

K investment: $K_{i,t+1} = I\left(\frac{p_t A_{i,t+1}}{c}, \frac{Q_{i,t}}{Q_t}, \Pi_{i,t}, \delta\right) K_{i,t} - (1-\delta) K_{i,t}$

The maximum amount of capital investment is bounded by profits, plus a bank loan proportional to profits

The desired amount of investment depends on $t+1$ unit costs, the capital depreciation rate δ and a mark-up $\mu_{i,t+1}$.

μ is an expected value that depends on the competition with other firms $Q_{i,t}/Q_t$ and on the demand elasticity (Cournot conjectures)

Change in capital stock will change the production and price in the next period (for the whole industry)

Industrial dynamics

Firm exit: $K_{i,t} < \underline{K}$

Firm entry

"Fission": probability of a fission follow a Poisson distribution with parameter $ms \cdot \phi^{Fis}$

- New firm has a capital and a market share which is less then a half the parent company

Back

Firm's output

Back

Each firm produces one good, satisfying one consumer need (= sector), with price (i_p) and quality (i_q).

Output constrained by **labour** and **capital** (Leontief PF):

$$Q_t = \min \left\{ Q_t^d; A_{t-1} L_{t-1}^1; DK_{t-1} \right\}$$

A_{t-1} is the labour productivity embedded in K vintages

Price is determined as a fixed mark–up μ on variable costs

- Firm organisations/size (S-1)
- Labour productivity (S-2)

Large $\mu \rightarrow$ Larger bonuses for executives

Factors of production: Labour

Back

S–1 Organisation of production

Demand for **first tier workers** L_t^1 adjusts to desired output and productivity.

Higher tiers workers co-ordinate a batch of ν subordinates

$$L_t^2 = L_t^1 \nu^{-1}$$
$$\vdots$$
$$L_t^\Lambda = L_t^1 \nu^{1-\Lambda}$$

where Λ is the total number of firms' layers

Large $\nu \rightarrow$ less workers per executive

Factors of production: Capital Stock

Back

S–2 Production technology

Investment decision of new capital units is unconstrained

$$k_t^e = (1+u)\frac{Y_t^e}{D} - K_{t-1}$$

u: reserve; $1/D$: K intensity.

Investment increases the efficiency of production incorporating new capital vintages

$$A_t = \sum_{\tau=0}^{t} \frac{k_\tau (1-\delta)^{t-\tau}}{K_t} a_\tau$$

δ: depreciation; a_τ: vintage productivity

Factors of production: Capital Stock

Back

S–2 Production technology

Capital good firms innovate improving the productivity of the supplied vintages proportionally to profits/sales:

- **Spend** a share ρ_k of cumulated profits $\Pi_{g,t}$ to hire R&D engineers
- **Probability of success**: $P^{inn}_{g,t} = 1 - e^{-\zeta L^{E}_{g,t-1}}$
- New vintage's **productivity increase** depends on the variance of a stochastic variable: $\varepsilon^{a}_{g,t} \sim N(0; \sigma^{a})$

Large $\rho_k \rightarrow$ more process innovation
Large $\zeta \rightarrow$ higher prob of success
Large $\sigma^{a} \rightarrow$ larger change in vintage productivity

Product innovation

Back

S–3 Product technology

1. **Spend** a share ρ of non invested profits in R&D: $R_{f,t}$
2. **Research** in a neighbourhood of the current sector/need n, limited by $\iota R_{f,t}$
3. **Select** the sector/need n' with the largest excess demand $Y^x_{n,t}$
4. **Develop** a new prototype with stochastic quality $q_{n',f,t} = f\left(\frac{\vartheta}{1-|n-n'|}\right)$
5. **Add** to the prototypes basket
6. **Market** a new product with probability $f\left(-\frac{\theta}{\Delta Y_{f,t}}\right)$, moving to a new sector/need only if competition pressure is lower

Large $\rho \rightarrow$ more product innovation
Large $\iota \rightarrow$ faster change in sectors
Large $\vartheta \rightarrow$ larger increase in product quality Large $\theta \rightarrow$ quicker

Income structure

Back

D–1 Income distribution

A **minimum wage** w^m is negotiated at the macro level

- labour market – wage + Beveridge curve (continuous)
- inflation and productivity (discrete)

Exponential wage structure along the organisational pyramid

$$\begin{aligned} w_t^1 &= \omega w_{t-1}^m \\ w_t^2 &= b w_t^1 \\ &\vdots \\ w_t^\Lambda &= b^\Lambda w_t^1. \end{aligned}$$

ω: firm bargain; b: executive multiplier

Executives receive **bonuses** ψ^l from **residual** profit shares $(1 - \rho)$

Large b $\rightarrow$ higher wage differences

Income classes and evolution of consumption

Back

D–2 Consumption shares

Consumption level differ by **labour/income** class.

Each class z is populated by the workers of a corporation's tier (identical wage and bonus)

Consumers in a class also consume according to the same **expenditure shares** and **preferences**.

Expenditure shares $c_{n,z}$ change across classes: satiation

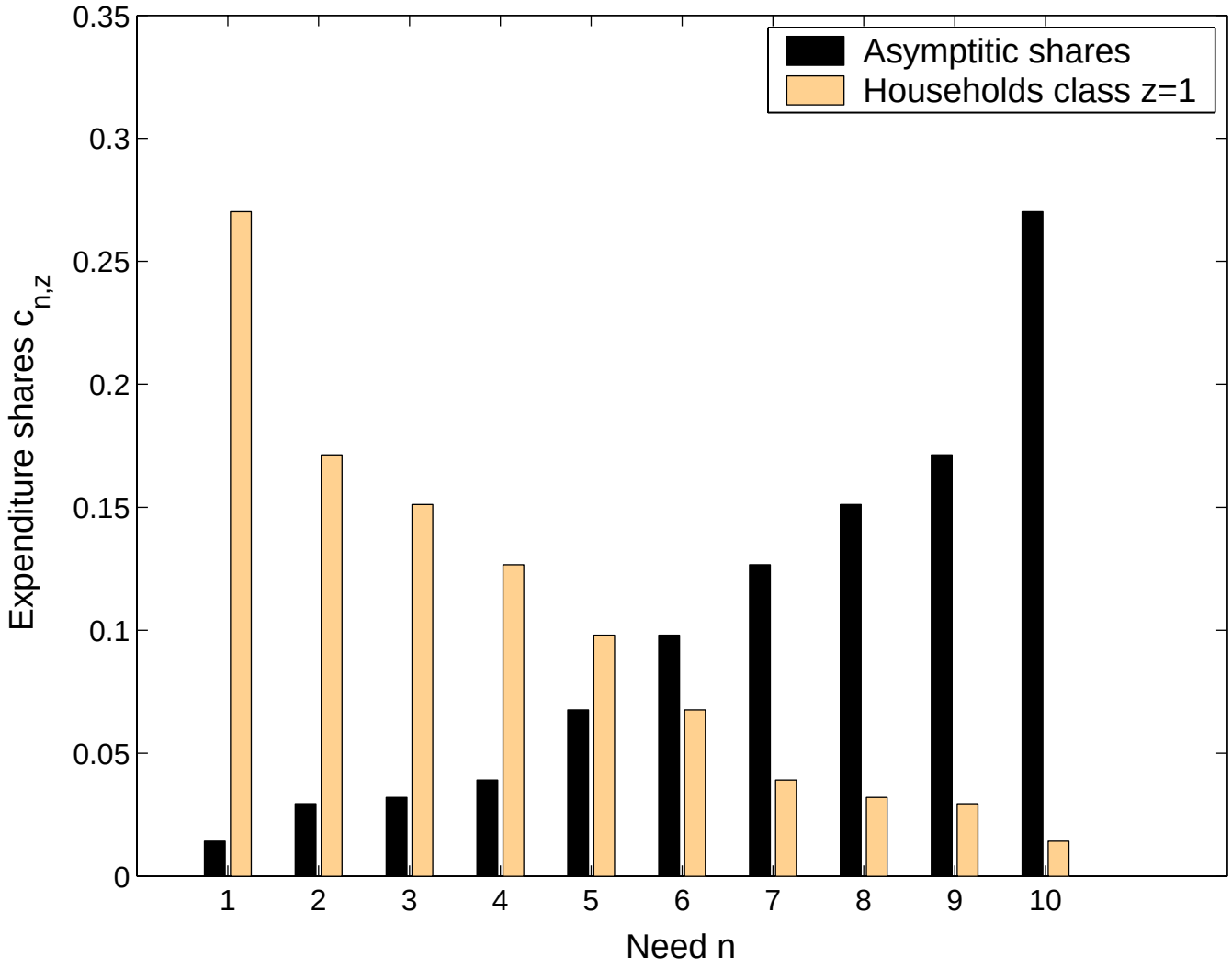
$$c_{n,z} = c_{n,z-1}\left(1 - \eta\left(c_{n,z-1} - \bar{c}_n\right)\right)$$

$\bar{c}_n$: an asymptotic value; η convergence (satiation) speed

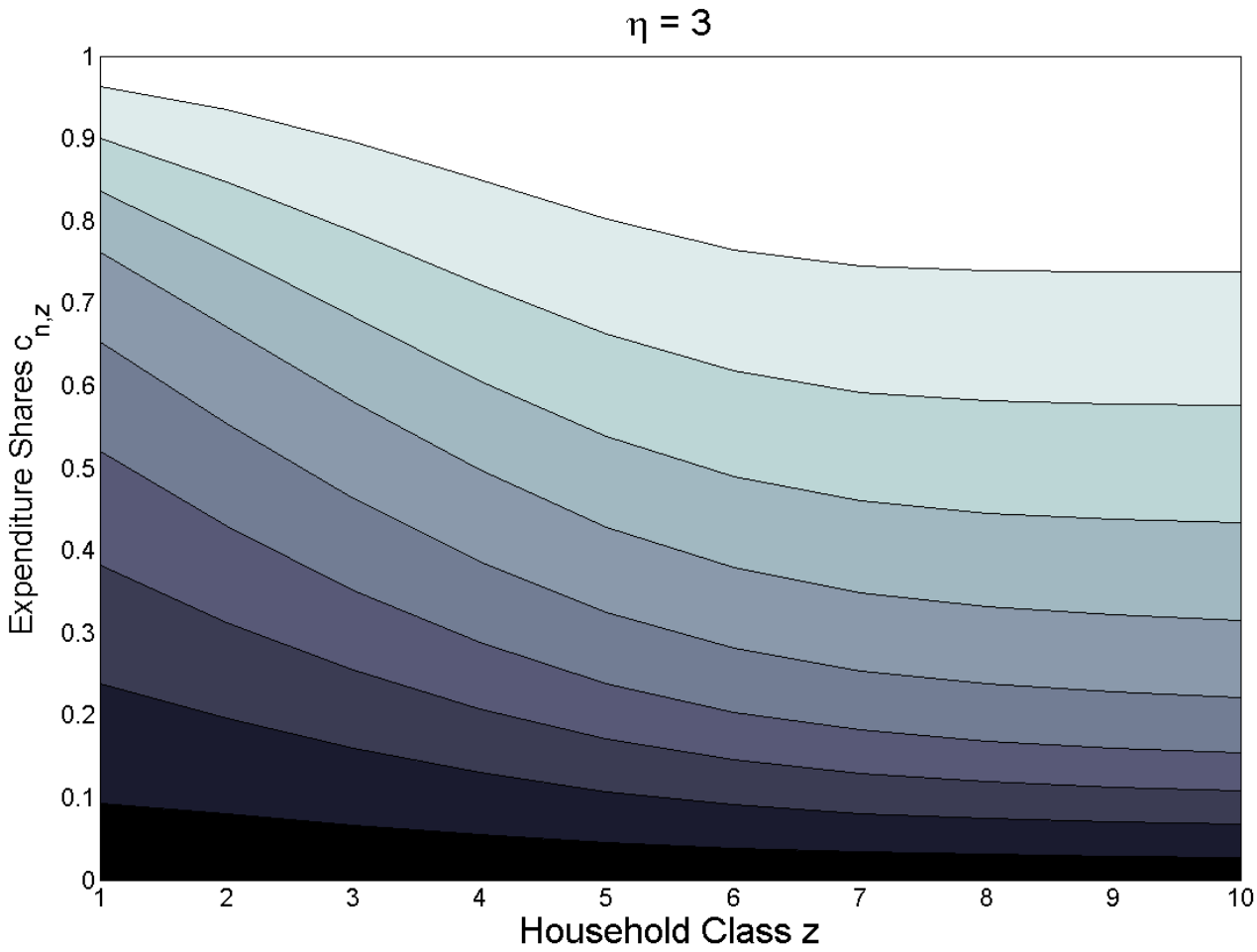
- We assume a need = a consumption category

