Biased Technological Change Direction and Intensity: a Macro-funded Local Adaptive Dynamics Analysis

Rodrigo Kataishi, Ph.D.

Universidad Nacional de Tierra del Fuego
Instituto de Desarrollo Económico e Innovación
Investigador CONICET

Córdoba, Argentina - 2018

- This is a work based on **macro-trends** and aggregated data.
- We know how the firm behaves, but there is a **lack of contribution on the macro-dimmension**.
- The main interest of this work is focused on the study of **Productivity trends** and **Technological Change**.
- Develope the **biased technological change (A&Q's) concept** and discuss it.
- Using the available data contribute to the study of the **local dynamics through a macro perspective**.

- Specific Objetives:
  - Discuss the nature of productivity dynamics
  - Relax the assumptions used in the traditional approach
  - Derive the Biased Technological Change concept. Discuss directionality and intensity (contribution of this work).
  - Explore the BTC intensity and direction at country, sector-level for 1973-2005. Explore the determinants of the BTC with two sets of econometric models.

- This is a work based on **macro-trends** and aggregated data.
- We know how the firm behaves, but there is a **lack of contribution on the macro-dimmension**.
- The main interest of this work is focused on the study of **Productivity trends** and **Technological Change**.
- Develope the **biased technological change (A&Q's) concept** and discuss it.
- Using the available data contribute to the study of the **local dynamics through a macro perspective**.

- **Specific Objetives**:
    - **Discuss the nature of productivity dynamics**
    - **Relax the assumptions used in the traditional approach**
    - **Derive the Biased Technological Change concept. Discuss directionality and intensity (contribution of this work).**
    - **Explore the BTC intensity and direction at country, sector-level for 1973-2005. Explore the determinants of the BTC with two sets of econometric models.**

The Staring Points

Putting some framework for the rest of this work: “Faith Jumps”

- Macroeconomics exits! -> Economies can be compared through time
- We can aggregate data and study average trends
- We can say something about productivity with that data

Then, about productivity:

- It is a measurable process
- It contemplates several assumptions
- Its measurement is a standardized process
  - Lots of discussion surrounding the traditional approach
  - Lack of concensus surrounding alternative measurements, dispersion of efforts and radical criticism limit the raise of new approaches
  - The value of standards to compare international dynamics

Basics on Productivity

- Inter-temporal indicator: measures changes from one period to the other
- Given a productive structure, the ammount of output vary
- The variation of the output can be attributed to different factors, but
- The most diffused arguments refer to technological aspects as determinants of output variation
- The most simple case can be analyzed with only two factors (labor and capital) in a complementary relation, but of course, is not the *only approach** (although it is the simpler by far)

**Alternative Approaches:* Ommited variables within Production Function (MFT) | Alternative Production Dynamics (CES) | Alternative Production Relations (Endogenous growth). The first two are related to this work. For simplicity, the conceptual case developed here is simpler, but able to include both arguments.

Formal aspects of productivity.

Example

A simple production relation:

$$Q_t = F(K, L, t) = A(t)f(K_{(t)}, L_{(t)}) = A_{(t)} L^{\beta}_{(t)} K^{\alpha}_{(t)}$$

$$\Delta Q \Rightarrow = \Delta A_{(t)} \overline{L^{\beta} K^{\alpha}}$$

$$\Delta Q \Rightarrow = \underbrace{A_{(t)}} \overline{L^{\beta} K^{\alpha}}$$

$A_{(t)}$ is exogenous. It is an inter-temporal difference. It is a *raw indicator on productivity shifts*. Is the so called "Solow's Residual". It is able to measure technological change IF technology is neutral.

From a technological point of view, there is an effect that is not considered:

- Given an exogenous technological shock, the modifications **will affect not only** $A_{(t)}$ **but also** α **and** β.

Example

$$Q = F(K, L, t) = A(t)f(K_{(t)}, L_{(t)}) = \underbrace{A_{(t)}} L^{\beta}_{(t)} K^{\alpha}_{(t)}$$

- Why?: New technologies imply new relations with factors and their capacity to produce.
- The traditional measurement of $A_{(t)}$ does not contain the complete effect of the **technological change.** It assumes Neutrality.
  - The inter-temporal modifications of α and β are not contemplated in the traditional approach. This effect was ommited through time until Acemoglu (1998) and Antonelli and Quatraro (2011, 2014).
  - The relaxation of neutrality assumptions are the focus of the BTC analysis

Motivating the Bias research:

The Technological Change problem

$$Q = F(K, L, t) = A(t) f(K_t, L_t) = \underbrace{A_{(t)}} K_t^{\alpha} L_t^{\beta}$$

- Technological shifts as theoretical - empirical comparisons.
- Technology is neutral