Large $\eta \rightarrow$ faster convergence to luxury goods

Change in consumption shares



Implicit Engel curves: evolution of consumption shares



Change in consumption share for $\eta = 3$ and ten consumer classes. In the model consumption classes emerge endogenously Init

Consumer behaviour

Back

For each need, given the **perceived** characteristics of a good $i^*_{f_n,m} = N\left(i_{f_n,m}, \sigma^i i_{f_n,m}\right)$ (quality and price), a consumer selects all the firm**s** that offer a good with **equivalent** values and shares the demand

$$i^*_{f_n,m} \equiv i^*_{B_n,m} \Leftrightarrow |i^*_{f_n,m} - i^*_{B,m}| < (1 - \upsilon_{z,m}) \cdot i^*_{B,m}$$

$\upsilon_{z,m}$: selectivity

The selectivity with respect to *less–then–optimal* quality on each characteristic defines consumer class preferences.

From low to high income classes the selectivity towards *good's quality* increases, and *price* becomes relatively indifferent

Total purchases close the model: firms sales.

Large $\upsilon_{z,m} \rightarrow$ larger preference differences across classes Back

Structural change, economic and social transformations: e.g. the industrial revolution in England

Firm size growth & concentration in large capital intensive firms (Desmet and Parente, 2009)

Increase in the number of goods for final consumption (Berg, 2002)

Closer involvement of science in technological change (Mokyr, 2002)

Increased use of capital in agriculture and manufacturing ⇒ technology embedded in machines ⇒ overall increases in productivity (Kuznets, 1973)

Urbanisation, income inequality and changes in social class composition (McCloskey, 2009)...

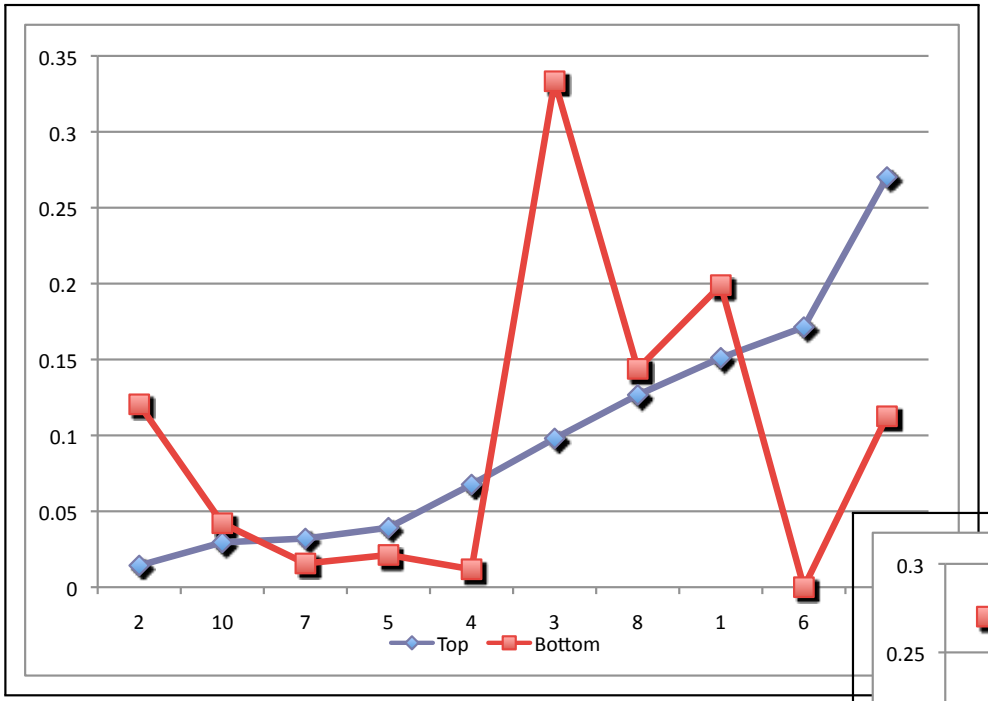
Some changes precede income growth, others unfold as a consequence of income growth

Untested parameters setting

Parameter	Description	Value	Data
$\underline{\underline{i_2}}$	Initial min quality level	98	Analysed
$\overline{\overline{i_2}}$	Initial max quality level	102	Analysed
a^s	Adaptation of sales expectations	0.9	// [a]
$\bar{s}$	Desired ratio of inventories	0.1	[0.11 - 0.25] [b]
u^l	Unused labor capacity	0.05	0.046 [c]
u	Unused capital capacity	0.05	0.046 [c]
δ	Capital depreciation	0.001	[0.03, 0.14]; [0.016, 0.31] [d]
$\frac{1}{B}$	Capital intensity	0.4	B = [1.36, 2.51] [e]
ϵ	Labor market friction (final firms)	0.9	0.6; [0.6, 1.5]; [0.7, 1.4]; [0.3, 1.4] [f]
ω	Minimum wage multiplier	2	[1.6, 3.7] [g]
$1-\gamma$	Smoothing parameter	0.2	[.04, .14]; [.06, .19] [h]
σ_j^i	Error in the consumer's evaluation of characteristics	$j = 1$: 0.05; $j = 2$: 0.1	// [i]
ω^E	Engineers' wage multiplier	1.5	[1.2, 1.4] [j]
$\upsilon^{min} = \upsilon_{2,1}$	Highest = first tier quality tolerance	0.1	//
$\upsilon^{max} = \upsilon_{1,1}$	Lowest = first tier quality tolerance	0.9	//
F	Final good firms	100	//
G	Capital good firms	10	//
H_z	Consumer samples	100	//
N	Number of needs	10	//

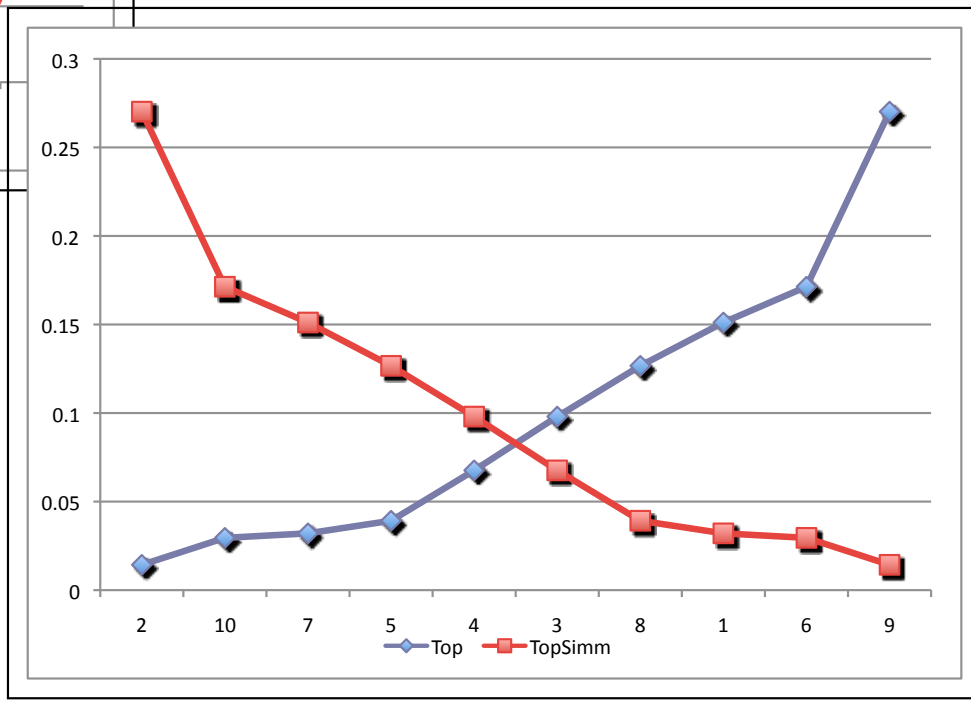
[a] Empirical evidence not available: the parameters has no influence on the results presented here. [b] U.S. Census Bureau (2008); Bassin et al. (2003). [c] Coelli et al. (2002) with reference to the 'optimal' unused capacity. [d] Nadiri and Prucha (1996); Fraumeni (1997) non residential equipment and structures. We use the lower limit value, (considering 1 year as 10 simulation steps) to avoid growth in the first periods to be determined by the replacement of capital. [e] King and Levine (1994). [f] Vacancy duration (days or weeks) over one month: Davis et al. (2010); Jung and Kuhn (2011); Andrews et al. (2008); DeVaro (2005). [g] Ratio with respect to the average (not minimum) wage in the OECD countries (Boeri, 2009). [h] Krueger and Perri (2005); Gervais and Klein (2010). [i] No empirical evidence available to the best of our knowledge. Parameters set using the qualitative evidence in Zeithaml (1988). [j] Relative to all College Graduates and to accountants (Ryoo and Rosen, 1992)

Expenditure shares ordered by UK top centile



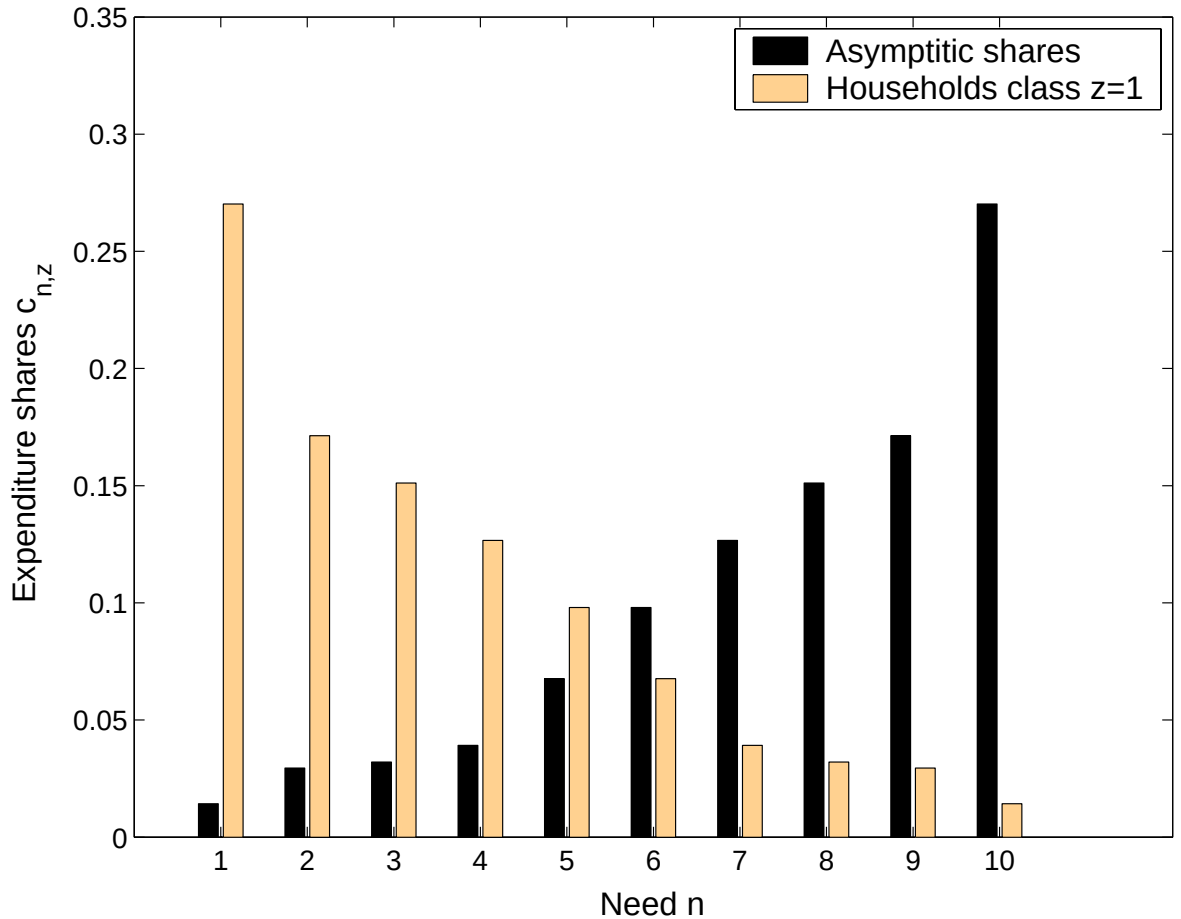
(**a**) Original distribution

Init



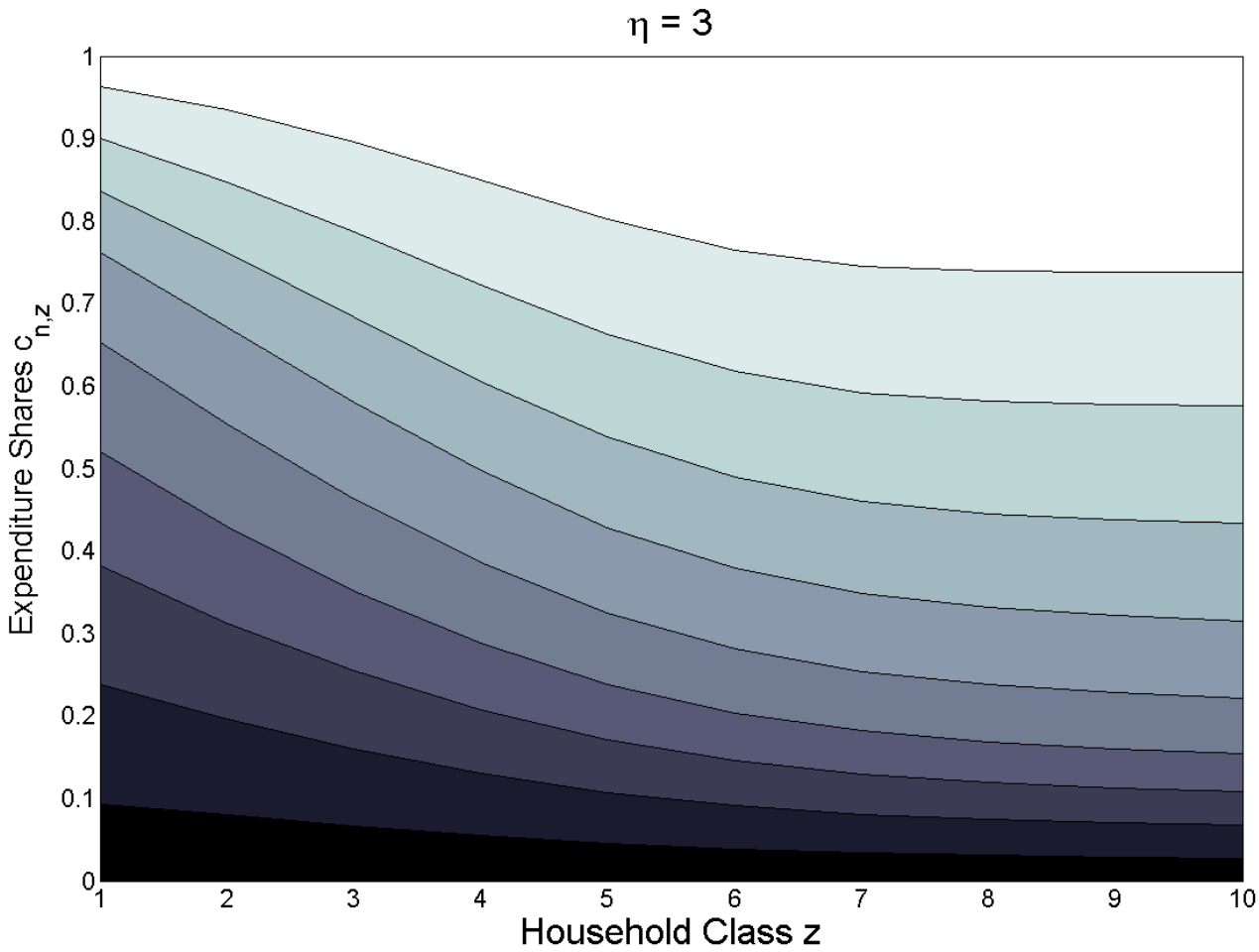
(**b**) Symmetric distribution

Change in consumption shares



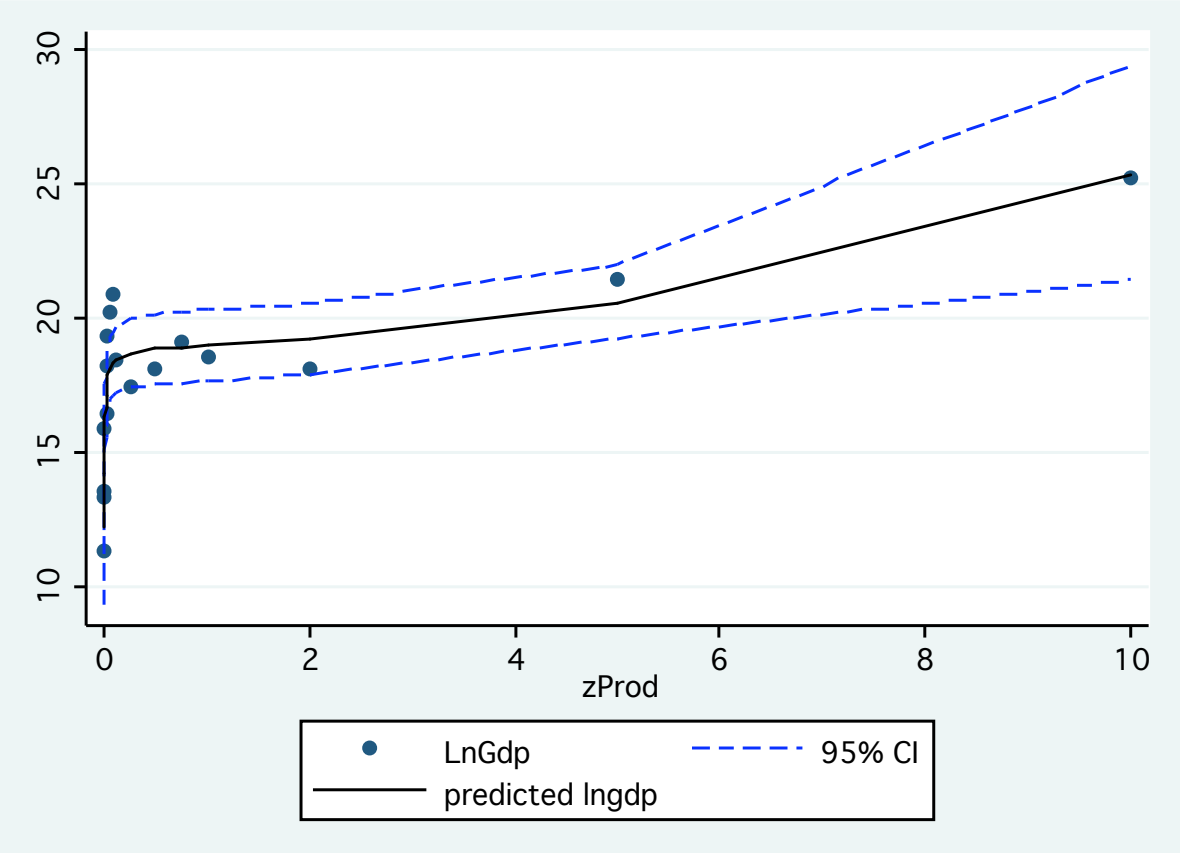
Consumptions

Implicit Engel curves: evolution of consumption shares



Change in consumption share for $\eta = 3$ and ten consumer classes. In the model consumption classes emerge endogenously Consumptions Init