- **Given a technological shock, the effect can be divided in two components:**
  - A modification on the general purpose production techniques. **Represented by $A_{(t)}$, which is the shift effect** (*and accounts for the complete effect of technological change if technology is neutral*).
  - If technology is not neutral, then **the shock imply changes in factors' output-elasticities too. This is the Bias effect.**

Motivating the Bias research:

The two effects on Technological Change

$$Q = F(K, L, t) = A(t)f(K_t, L_t) = \underline{A_{(t)}} \overbrace{K_t^{\alpha} L_t^{\beta}}$$

- The Bias effect complements the shift effect
- It gives information on the changes in output elasticities in relation with the factoral dotation

- Stylized implications:
  - α ,β, L and K gives information on how the technological shock impact on productive relations
  - These relations are adaptive and complement the shift effect
  - These dynamics can take place only at the local level
  - If the bias effect is zero, then the technological shock is neutral (and Solow's TFP holds)

The research questions are:

- According to the empirical evidence, how pertinent is the BTC study?
  - are output elasticities variable over time?
  - is technological change always neutral?
  - What are the Bias dynamics?
- What imply and what are the **determinants** of the **BTC direction**?
- What imply and what are the **determinants** of the **BTC Intensity**?
- What are the general implications of the use of these indicators?

- **Solow's Techonological Change**:

Starting from $Y_{i,t} = A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{\beta}$, then $A_{i,t} = \frac{Y_{i,t}}{K_{i,t}^{\alpha} L_{i,t}^{\beta}}$, so:

Total Factor Productivity

$$log(A_{i,t}) = log(\dot{Y}_{i,t}) - \alpha_{i,t} log(\dot{K}_{i,t}) - \beta_{i,t} log(\dot{L}_{i,t})$$

- The log transformation allows to explore the technological change as the empirical residual of total factor productivity.

then, according to Euler's theorem: $\beta_{i,s,t} = \frac{P_L L}{Y} = \frac{w_{i,s,t}.L_{i,s,t}}{Y_{i,s,t}}$,
The framework assumes CRS, so $\beta_{i,t} = 1 - \alpha_{i,t}$

- Given a shock, the technological effect can be divided in two components:
  - The shift of the isoquants, represented by $A_{i,t}^{Solow}$
  - The shape of the isoquants, represented by the BTC, $A_{i,t}^{bias}$

If $A_{i,t}^{bias}$ can be isolated, then:

- That technological change is not necessarily neutral
- That factor output elasticities change over time and region
  - That these adaptive processes are necessarily local, since K_i and L_i are context specific.

- The problem: how to isolate the bias?

- **Bias Technological Change estimation:**
  - The BTC is estimated using an indicator built with **fixed output elasticities**
  - $A_{i,t}^{Fixed}$ **estimates technological variation as if the output-elasticities had not changed over time** (with α, β fixed on $t = 0$) capturing the total effect of technological change

The difference between $A_{i,t}^{Fixed}$ and $A_{i,t}^{Solow}$ is able to isolate the bias effect

1. $$A_{i,t}^{Solow} = \frac{Y_{i,t}}{K_{i,t}^{\alpha_{i,t}} L_{i,t}^{\beta_{i,t}}}, \; \alpha \text{ and } \beta \text{ vary on } t$$
2. $$A_{i,t}^{Fixed} = \frac{Y_{i,t}}{K_{i,t}^{\alpha(\overline{t_0},i)} L_{i,t}^{\beta(\overline{t_0},i)}}, \; \alpha \text{ and } \beta \text{ are fixed at } t_0$$
3. $$A_{i,t}^{Fixed} - A_{i,t}^{Solow} = A_{i,t}^{Bias}$$

Some implications on $A_{i,t}^{Fixed} - A_{i,t}^{Solow} = A_{i,t}^{Bias}$

- the null value $A_{i,t}^{bias} = 0$ takes place when output elasticities doesn't change over time. It is Solow's case of neutral technology.
- $A_{i,t}^{bias}$ is an indicator that vary above and below zero

- The **direction** of the bias depends on its sign, such that:

$$\begin{cases} \Delta BTC = 0, & \textit{Neutral Adaptation} \quad \Rightarrow \Delta\beta = \Delta\alpha = 0 \\ \Delta BTC > 0, & \textit{Coherent Adaptation} \quad \Rightarrow \Delta\frac{L}{K} > 0 \textit{ and } \Delta\beta > 0 \\ & \Rightarrow \Delta\frac{L}{K} < 0 \textit{ and } \Delta\beta < 0 \\ \Delta BTC < 0, & \textit{Non Coherent Adaptation} \quad \Rightarrow \Delta\frac{L}{K} > 0 \textit{ and } \Delta\beta < 0 \\ & \Rightarrow \Delta\frac{L}{K} < 0 \textit{ and } \Delta\beta > 0 \end{cases}$$

- The **intensity** of the bias depends on the distance to zero.