Research width: variety as exploration of new markets

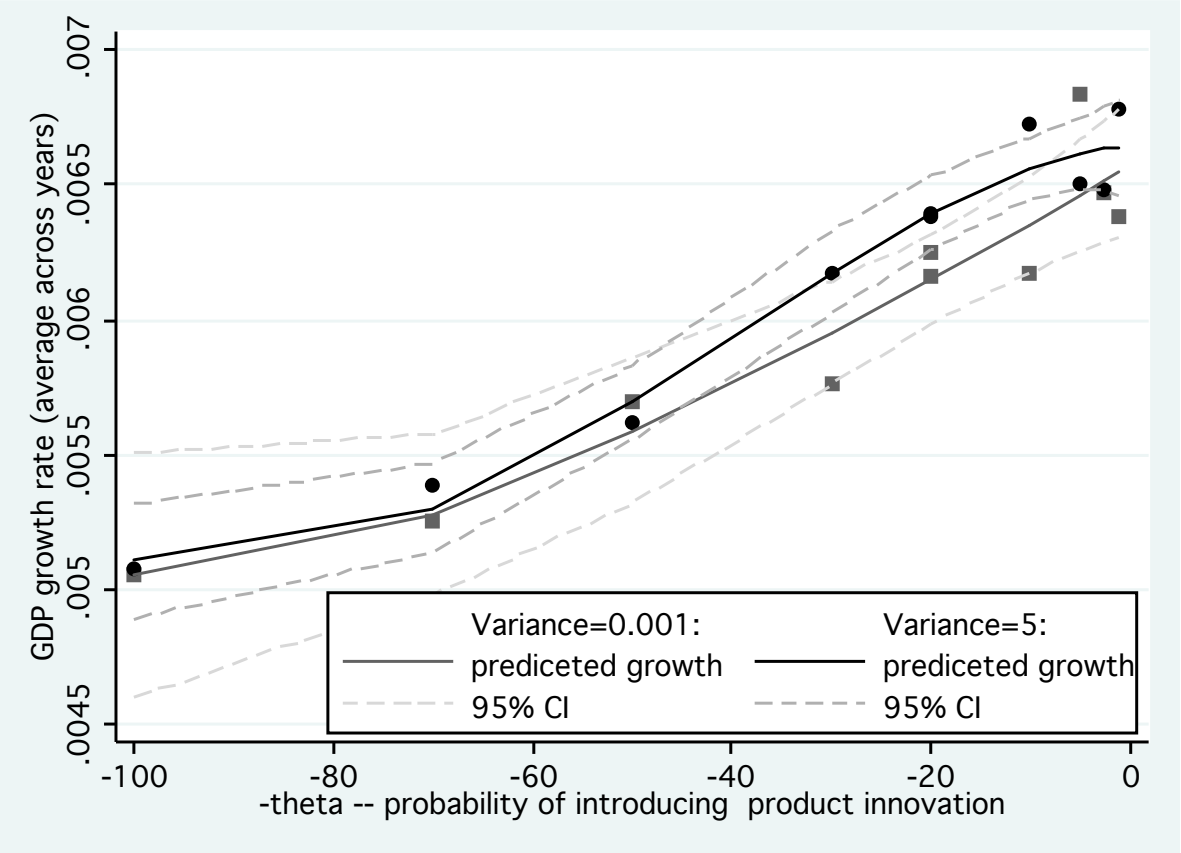


Ability to search into farther new potential sectors

Increases output, below a small threshold: increase in final demand

Back

Rate of introduction of new goods: emergence of new sectors

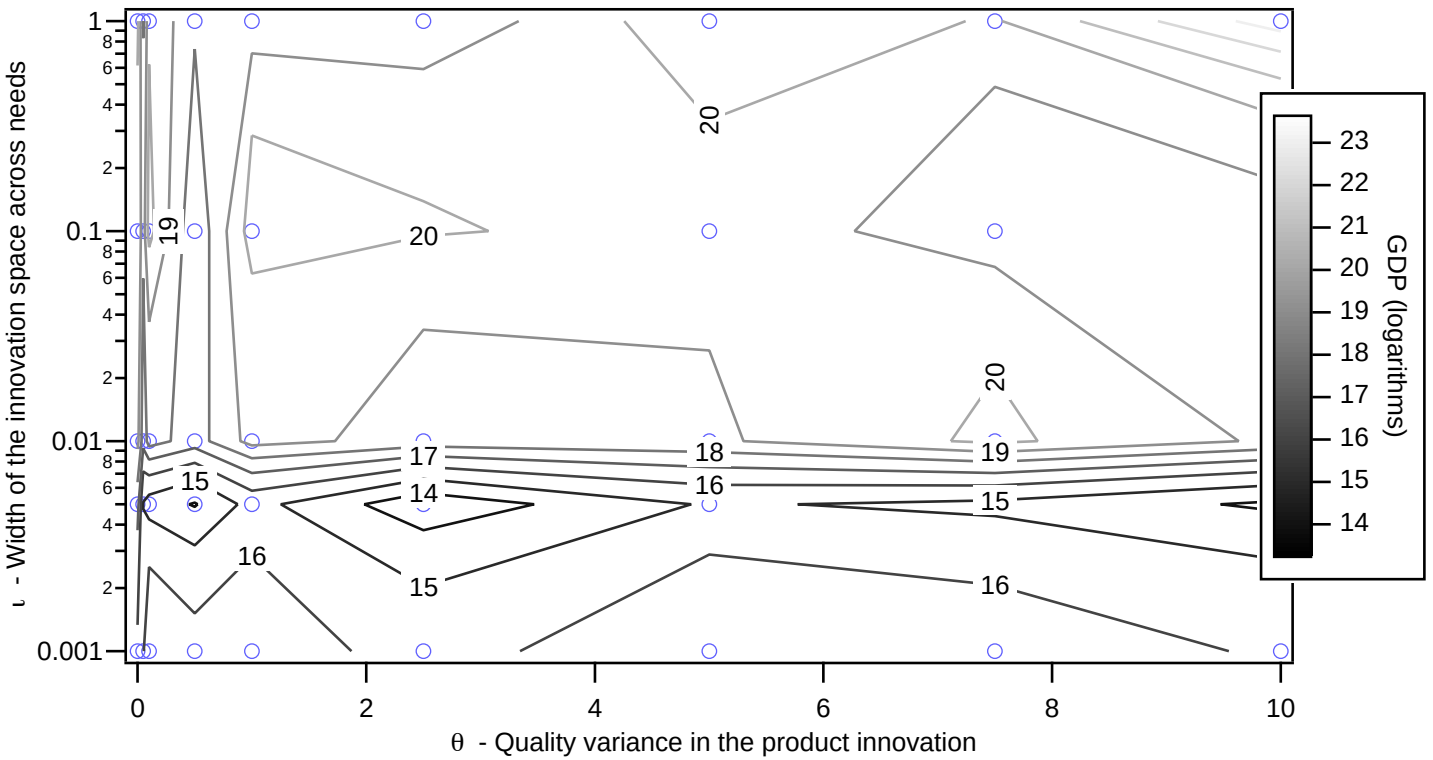


Accelerating the rate at which the prototypes are marketed

— Increases Output growth

Back

Product quality: variety as different innovation output

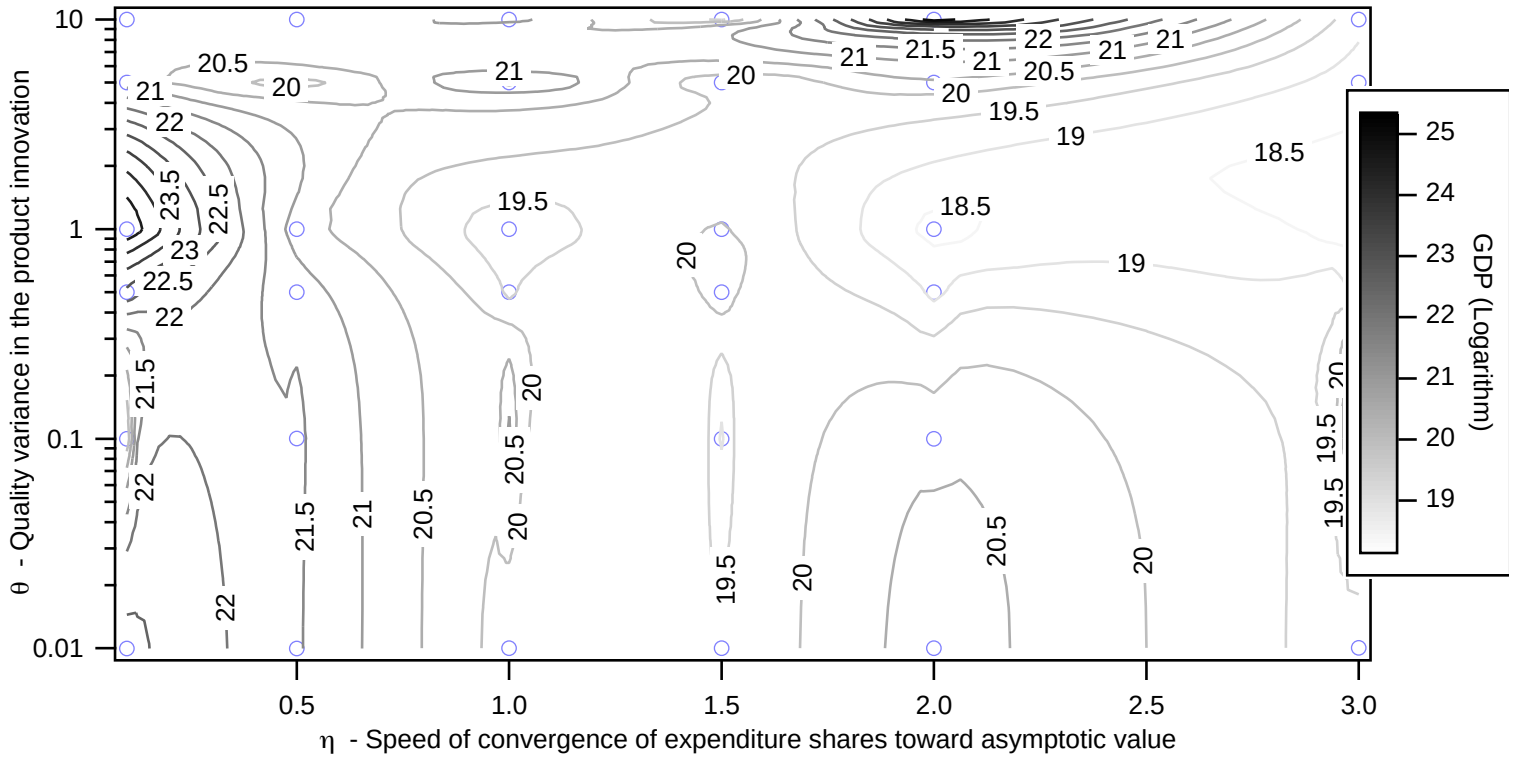


Larger improvements in the quality of new goods

Have only a marginal effect on output (with respect to the emergence of needs)

Back

Rate of convergence of expenditure shares: demand variety



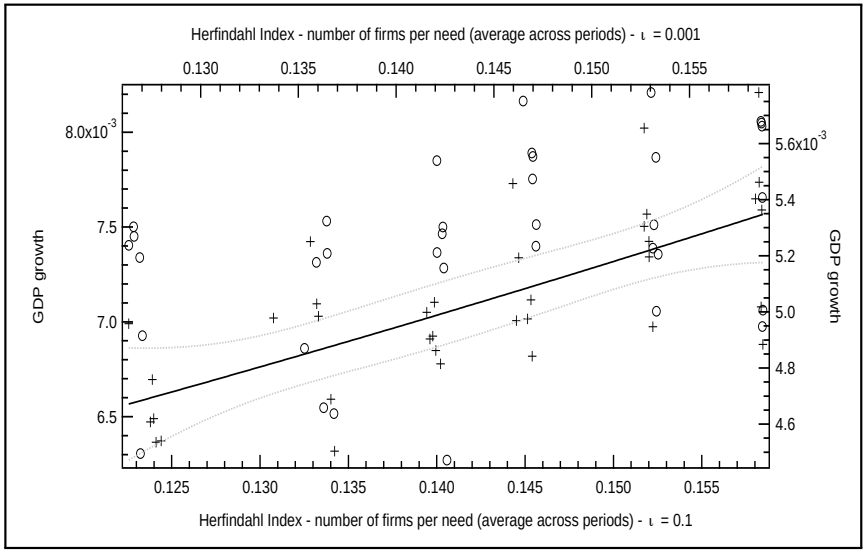
Increasing the rate at which emerging consumer classes move to 'luxury' needs

Has a negative effect on growth

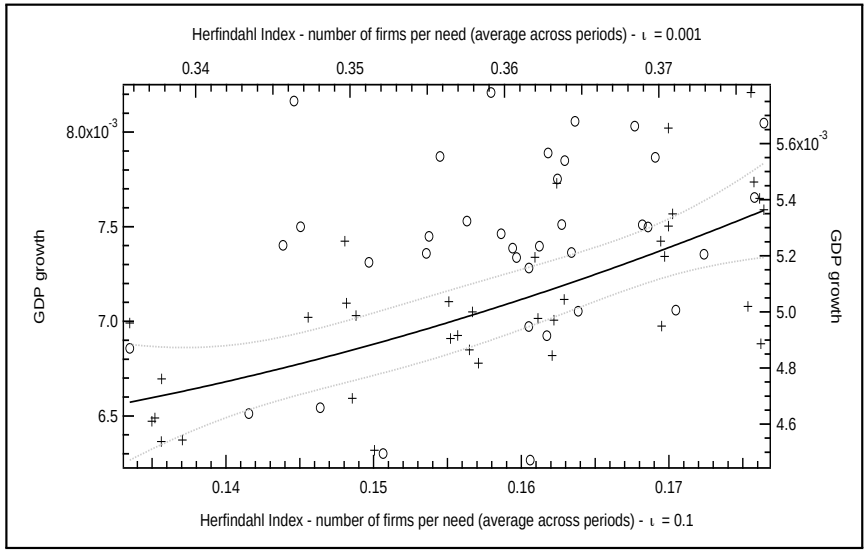
Only partially mitigated by larger innovation variety

Back

Market concentration and growth



(**a**) Demand market concentration



(**b**) Supply market concentration

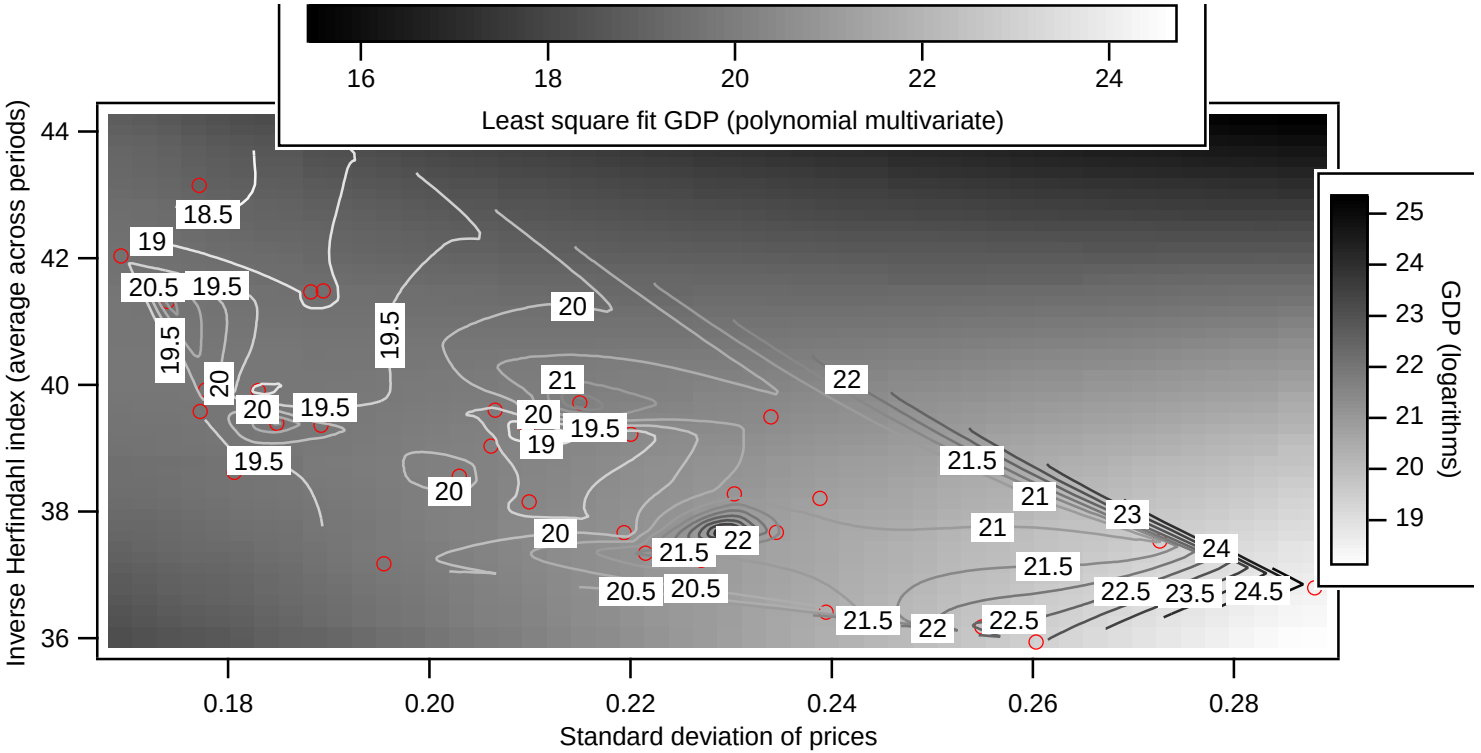
Market concentration increases output growth

– For high rate of convergence of expenditure shares, demand and supply quickly distribute across markets: ↑ firm size & investment

– Concentration of production induces cumulative causation

Back

Expenditure shares, firm heterogeneity and growth



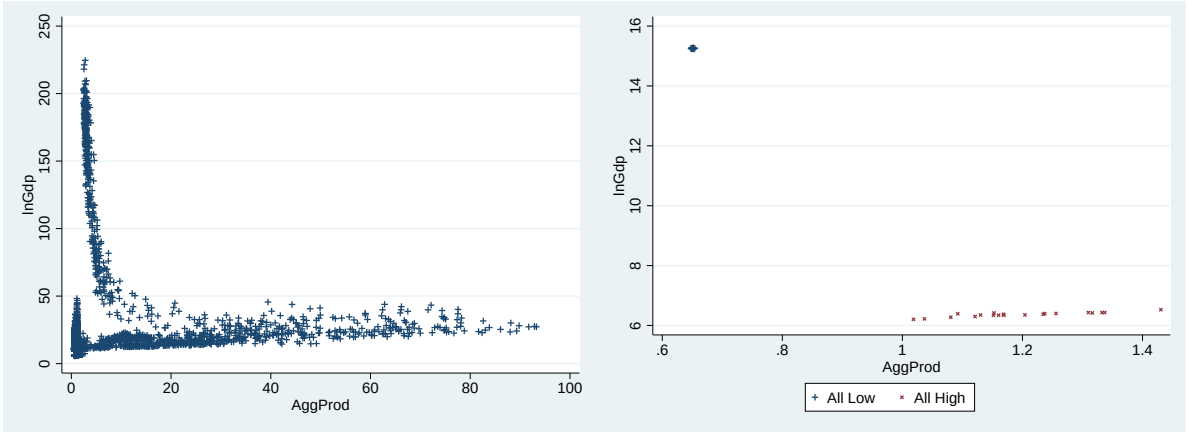
Firms (price) heterogeneity → market concentration → innovation and growth

– ↑ convergence ↑ D dispersion ↓ firm growth (due to within sector price differences and Mkt concentration) ↓ K accumulation, productivity, D, ...

– Quick inducement of demand variety reduces K accumulation

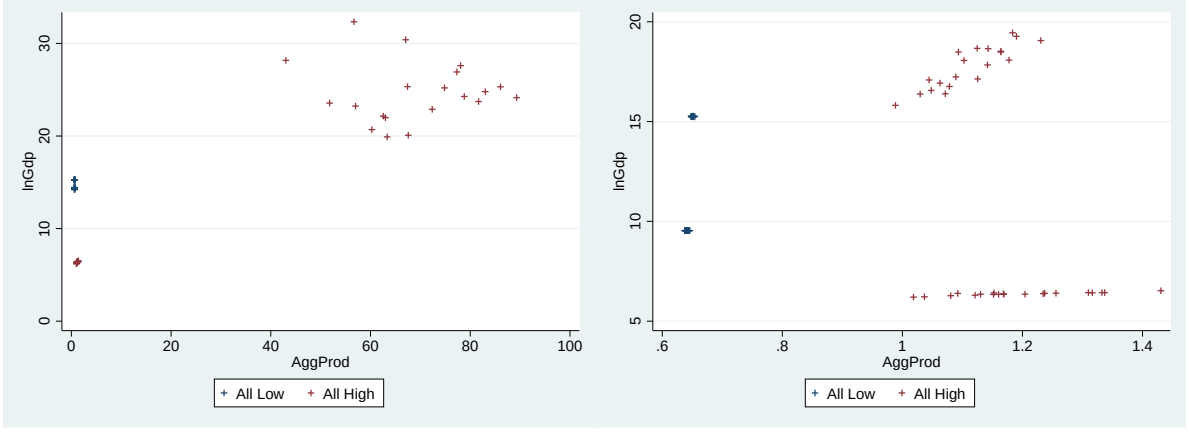
Aggregate productivity Vs output (Log)

Back



(a) No restrictions on factors

(b) All factors Low or High



(c) All factors Low or High, except ρ

(d) All factors Low or High, except μ

Growth regimes

Back

Institutional regulations that influence the design of markets and economic relations

How changes in labour relations, competition, international relations and trade, finance, and governance institutions have changed with technologies and the organisation of production in the 20^{th} century (Petit, 1999; Boyer, 2010)

$\sim$ varieties of capitalism (Hall and Soskice, 2001)

Firm's output

Back

Each firm produces one good, satisfying one consumer need (= sector), with price (i_p) and quality (i_q).

Output constrained by **labour** and **capital** (Leontief PF):

$$Q_t = \min \left\{ Q_t^d; A_{t-1} L_{t-1}^1; \bar{B} K_{t-1} \right\}$$

A_{t-1} is the labour productivity embedded in K vintages; $\frac{1}{\bar{B}}$ a constant capital intensity

Price is determined as a mark-up $m_{f,t}$ on variable costs (firm organisations/size (S-1) and labour productivity (S-2))

m_f increases from the minimum $\bar{m}$ when demand exceeds a firm's production capacity and reduces when inventories ($I_{f,t}$) exceed a desired ratio.

Factors of production: Labour

Back

S–1 Organisation of production

Demand for **first tier workers** $L_{1,f,t}$ adjusts to desired output and productivity.

Higher tiers workers co-ordinate a batch of ν subordinates

$$\begin{aligned} L_{2,f,t} &= L_{1,f,t}\nu^{-1} \\ &\vdots \\ L_{\Lambda_f,f,t} &= L_{1,f,t}\nu^{1-\Lambda} \end{aligned}$$

where Λ is the total number of firms' layers

Factors of production: Capital Stock

Back

All capital investment is financed with loans

$$k_f^d(t) = max\{min\{Y_f^L(t)\alpha_k; \left(Y_f^e(t) + \bar{B}L_f(t)\beta_k\right)(1+\upsilon)\} - Y_f^K(t); 0\}\bar{B}$$

υ: reserve; $\bar{B}$: K intensity.

Loan is granted with a probability proportional to the ratio between the cash available in the institution ($\Gamma(t)$) and the total value of the resources in the financial sector ($\Theta(t)$)

Investment increases the efficiency of production incorporating new capital vintages

$$A_t = \sum_{\tau=0}^{t} \frac{k_\tau(1-\delta)^{t-\tau}}{K_t} a_\tau$$

δ: depreciation; a_τ: vintage productivity

Factors of production: Capital Stock

Back

S–2 Production technology

Capital good firms innovate improving the productivity of the supplied vintages proportionally to profits/sales:

- **Spend** a share ρ_k of cumulated profits $\Pi_{g,t}$ to hire R&D engineers
- **Probability of success**: $\Phi_{g,t} = 1 - e^{-\zeta L_{0,g,t-1}}$
- New vintage's **productivity increase** depends on the variance of a stochastic variable: $\varepsilon^a_{g,t} \sim N(0; \sigma^a)$

Product innovation

Back

S–3 Product technology

A successful innovation is modelled as an increase in the quality $q_{n,f}(t)$ of the final good, within the same sector

R&D expenditure as a fixed share ρ of the moving average of expected sales: $R_{f,t} = \rho \bar{Y}^e_{f,t} \rightarrow$ innovation trials: $RT_{f,t} = log(1 + R_{ft})$ with a given probability χ of success

If a trial is successful, the new quality is

$$q^e_{f,t} \sim N(q_{f,t-1}; q_{f,t-1} * \sigma^q)$$

Industrial dynamics (competition)

Back

S–4 Entry and exit

A new firm enters in any final good sector with a probability ϑ

- highest quality on the market
- initial loan to acquire capital goods to produce
- low "visibility"

Firms exit when their estimated return on capital falls below ξ.

$$RoK_f(t) = \frac{\hat{\Pi}_f(t)}{\hat{K}_f(t)}$$

$\hat{\Pi}_f(t)$: profits' moving average;
$\hat{K}_f(t) = \sum_{j=t_f}^{t} [J_f^k(j) + J_f^l(j)]$
$J_f^k(j)$: loans for K goods; $J_f^l(j)$: loans for losses.