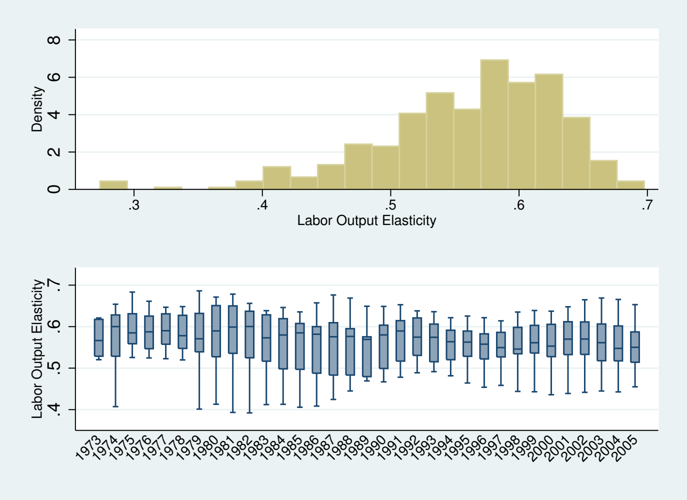
The data:

- KLEMS Database (EUKLEMS)
  - 102 Sectors Productivity data and Economic performance detailed in 60 variables (1970-2005) for 34 Countries (OECD)
- Stan-OECD Database
  - 307 variables at national level for 38 countries (1970-2011)
- World Developent Indicators
  - 315 variables at National Level (life conditions, socio-economic, market and labor data) (1960-2005) for 215 countries
- UNESCO Indicators on education
  - Historical trends on educational indicators (1970-2011)
- **Database combining KLEMS+STAN+WDI+UNESCO:**
  - Detailed data for this work: 13 countries from 1973-2005 (ISIC rev. 3, PPP - 2005 at sector level)

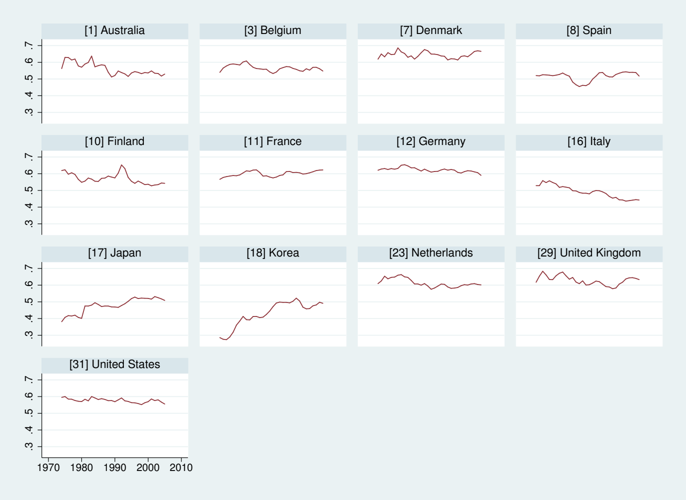
Productivity, Labor Output Elasticity and Income per-capita over time and country.

Countries	Period 1973-1985			Period 1986-1995			Period 1995-2005		
	TFP Index	LOE	Y/L	TFP Index	LOE	Y/L	TFP Index	LOE	Y/L
Australia	1.578434	.5353162	86.42334	1.501543	.5368392	62.61677	1.21056	.5974367	25.83666
Belgium	1.411428	.5558003	72.13943	1.344253	.5573222	50.91661	1.15923	.5787216	24.49079
Denmark	1.332776	.6486163	423.9943	1.288689	.6456023	300.4703	1.134518	.6444869	138.8483
Spain	2.218234	.5306762	45.03414	2.076972	.4974126	30.34919	1.462146	.515945	9.391023
Finland	1.955864	.5416538	62.95258	1.791274	.587758	38.59437	1.378104	.5796584	15.4768
France	1.440428	.6116759	59.60337	1.395652	.5924944	47.65792	1.162934	.5979054	21.05193
Germany	1.280618	.6072135	54.8773	1.215992	.6197691	40.47454	1.080087	.6342067	23.79358
Italy	2.171076	.4458515	61.42938	1.9830	.4862166	37.80574	1.422708	.529206	11.07388
Japan	1.046568	.5198265	85.75852	1.085054	.4874466	83.40566	1.054056	.4409441	53.97445
Korea	1.717608	.4864727	41.84095	1.5613	.4732701	175.0383	1.274825	.355302	43.76594
Netherlands	1.289054	.5978549	52.51111	1.216983	.5938779	39.4917	1.11384	.6371915	27.11373
U.K.	2.065573	.6239046	37.05063	1.902748	.6082837	23.41537	1.35645	.6496711	8.089779
United States	1.326672	.5657875	76.34059	1.250145	.5748247	52.5932	1.107642	.5849698	29.29434