Income structure (wage/labour nexus)

Back

D–1 Income distribution

A **minimum wage** w_m is negotiated at the macro level

- labour market – wage curve
- adjusts with inflation (ϵ_P) and productivity shocks (ϵ_A)

Exponential wage structure along the organisational pyramid

$$w_{1,t} = \omega w_{m,t-1}$$
$$w_{2,t} = b w_{1,t}$$
$$\vdots$$
$$w_{\Lambda,t} = b_\Lambda w_{1,t}.$$

ω: minimum wage multiplier; b: executive multiplier

Executives receive **bonuses** ψ^I from **residual** profit shares $\pi\Pi_{f,t}$

Income structure: dividends

Back

D–1 Dividends

The savings used by firms in the form of loans are repaid to consumers in the form of dividends, proportional to the share of financial assets owned by the class in the previous period:

$$E_i(t) = R(t) * \frac{U_i(t-1)}{\sum_{j=1}^{\Lambda(t)} U_j(t-1)} \ , \forall i \in \{0; 1; ...; \Lambda(t)\}$$

$R(t)$: sum of firms' profits net of the wage bonuses and the R&D expenses.

Class disposable income

$$D_i(t) = W_i(t) + \Psi i(t) + E_i(t) \ , \forall i \in \{0; 1; 2; ...; \Lambda(t)\}$$

Income classes and evolution of consumption

Back

D–2 Consumption shares

Consumption level differ by **labour/income** class.

Each class i is populated by the workers of a corporation's tier (identical wage and bonus)

Consumers in a class also consume according to the same **expenditure shares** and **preferences**.

Expenditure shares $c_{i,n}$ change across classes: satiation

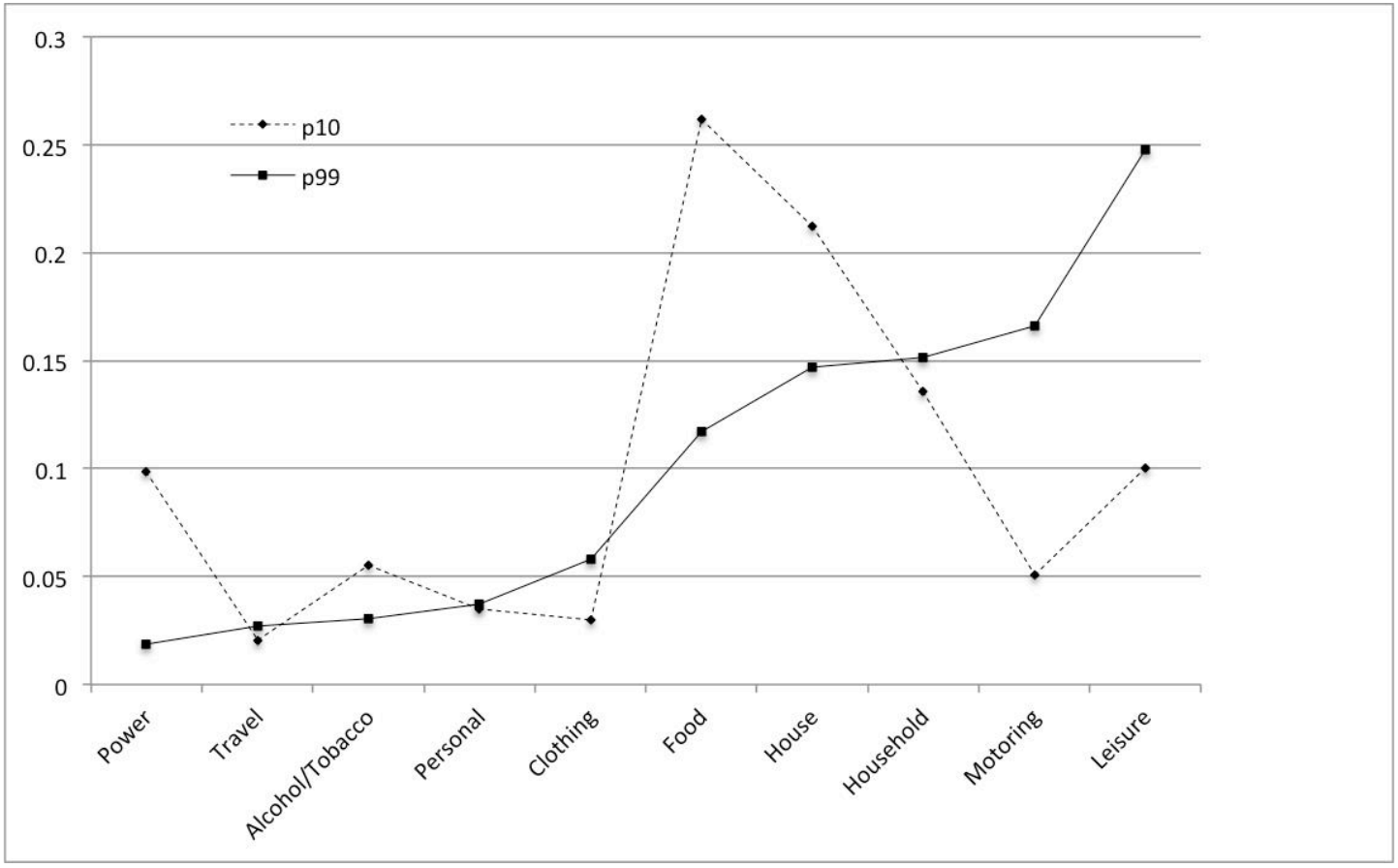
$$c_{i,n} = c_{i-1,n}\left(1 - \eta\left(c_{i-1,n} - \bar{c}_n\right)\right)$$

$\bar{c}_n$: an asymptotic value; η convergence (satiation) speed

- We assume a need = a consumption category

Large $\eta \rightarrow$ faster convergence to luxury goods

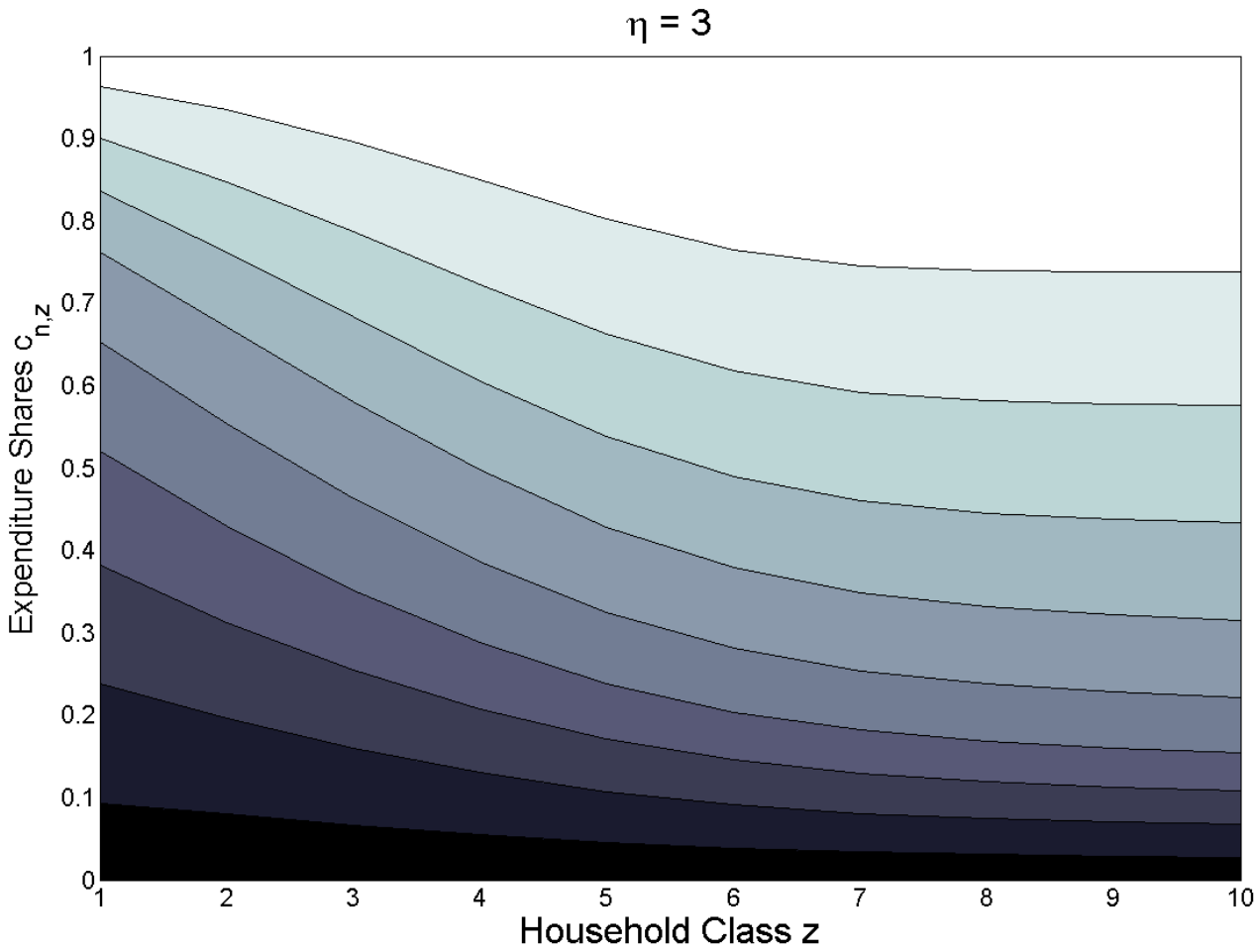
Expenditure shares: bottom ($c_{i,n}$, p10) and asymptotic ($\bar{c}_n$, p99)



Source: Own elaboration using UK FES

Init

Implicit Engel curves: evolution of consumption shares



Change in consumption share for $\eta = 3$ and ten consumer classes. In the model consumption classes emerge endogenously Init

Consumer behaviour (selection and consumption)

Back

For each need, given the **perceived** price/quality of a good $p^*_{f_n} = N(p_{f_n}, \sigma^p p_{f_n})$, a consumer selects all the firm**s** that offer a good with **equivalent** values and shares the demand

$$p^*_{f_n} \equiv p^*_{B_n} \Leftrightarrow |p^*_{f_n} - p^*_B| < (1 - \lambda_{p,i}) \cdot p^*_B$$

φ_i: selectivity; $p^*_{B_n}$: best price in the market

The **selectivity** with respect to *less–then–optimal* price/quality defines consumer class preferences.

From low to high income classes the selectivity towards good's *quality* increases, and *price* becomes relatively indifferent

$$\lambda_{p,i} = (1 - \eta_\lambda)\lambda_{p,i-1} + \eta_\lambda \lambda_{min} \quad (1)$$

$$\lambda_{q,i} = (1 - \eta_\lambda)\lambda_{q,i-1} + \eta_\lambda \lambda_{max} \quad (2)$$

Total purchases close the model: firms sales.