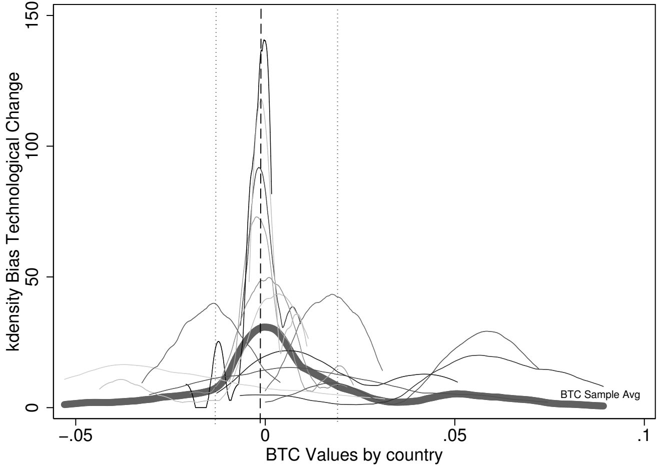
Non constant nor statics Labor Output Elasticities dynamics.



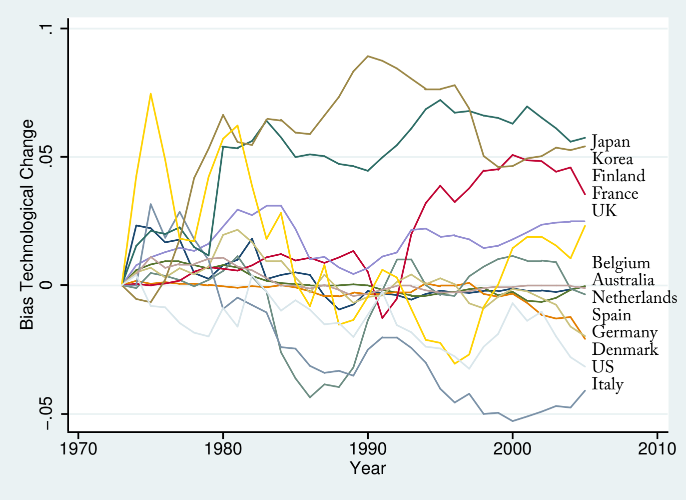
Labor Output Elasticities over time, by country.



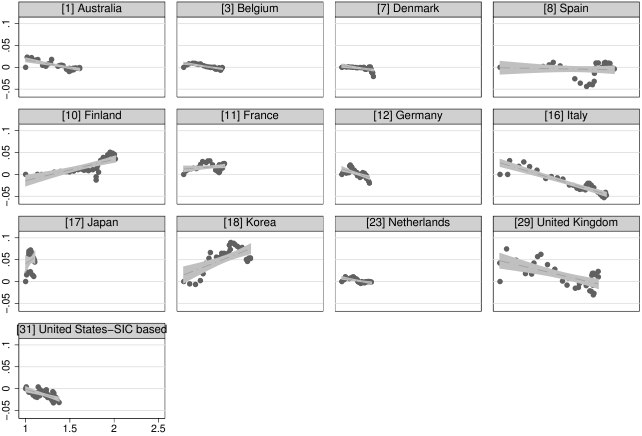
Empirical Evidence on the Neutral Technological Change



Empirical Evidence on the Biased Technological Change



Bias and Solow's Technological Change



BTC by TFP Index by Country

Summarizing:

- Factor output elasticities are not fixed over time and country
- Neutral Technological Change is not the general case
- Biased Technological Change vary over time and country
- The BTC and TFP relation depends on each economy

If the bias is theoretically and empirically relevant, then what are its determinants?

Discussion on the determinants of the BTC direction

- **Factor Output Elasticities:**
  - Are local, change in time and have information on the capabilities and efficient use of factors
  - It is an exploratory relation based on technological dynamics
- **Income per-capita:**
  - Structural and wealth related indicators are expected to influence the bias trends
  - It is an exploratory relation based on structural dynamics
- **Previous founds:**
  - Patents, with negative relation (or not significant).
  - Wages, as price signaling on the output elasticities and factor allocations.
  - Education level, as a labor characteristic.

Empirical Strategy:

- Take advantage of the strongly balanced panel data
  - Avoid simultaneity problems making use of self-instrumented variables
  - Be able to restrict structural relations based on time-lags
- Implement a set of models (instead of one) to add robustness to the results
- **Selected Strategy: a set of Fixed Effects models**

The raw setup (intuition purposes only):

$$A^{bias}_{t,i} = \beta_1 \, loe_{(i,t)} + \beta_2 \, y/l_{(i,t)} + [\beta_x \, X_{(i,t)}] + \eta_i + \tau_t + \epsilon_{i,t}$$

$loe_{(i,t)}$: stands for Labor Output Elasticities
y/l: income per-capita
X: set of control variables
η_i: country fixed effect
τ_t: time fixed effect

- To solve simultaneity: time-lags λ imposing exogeneity by construction
- To avoid ommited variable bias: complete set of controls based on previous research

The structured specification:

$$A_t^{bias} = \beta_1\, loe_{(i,t-\lambda_1)} + \beta_2\, y/l_{(i,t-\lambda_2)} + \beta_3\, w_{(i,t-\lambda_3)} +$$

$$+\beta_4\, T.E.P_{(i,t-\lambda_4)} + \beta_5\, \Delta T.E.P._{(i,t-\lambda_5)} + \beta_6\, Pat_{(i,t-\lambda_6)} +$$

$$+\eta_i + \tau_t + \epsilon_{i,t}$$

$loe_{(i,t)}$: stands for Labor Output Elasticities
y/l: income per-capita
w:local wages
$T.E.P_{i,t}$: is the proportion of population with tertiary education
$DeltaT.E.P._{i,t}$: tertiary educated people growth
$Pat_{i,t}$: patents creation per-capita
η_i: country fixed effect
τ_t: time fixed effect

Results:

Variable	λ	ARMA-FE(1)	ARMA-FE(2)	ARMA-FE(3)	ARMA-FE(4)	ARMA-FE(5)
LOE	*1*	.30767288**	.26117984*	.26275519*	.27578383*	.2791132**
Y/L	-	-.371107*	-.849607*	-.102306**	-.141006*	-.779107*
	1			.0001917	.006767	.0003239
w	*2*	-.00041677	-.00199682	-.00185753		.00038965
	3	.00070776	.00272191*	.00257459*	.00064624	
T.E.P.	*1*	-.0526			-0,06155	
Δ*T.E.P.*	*2*		-0,000005232	-0,000005229		-.559009*
Patents p.c.	*1*		.00670819	.00649841	.00285513	
_cons		-.15602108**	-.11463721	-.11568707	-.12669465	-.14814135**

Discussion on the determinants of the BTC Intensity

- Measures the non-neutral effect of technological change
- The greater the distance from zero, the higher the bias intensity effect (i.e. $D^{bias} = |A^{bias}|$)
- It accounts for the local adaptations instead of the general purpose technology shifts

Determinants:

- No previous estimations
- **Intuitions on the explanatory variables:**
    - **Patents**
    - **Income per-capita**
    - **Technological profile**
    - **Output elasticities**

- The strategy varies:
  - is a two-steps System-GMM
  - It involves several autoregressive terms
- To impose exogeneity by construction: time-lags λ

The structured specification:

$$D_t^{bias} = \beta_1 \, log(D^{bias})_{(i,t-\lambda_1)} + \beta_4 \, log(y/l)_{(i,t-\lambda_4)} +$$

$$+\beta_5 \, log(Pat)_{(i,t-\lambda_5)} + \beta_2 \, log(Y_{low})_{(i,t-\lambda_2)} + \beta_3 \, loe_{(i,t-\lambda_3)} +$$

$$+\beta_6 \, log(Y_{high})_{(i,t-\lambda_6)} + \eta_i + \tau_t + \epsilon_{i,t}$$

y/l: income per-capita
$Pat_{i,t}$: patents creation per-capita
Y_{low}:share of low-tech sectors on gdp
Y_{high}: share of high-tech sectors on gdp
loe: labor output elasticity
η_i: country fixed effect
τ_t: time fixed effect

Results:

Variable	λ (lag)	gmm_1	gmm_2	gmm_3	gmm_4	gmm_5
log(D_{bias})	*1*	.0629227***	.060798***	.0628534***	.0590552***	-
log(y/l)	*2*	-.042781*	-.043665*	-.042486*	-.030957*	-.05351*
log(pat_pc)	*2*	-.0231179*	-.093711**	-.024264*	-.01299878**	-.0104853**
log(y_{low})	*1*	.0501775***	.0486555***	-	-	-.0165375
	2	-	-	.0509764*** .	.0280107	-
_cons		.01702313	.01684888	01764575	.01818465	-.02102795
η_i		yes	yes	yes	yes	yes
τ_t		yes	yes	yes	yes	yes
X_{ti} controls		*yes*	*yes*	*yes*	*yes*	*yes*

On the general objectives:

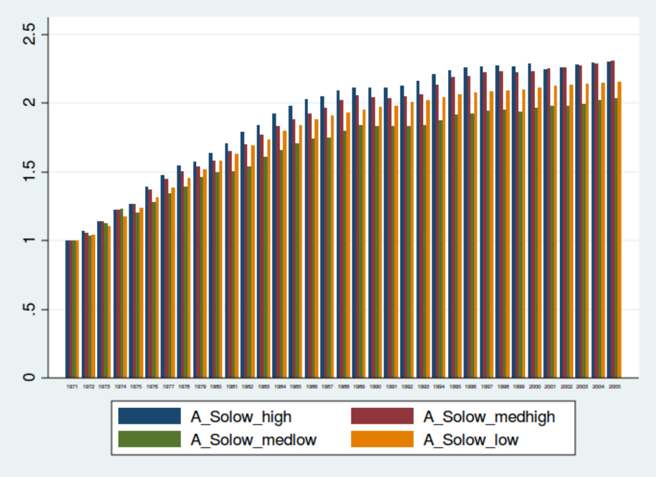
- Technolgical dynamics are composed by two effects: the neutral and the Biased Technological Change
- Output elasticities vary over time and location. Neutral technological change is not the general case (for the considered sample)
- The BTC derivation offers two types of information: the direction and the intensity of the bias
- The use of the BTC offers insights on the local adaptive dynamics derived from technological shocks

On the determinants of the Bias:

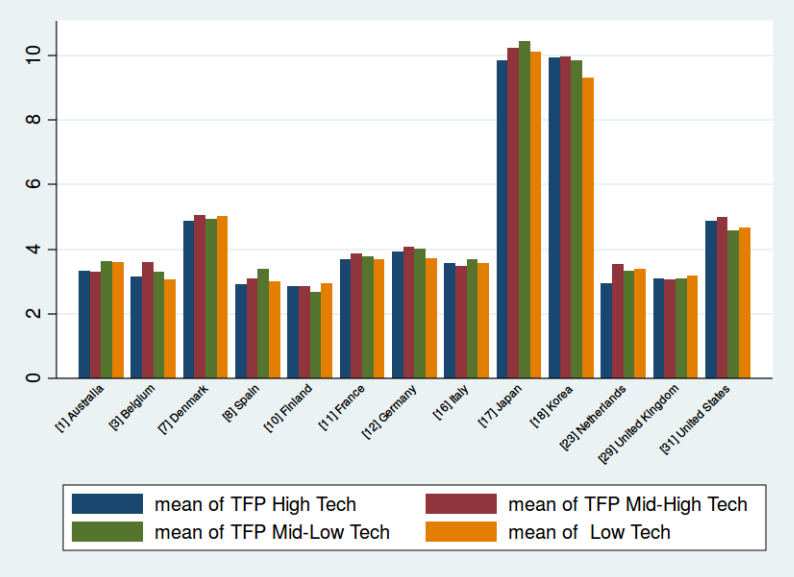
- The **determinants of the BTC direction** are associated with:
  - Structural characteristics of the economies (i.e. income per-capita)
  - Output elasticities levels (α and β). This imply locallized diversity on the use of available general purpose technologies
- The **determinants of the BTC intensity** are associated with:
  - Path dependence on the BTC intensity levels
  - Structural characteristics of the economies
  - Negatively associated with patents creation
  - Positively associated with low-tech specialization

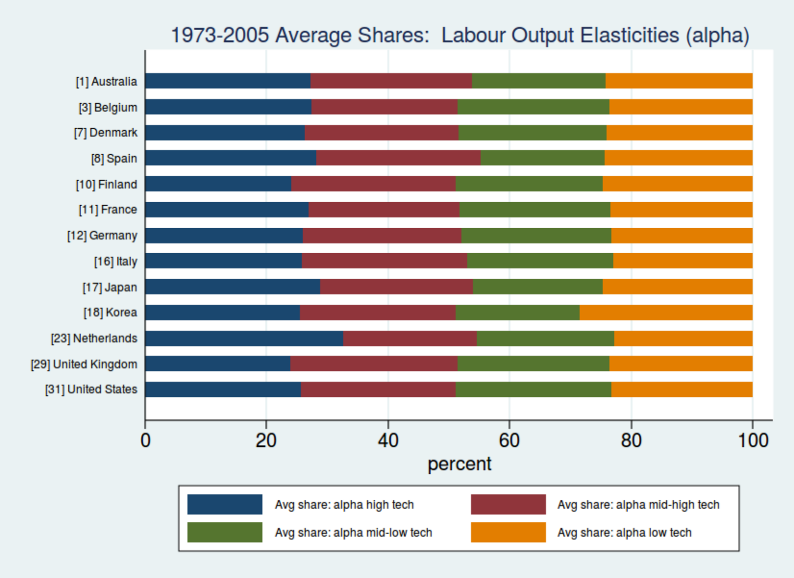
Gracias! (Si hay tiempo, les muestro lo que sigue)