Financial sector

Back

Stock-flow: the value of all the financial assets owned by households is identical to the value of all assets stored in the financial institution ($\Theta(t)$).

$$\Theta(t) = \Gamma(t) + \sum_{k=1}^{F+G} \hat{K}_k(t)$$

Cash

$$\Gamma(t) = \Gamma(t-1) + \sum_{i=1}^{\Lambda} S_i(t) - \sum_{k=1}^{F+G} J_k^l(t)$$

Loans

$$\sum_{k=1}^{F+G} \hat{K}_k(t) = \sum_{k=1}^{F+G} \hat{K}_k(t-1) + \sum_{k=1}^{F+G} J_k^l(t) - \sum_{k \in W(t)} \hat{K}_k(t)$$

Financial sector

Back

Households' dividends to a class is the share of distributed profits proportional to the share of the assets owned by the class

$$E_i(t) = (1 - \pi - \rho) \sum_{i=f}^{F} \Pi_f \frac{U_i(t)}{\sum_{j=1}^{\Lambda(t)} U_j} + (1 - \pi - \rho_g) \sum_{i=g}^{G} \Pi_g \frac{U_i(t)}{\sum_{j=1}^{\Lambda(t)} U_j}$$

Where the price of an asset is the ratio between the total value of the financial sector $\Theta(t-1)$ and the number of financial assets

$$P_u(t) = \frac{\Theta(t-1)}{\sum_{i=1}^{\Lambda} U_i(t-1)}$$

Parametrisation and empirical evidence

Parameter	Description	Value	Data
α	Adaptation of sales expectations	0.9	–[a]
ϕ	Desired ratio of inventories	0.1	[0.11 - 0.25][b]
υ	Unused labor/capital capacity	0.05	[0.042 - 0.075][c]
υ_g	Unused labor capacity in the capital sector	0.2	[0.042 - 0.075][c2]
$\bar{m}$	Minimum mark-up	0.15	[0-0.28]; [0.1, 0.28]; [0.1, 0.39][a]
μ	Mark-up variation	0.3	[0-0.28]; [0.1, 0.28]; [0.1, 0.39][a]
$\bar{m}_g$	Mark-up in the capital good sector	0.2	[0-0.28]; [0.1, 0.28]; [0.1, 0.39][a]
δ	Capital depreciation	0.001	[0.03, 0.14]; [0.016, 0.31][e]
$\frac{1}{\bar{B}}$	Capital intensity	0.5	$\bar{B} = [1.36, 2.51]$[f]
ϵ	Labor market friction	0.3	0.6; [0.6, 1.5]; [0.7, 1.4]; [0.3 1.4][g]
ω	Minimum wage multiplier	1.6	[1.6, 3.7][h]
b	Executives wage multiplier	1.6	[1.5, 2][h]2analysed
ω_0	Engineers' wage multiplier	2	[1.2, 1.4][h]3
π	Profits shared as bonuses	0.15	–[i] analysed
ν	Tier multiplier	3	[2, 7][j]

Parametrisation and empirical evidence

Parameter	Description	Value	Data
η_λ	λ inter-class multiplier	0.25	[-0.8, 2.4][k], analysed
$\lambda_{min} = \lambda_{q,1}$	Lowest selectivity = first tier quality selectivity	0.85	–[l]
$\lambda_{max} = \lambda_{p,1}$	Highest selectivity = first tier price selectivity	0.95	–[l]
η	Convergence to asymptotic consumption shares	0.4	analysed
ρ	R&D investment share in final good sectors	0.2	[0.01-0.231][m]
ρ_g	R&D engineers share in capital good sector	0.1	[0.01-0.231][m]
ζ	Probability of process innovation success	0.01	[0.07, 0.18]; [0.013, 0.198][n]
χ	Probability of product innovation trial success	0.05	[0.07, 0.18]; [0.013, 0.198][n]
Ξ	Min. interval between two successful innovations	10	–
σ^a	Standard deviation productivity shock	(0.015, 0.004)	–[o]
σ^q	Standard deviation product quality innovation	0.01	–[o1]

Parametrisation and empirical evidence

Parameter	Description	Value	Data
$\bar{c}_n$	Asymptotic consumption shares	_+,x1	_+,p1
$c_{1,n}$	First class consumption shares	_+,x2	_+,p2
ς	Increase in saving rate across income classes	0.2	_q
$1-\gamma$	Expenditure smoothing parameter	0.2	[.04, .14]; [.06, .19]r
ϵ_U	Wage curve unemployment pressure	0.1	0.1s
ι	Error in the consumer's evaluation of characteristics	p: 0.05; q: 0.1	_t
β	Beveridge curve parameter	20	[6, 10]u
Υ	Beveridge curve constant	0.2	_u
ϵ^P	Wage curve inflation elasticity	1	analysed
ϵ^A	Wage curve productivity elasticity	1	analysed
Ω^A	Increase in average productivity for wage renegotiations to occur	0.0001	_w

Init2

Parametrisation and empirical evidence

Parameter	Description	Value	Data
Ω^P	Increase in average price for wage renegotiations to occur	0.0001	$\_^w$
ϑ	Probability of firm entry in a sector	0.08	– analysed
a	Smoothing parameter of profits moving average	0.95	–
α_k	Labour multiplier in capital investment decision	10	–
β_k	backlogs absorption in capital investment decision	0.1	–
ϱ	Atkinson index inequality aversion	0.5	–

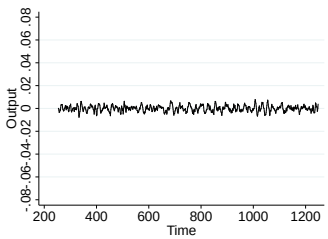
Init2

Parametrisation and empirical evidence

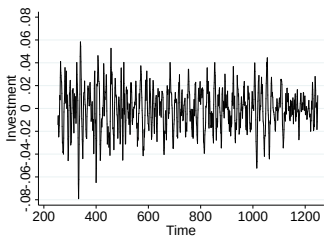
[a]Empirical evidence not available: the parameters has no influence on the results presented here. [b]U.S. Census Bureau (2008); Bassin et al. (2003). [c]Coelli et al. (2002) with reference to the 'optimal' unused capacity for labour (low value) and to the average ratio between technical efficient production and ray economic capacity in the airline industry. [c]2 Larger than in the consumer good sector, due to the lumpiness of orders for capital goods (Doms and Dunne, 1998). [d]Marchetti (2002); De Loecker and Warzynski (2009); Joaquim Oliveira et al. (1996). [e]Nadiri and Prucha (1996); Fraumeni (1997) non residential equipment and structures. We use the lower limit value (the lower value reflects the assumption that in our model one simulation step represents approximately the dynamics of a fortnight (one year is 24 steps). [f]King and Levine (1994). [g]Vacancy duration (days or weeks) over one month: Davis et al. (2010); Jung and Kuhn (2011); Andrews et al. (2008); DeVaro (2005). [h]Ratio with respect to the average wage (not minimum) in OECD countries Boeri (2009). [h2]Simon (1957). [i] With reference to qualitative evidence from various sources. [h3]Relative to all College Graduates and to accountants Ryoo and Rosen (1992). We set the parameter to a higher value to differentiate engineer's compensation from shop-floor workers'. [j]Simon (1957). [k]Change of price selectivity for food product categories (Zheng and Henneberry, 2011) (inverted signs, as we use the change in selectivity rather than in price elasticity). [l]Empirical evidence not available to our knowledge: based on qualitative evidence. [m]Hernández et al. (2015). We use a ratio close to the high end of high tech sectors. [n] Respectively Hay et al. (2014) and Pammolli et al. (2011) on the pharma industry from phase I to approval. For product innovation we take a lower bound value, given that the pharma industry is particularly innovative. For process innovation (capital good sector) we take a lower value.

[o]Empirical evidence not available to our knowledge. Extensive analysis of this parameter has was done in past models (Ciarli et al., 2012), and is left for future work on this model. The two values refer, respectively, to the validation and the regimes analysis. We reduce variance in the analysis of regimes substantially in order to limit the effect due to stochastic shocks. [o1]Empirical evidence not available to our knowledge. [p1]We use the UK Family Expenditure Survey (FES) to compute the consumption shares across the ten aggregate consumption categories for the top centile of UK consumers (p99 in Figure). [p2]We use the UK FES to compute the consumption shares across the ten aggregate consumption categories for the bottom decile of UK consumers (p10 in Figure). Gervais and Klein (2010). [q]Based on the evidence on the increase in the saving rate by income quintile in Dynan et al. (2004). [r]Krueger and Perri (2005). [s]We implement the estimated wage equation in logs and use the widely estimated parameter (Nijkamp and Poot, 2005; Blanchflower and Oswald, 2006). [t]Specific empirical evidence not available to the best of our knowledge. Parameters set using the qualitative evidence in Zeithaml (1988) and the findings summarised in Rotemberg (2008). [u]Estimates from Börsch-Supan (1991). Most empirical exercises test a linear or quadratic form of the Beveridge curve (Wall and Zoega, 2002; Nickell et al., 2002; Teo et al., 2004; Bouvet, 2012) – a mean value of these estimates is found in Fagiolo et al. (2004). For modelling purposes the hyperbolic form is more convenient, but estimates are a bit outdated, so we adapt them using the more recent papers covering several countries. The constant Υ is meant to avoid extreme asymptotic values. [w] We assume a nearly continuous adjustment. *Endogenous. +Various

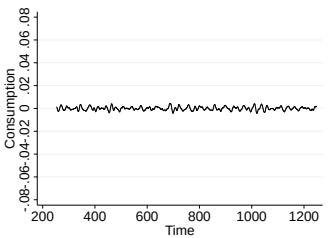
Feedbacks between innovation and demand dynamics generate business cycles



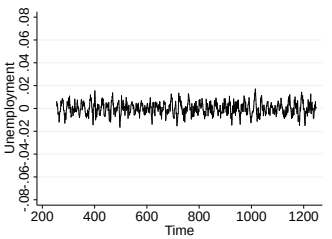
(a): Output



(b): Investment

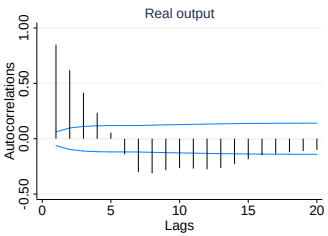


(c): Consumption

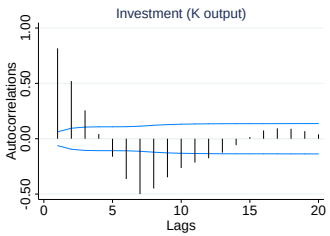


(d): Unemployment

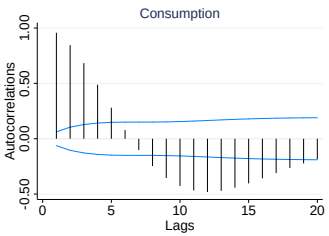
Autocorrelation of the main macro variables



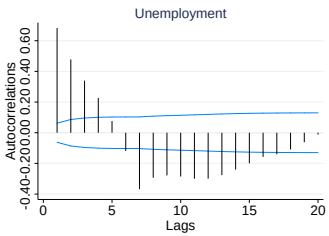
(a): Output



(b): Investment

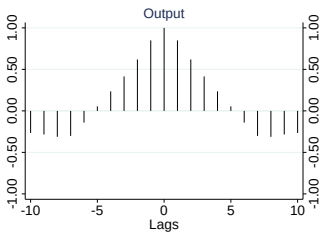


(c): Consumption

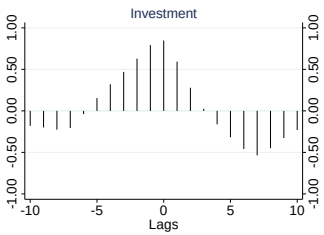


(d): Unemployment

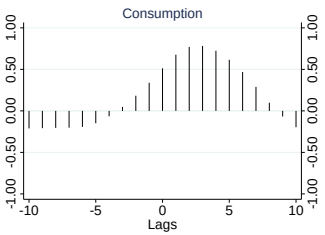
Crosscorrelation between the cyclical component of output and the main macro variables



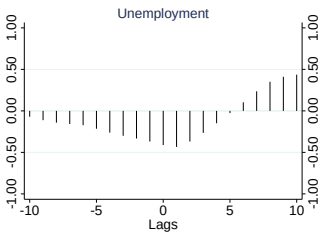
(a): Output



(b): Investment

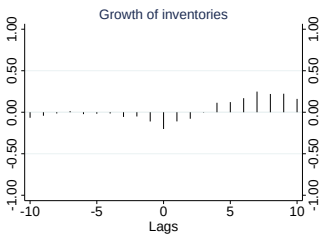


(c): Consumption

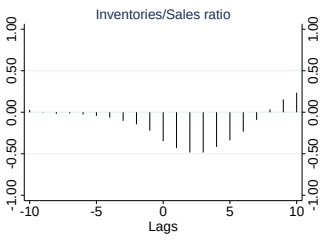


(d): Unemployment

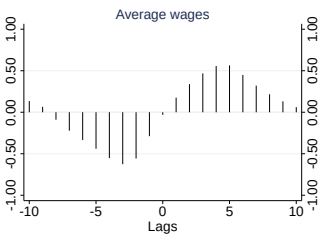
Crosscorrelation between the cyclical component of output and other aggregate variables



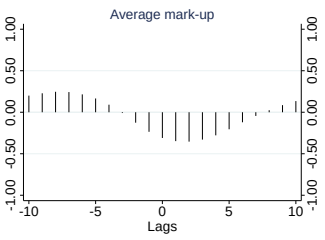
(a): Inv Gr.