TFP Trend by Technology Class

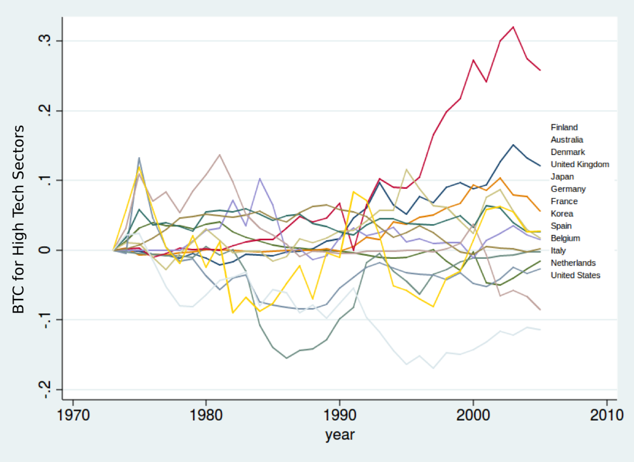


Average TFP by Country and Technological Class

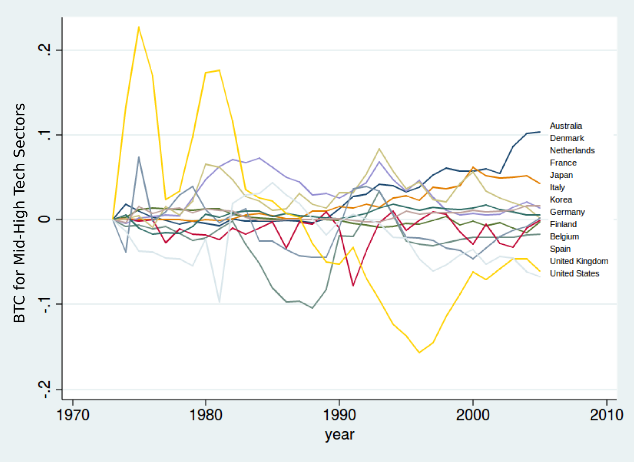



1973-2005 Average Shares: Labour Output Elasticities (alpha)
[1] Australia
[3] Belgium
[7] Denmark
[8] Spain
[10] Finland
[11] France
[12] Germany
[16] Italy
[17] Japan
[18] Korea
[23] Netherlands
[29] United Kingdom
[31] United States
0
20
40
60
80
100
percent
Avg share: alpha high tech
Avg share: alpha mid-high tech
Avg share: alpha mid-low tech
Avg share: alpha low tech

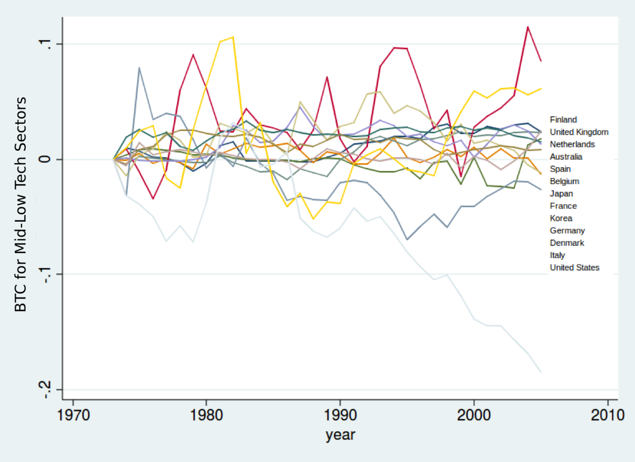
Biased Technological Change Dynamic: High-Tech Class



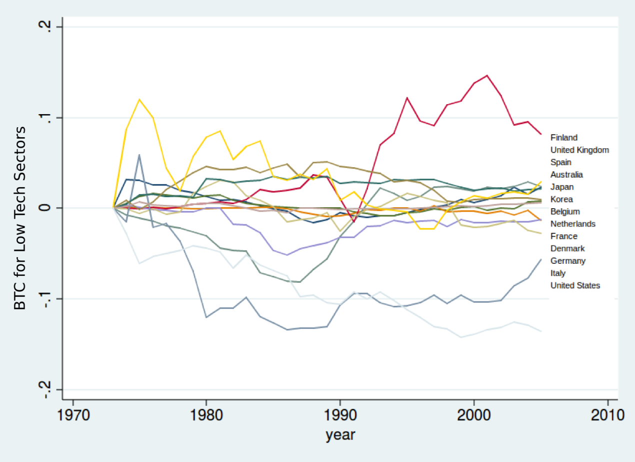
Biased Technological Change Dynamic: MidHigh-Tech Class



Biased Technological Change Dynamic: MidLow-Tech Class



Biased Technological Change Dynamic: Low-Tech Class



- Each technological class show their own trend
  - The bias is persistently negative for some sectors and countries for long periods of time
  - For some cases, the trend alternates from positive to negative (and *vice versa*)
    - Then... Are they recurrently inefficient or there is something else going on?
- Recall: the BTC indicates the relation between elasticities and relative endowments
- Recall: factors are embedded in the local system and are specific

- With this setup we are relaxing additional assumptions:
  - IF we consider heterogeneity within economies (e.g. sectoral, regional)
  - IF we consider frictions in the specialization processes and re-allocation of resources (i.e. lock-in effects)
- Then:
  - A Negative BTC IS NOT NECESSARILY INEFFICIENT
  - Why? There is a trade-off and Lock-in effect combined
    - Specialization towards one activity limits (or boost) the development of other activities
    - Specialization is a Path-dependent process
    - Sectors interact with each other
    - National aggregated BTC is insufficient to evaluate a negative BTC (there is a need of sector based analysis)

What are the determinants of this process?
The model:

$$A_{bias} = C + \beta_{1_1} A_{bias(i,c,t-1,2,3)} + \beta_{1_2} A^{c}_{bias(i,s,t-1,2,3)} + \beta_{2_1} te_{it-1,2,3} + \\ + \beta_{2_2} T_{it-1,2,3} + \beta_3 w_{it-1,2,3} + \beta_4 X_{it} + \eta_t + \tau_i + \epsilon_{i,t}$$

Where te_i: proportion of the population with tertiary education
$A^{tech-level}_{cumulative-bias}$: amount of bias cumulated through time (path dependence on allocation choices)
T_i: patents by sector
w: wage by sector
η_i: fixed effect

- Strategy: Fixed Effects (ARMA2) and System GMM
  - Small T, Small N (Nickel Bias)
    - Potential heteroskedastic clustered errors

Results: High Tech Technological Class

DepVar: BTC High Tech		**Fixed Effects**		**GMM**	
Tertiary Ed	*Lag 1*	0.398	*(1.22)*	0.223	*(1.11)*
Patents	*Lag 1*	0.00343	*(0.46)*	-0.000553	*(-0.49)*
Wage	*Lag 1*	0.0341	*(1.57)*	-0.0000652**	*(-3.91)*
	Lag 2	-0.0594*	*(-2.74)*	0.000120***	*(6.14)*
	Lag 3	0.0235	*(1.14)*	-0.0000545	*(-2.04)*
BTC High Tech	*Lag 1*	0.793***	*(8.00)*	0.891***	*(11.41)*
	Lag 2	0.198	*(1.88)*	0.138	*(1.22)*
	Lag 3	-0.161	*(-1.47)*	-0.100	*(-0.95)*
BTC MidHigh Tech	*Lag 1*	0.134	*(1.22)*	0.119	*(0.93)*
	Lag 2	-0.340*	*(-2.48)*	-0.375	*(-2.04)*
	Lag 3	0.120	*(1.66)*	0.173	*(1.99)*
BTC MidLow Tech	*Lag 1*	-0.271*	*(-3.04)*	-0.285**	*(-3.34)*
	Lag 2	0.184	*(1.36)*	0.272	*(1.75)*
	Lag 3	-0.000189	*(-0.00)*	0.0360	*(0.34)*
BTC Low Tech	*Lag 1*	0.0314	*(0.19)*	0.131	*(0.72)*
	Lag 2	0.113	*(0.53)*	0.118	*(0.61)*
	Lag 3	-0.0117	*(-0.06)*	-0.156	*(-1.04)*
_cons		0.178*	*(2.22)*	0.0370	*(0.70)*

Results: Technological Classes Relations

Variable	Lag	FE high	FE mhigh	FE mlow	FE low	gmm high	gmm mhigh	gmm mlow	gmm low
Tert.Educ.	L1.			+*					
Patents	L1.								
Wages	L1.		-**	-**		-**			
	L2.	-*	+**	+**		-**		+**	
	L3.		-**	-**	+*			-**	
BTC_high	L1.	+***				+***			
	L2.								
	L3.								
BTC_medhigh	L1.		+**				+**		
	L2.	-*			-*				
	L3.								-**
BTC_medlow	L1.	-*		+***	-*	-**		+***	-**
	L2.								
	L3.								
BTC_low	L1.				+***				+***
	L2.								
	L3.								
_cons		+*		+*	+**		+**		

19 Sectors relations summary

Variable	Relation	Lag	Significance	frequency	% of sectors
Path dependence ($BTC_{s,t-1,2,3}$)	+	L1 (100%)	*** (89%)	-	100%
			**(11%)		
Sector interaction	-	L1 (29%)	*** (14%)	2,9	89%
	(sector substitution)	L2 (38%)	** (53%)		
		L3(32%)	* (33%)		
($BTC_{v,t-1,2,3}, \forall v \neq s$)	+	L1 (52%)	*** (60%)	1,6	89%
	(Complementarity)	L2 (19%)	** (28%)		
		L3(28%)	* (10%)		

Thanks for your attention

rkataishi@untdf.edu.ar