(b): Inv. Ratio

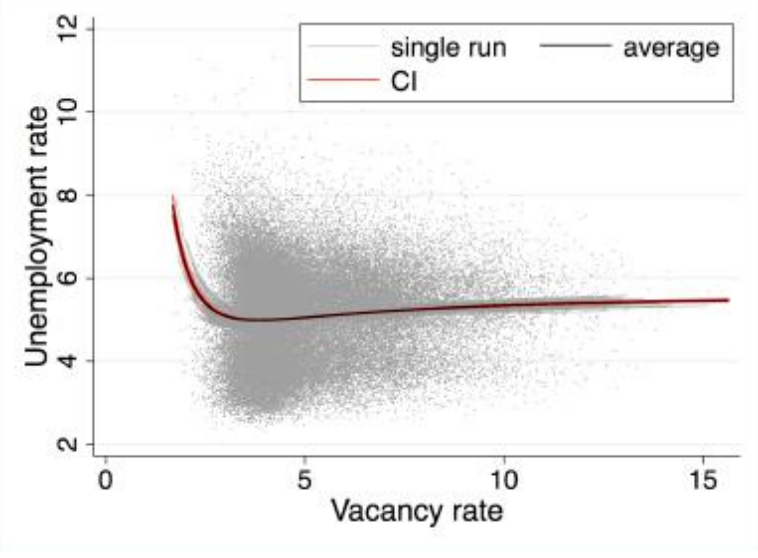


(c): Wages

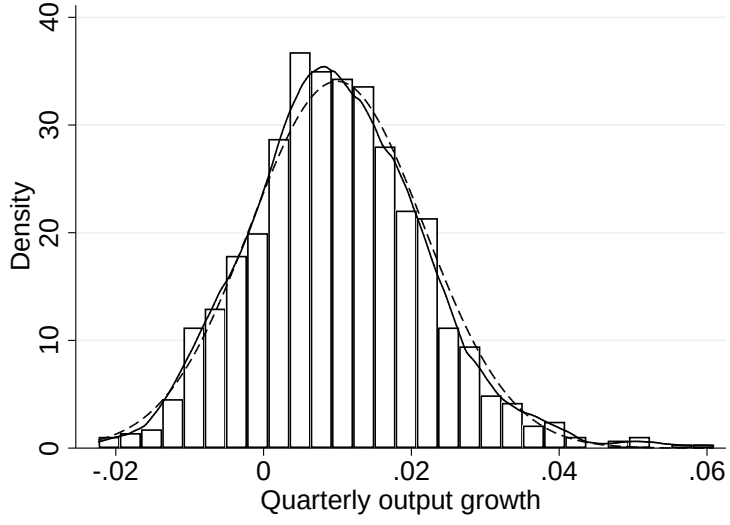


(d): Markup

Beveridge curve and output growth rate distribution



(a): Beveridge

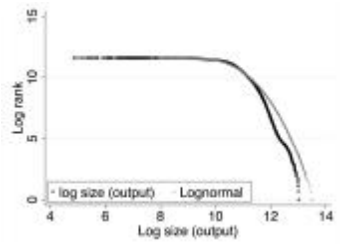


(b): Output growth rate distribution

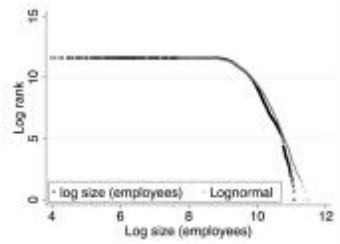
Wage curve

VARIABLES	(1) Wage (log)
Unemployment (Log)	-0.14***
	(0.05)
Prod Index	0.00***
	(0.00)
CPI	0.02***
	(0.00)
Constant	4.21***
	(0.22)
Observations	100,100
Number of id	100
R-squared	0.98
within R^2	0.981
F	64662
Prob > F	0

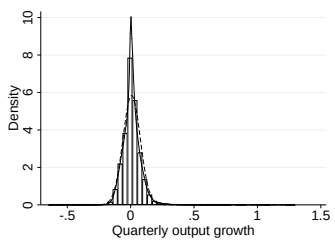
Log-log plot of firm size distribution



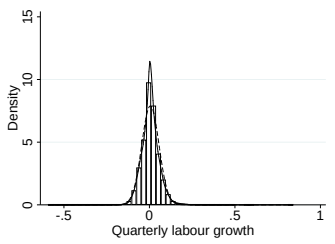
(a): Output



(b): Employment

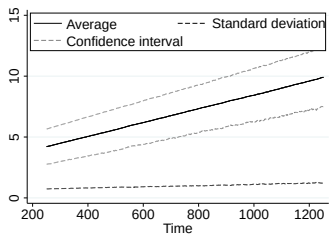


(c): Gr output

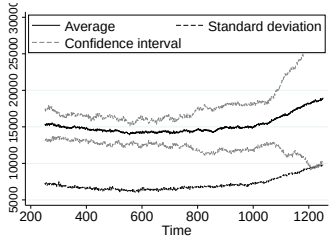


(d): Gr emp

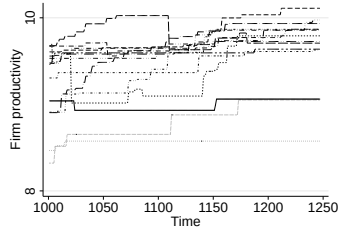
Firm productivity, capital, and size



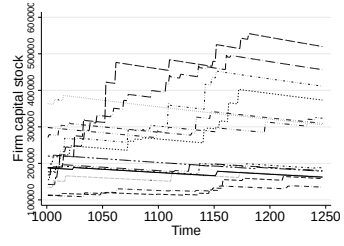
(a): Prod



(b): Size



(c): Prod 14 firms



(d): K: 14 firms

(Exp. Design) (Growth regimes)

Wage-labour nexus

		b				
		1,4	1,5	1,6	1,7	1,8
	0,1	0,134***	0,157***	0,185***	0,216***	0,249***
	0,15	0,139***	0,163***	*0,189*	0,219***	0,253***
π	0,2	0,144***	0,167***	0,193***	0,223***	0,256***
	0,25	0,149***	0,173***	0,198***	0,228***	0,261***
	0,3	0,155***	0,176***	0,202***	0,229***	0,262***
	0,35	0,159***	0,181***	0,206***	0,234***	0,266***

		b				
		1,4	1,5	1,6	1,7	1,8
	0,1	4864020***	4235668***	4011631**	3683588	3376438**
	0,15	4661710***	4203255***	*3759496*	3394171***	3280909**
π	0,2	4654574***	3987314*	3519672***	3335034***	3179175**
	0,25	4305037***	4070668*	3631770	3280466***	3074743**
	0,3	4439873***	3781925	3428948**	3108936***	2915391**
	0,35	4187097***	3697132	3257111***	3058699***	2824506**

Wage-labour nexus (Back)

		b				
		1,4	1,5	1,6	1,7	1,8
ϵ^A; ϵ^P	1	0,139***	0,163***	*0,190*	0,220***	0,254***
	0,95	0,139***	0,163***	0,190	0,220***	0,254***
	0,9	0,139***	0,164***	0,189	0,219***	0,256***
	0.85	0,139***	0,163***	0,189	0,219***	0,253***
	0,8	0,140***	0,162***	0,190	0,219***	0,254***
	0,75	0,140***	0,162***	0,189	0,219***	0,253***

		b				
		1,4	1,5	1,6	1,7	1,8
ϵ^A; ϵ^P	1	4740017***	4369584***	*3820829*	3416749,5***	3271559***
	0.95	4745794***	4230409***	3816053	3394517***	3264894***
	0.9	4596226***	4265252***	3715884	3549755***	3278798***
	0.85	4595772***	4156223***	3717243	3526538***	3280086***
	0.8	4846935***	4109146***	3835208	3451350***	3247899***
	0.75	4999338***	4167746***	3660339,5**	3469940***	3303616***

Norms of competition (Back)

		ϑ				
		0.06	0.07	0.08	0.09	0.1
	$0.72\overline{5}; 0.27\overline{5}$	0,196***	0,194***	0,193***	0,192***	0,192***
	$0.77\overline{5}; 0.22\overline{5}$	0,193***	0,193***	0,191***	0,189	0,188
$\lambda_{p,1}$;	$0.82\overline{5}; 0.17\overline{5}$	0,191***	0,191**	*0,189*	0,186***	0,185***
$\lambda_{q,1}$	$0.87\overline{5}; 0.12\overline{5}$	0,189	0,187*	0,186***	0,185***	0,183***
	$0.92\overline{5}; 0.07\overline{5}$	0,187**	0,186***	0,184***	0,182***	0,182***
	$0.97\overline{5}; 0.02\overline{5}$	0,186***	0,184***	0,183***	0,182***	0,181***

		ϑ				
		0.06	0.07	0.08	0.09	0.1
	$0.72\overline{5}; 0.27\overline{5}$	3437995***	3750586***	4037649	4475096***	5066091
	$0.77\overline{5}; 0.22\overline{5}$	3330494***	3823845**	4147320	4244693	4757535
$\lambda_{p,1}$;	$0.82\overline{5}; 0.17\overline{5}$	3259839***	3731741***	*4094730*	4179639	4659407
$\lambda_{q,1}$	$0.87\overline{5}; 0.12\overline{5}$	3230594***	3570274***	4044367	4312567**	4694119
	$0.92\overline{5}; 0.07\overline{5}$	3136186***	3501718***	3917487*	4200508	4742372
	$0.97\overline{5}; 0.02\overline{5}$	3156582***	3461134***	3908788*	4431726	4821741

Norms of consumption (Back)

		η_λ 0.2	0.23	0.25	0.27	0.3
	0.3	*0.1880*	0.1885	0.1880	0.1890	0.1897
	0.35	0.1889	0.1884	0.1886	0.1903*	0.1903**
η	0.4	0.1889	0.1886	*0.1886*	0.1896	0.1902**
	0.45	0.1878	0.1879	0.1888	0.1898	0.1899*
	0.5	0.1881	0.1880	0.1886	0.1902*	0.1899

		η_λ 0.2	0.23	0.25	0.27	0.3
	0.3	3740007	3699658	3706482	3726182	3633038
	0.35	3970438***	3800109	3823381*	3783792	3921054***
η	0.4	3723198	3645007	*3653136*	3737845	3775070*
	0.45	3722838	3700330	3788916	3797486*	3732221
	0.5	3847599**	3780407	3798296*	3841521**	3752458

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