



DYNREG



CITIZENS AND GOVERNANCE IN A
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**Dynamic Regions in a Knowledge-Driven Global Economy:
Lessons and Implications for the European Union - DYNREG**

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**Inflation, financial development and long-run total
factor productivity growth**

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1. Motivation

1. Does inflation affect long-run economic growth?
2. If so, what is the underlying transmission mechanism?

Inflation & growth

- What do we know:
 - Empirical: negative relation between inflation and GDP-growth from panel data analysis (e.g. Barro 1996)
 - Theoretical: transmission channel typically via changes in aggregate quantity of investments (e.g. King et al. 1988, Fatas 2001)
 - Effect not via factor accumulation (Ramey & Ramey 1995)
 - Fisher (1993) finds *negative causal effect of inflation on TFP-growth*
- we suggest a new monetary transmission channel via changes in the quality (composition) of investments

Contribution to the literature

- **Confirm** robustness of Fisher's result using dynamic (country) panel estimation following Blundell and Bond (1998)
- Put forward a new monetary transmission mechanism in a DSGE model by combining elements from the literature
 - short-run cash-in-advance constraint for households (e.g. Lucas 1990)
 - financial market incompleteness (Holmstrom & Tirole 1998)
 - endogenous technology choice, technical change (Aghion et al. 2005)
- Aghion et al. (2005): analyze effect of volatility on composition of investment over the business cycle via financial market incompleteness
- In contrast, we focus on link between (levels of) nominal variables (expected inflation) and TFP-growth
 - endogenous financial market incompleteness allows for verifiable model-specific implications

Agenda

1. Motivation
2. Outline of the model
3. Empirical test of model specific implications
4. Conclusion

2. Key ingredients of endogenous growth model

1. **Nominal portfolio choice for households** due to cash-in-advance

2. **Endogenous technology choice:**

- two CRS technologies (intermediates):

$$\left. \begin{array}{l} 1. \text{ basic: } \mathcal{T}_t A \phi(k_{t-1}, l_t^k) \\ 2. \text{ advanced (R\&D): } \mathcal{T}_t V f(z_{t-1}, l_t^z) \end{array} \right\} A < V$$

- advanced technology s.t. idiosyncratic liquidity shocks ξ_t^i , *cdf* $G(\cdot)$

3. **Endogenous incomplete financial markets:**

- partial insurance against idiosyncratic liquidity shocks via provision of corporate liquidity holdings

→ inflation induces a cost for corporate liquidity holdings and hence a cost for the advanced technology relative to the basic one

Short-run: nominal and financial frictions

Short-run:



- Moral hazard ($B = bP_t^z \hat{y}_t^z$) creates a wedge between full and external value of project [Holmstrom & Tirole (1998)]
- **Optimal contract** ($\mathcal{C}_t = \{z_t, l_t^z, \Gamma_t(\xi_t), \tau_t(\xi_t)\}$) under limited liability

$$\Gamma_t(\xi_t) = \begin{cases} 1, & \text{if } \xi_t \leq \hat{\xi}_t^* \\ 0, & \text{if } \xi_t > \hat{\xi}_t^* \end{cases}$$

Long-run: endogenous technological change

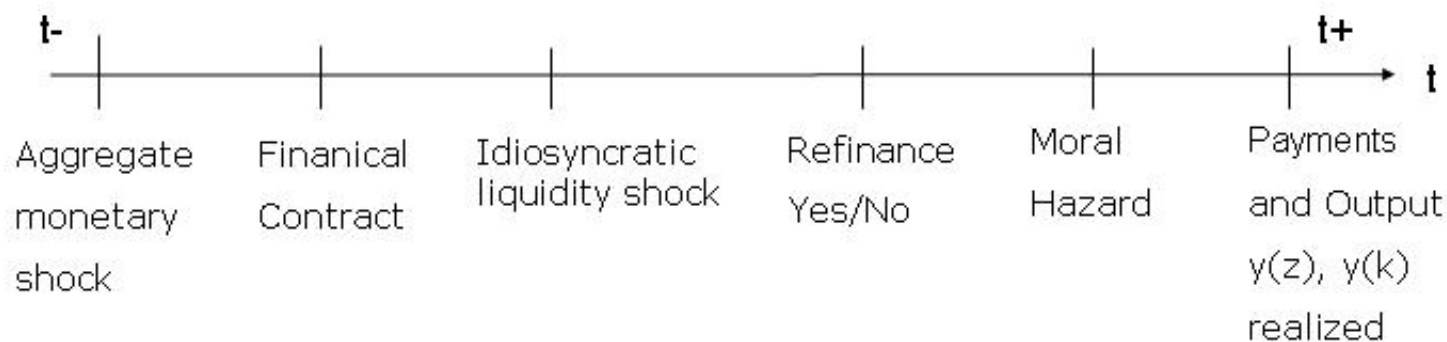
- Advanced projects (y_t^z) embody investments in R&D; thus, they generate spill-overs on future stock of knowledge
- Law of motion of stock of technologies depends on R&D investments:

$$\mathcal{T}_{t+1} = \mathcal{T}_t \left(1 + \epsilon \int_0^1 y_{t,i}^z di \right) = \mathcal{T}_t \left(1 + \epsilon \int_0^1 G(\hat{\xi}_t^*) \tilde{y}_{t,i}^z di \right),$$

where $0 < \epsilon \leq 1$ represents the fraction of R&D investments in y_t^z

Timing of events

Short-run:



Long-run:



Long-run balanced growth rate

- Empirical implications:

$$\mathbf{H1:} \quad \frac{d\gamma}{d\pi_t} = \frac{d\gamma}{d\hat{\xi}_t^*} \frac{d\hat{\xi}_t^*}{d\pi_t} < 0$$

- Each level of inflation implies a different long-run balanced growth rate:

$$\gamma = \gamma(\pi)$$

- Countries/periods that feature high inflation suffer from reduced long-run productivity growth
- In first-best case of complete financial markets ($b = 0$) exists strictly superior single long-run balanced growth rate
- Additional model-specific empirical implications :

$$\mathbf{H2:} \quad \frac{d}{d\sigma_\xi} \left(\frac{d\gamma}{d\pi_t} \right) < 0$$

3. Disaggregated data: industry level

- Model specific implications:
 - **H2** : sensitivity of TFP-growth w.r.t. inflation higher in **riskier sectors**
- Classify sectors according to their median and 1./3. quartile of average volatility of growth in value added per worker (taken from Koren & Tenreyro (2005))
- Apply **dynamic panel estimation** following Arellano and Bond (1991)
- Data (55 countries, 29 industries, 1980-2000):
 - aggregate level: World Bank [WDI], financial proxies from Beck and Levine (2001)
 - industry level: 29 US industries (yearly, 3-digit, 1980-2000) [UNIDO]

Table 6: Inflation-sensitivity in volatile vs. non-volatile sectors

	Growth rate of value added			
	vol>med	vol≤med	vol>1. qua	vol<3. qua
infl	-.0074*** (-4.63)	.0240 (.81)	-.0073*** (-4.56)	.0438 (0.88)
credit	.3332 (1.08)	2.15 (1.14)	-.0163 (-.12)	3.52 (1.20)
smtra	.2111 (1.52)	-.4035 (-.68)	.0308 (.62)	-.5175 (-.54)
fin	-.0776 (-.77)	-.2109 (-.73)	.0483 (.72)	-.5061 (-.93)
inv-share	-.0003 (-.05)	.1360 (.89)	.0090** (2.13)	.2361 (.94)
Instit. controls	yes	yes	yes	yes
Per./Obs.	19/10444	19/10661	19/4711	19/6874
1. auto-cor.	0.082	0.268	0.059	0.267
2. auto-cor.	0.085	0.473	0.264	0.478
Sargan-test	-	-	-	

Additional institutional controls (not reported): government share as % of GDP, amount of trade in goods as % of GDP, terms of trade, index of overall property rights. 1980-2000 yearly data. Always include a constant, heteroscedasticity. robust s.e.; t-statistics in parenthesis. ***, **, * significant at 1%, 5%, 10%.

Firm level

- Model specific mechanism: inflation \rightarrow corporate liquidity holdings \rightarrow investment portfolio (R&D) \rightarrow aggregate TFP-growth
 - corporate liquidity augments firm-level R&D ($\frac{\partial y_t^z}{\partial \hat{\xi}_t^*} > 0$): Opler et al. (1997) : yearly data 1970-1993: firms with higher R&D expenditures also higher liquidity holdings (cash & marketable securities)
 - inflation reduces firm-level R&D ($\frac{\partial y_t^z}{\partial \pi_t} < 0$): apply US firm-level data to test this hypothesis
 - inflation reduces corporate liquidity ($\frac{\partial \hat{\xi}_t^*}{\partial \pi_t} < 0$): apply US firm-level data to test this hypothesis
- yearly (1970-1999) US data: inflation [BEA], firm level R&D expenses, liquidity holdings, total assets, investments, operating income retained earnings [Compustat]

Table 4: U.S. firm-level yearly data: Inflation, liquidity holdings and R&D expenses

	Corporate liquidity		R&D			inv		
	OLS	GMM-sys	OLS	OLS	GMM-sys	GMM-sys	GMM-sys	GMM-sys
inflation	-1.73*** (-7.45)	-2.36*** (-4.88)	-.1692*** (-3.82)	-.1291*** (-3.03)	-.1919* (-1.69)	-.0612 (-.66)	.1771 (.14)	-.5942 (-.40)
corp. liquidity				.0173*** (3.65)		.0470*** (2.95)		-.1099 (-.66)
assets	.0056 (1.56)	.0055 (.74)	-.0009** (-2.05)	-.0011*** (-2.79)	-.0018* (-1.84)	-.0019** (-1.95)	-.0109 (-.40)	-.0063 (-.25)
opincome	.0034 (.09)	-.0003 (-.03)	.0115*** (3.65)	.0109*** (3.36)	.0298*** (3.39)	.0225*** (2.90)	.5931*** (4.27)	.6211*** (4.07)
reearn	.0213 (1.49)	.0749** (2.14)	.0009 (.72)	-.0001 (-.09)	.0011 (.48)	-.0033 (-1.03)	-.0418 (-.47)	-.0257 (-.32)
lag-dep.-var.	.898*** (29.11)	.7578*** (9.44)	1.03 (75.78)	1.00 (59.16)	.9782 (21.1)	.9248 (14.8)	.9773 (12.7)	.9634 (13.6)
Firms	8285	8285	8287	8287	8287	8287	8276	8276
Observations	64681	64681	64708	64703	64708	64703	64494	64494
1. auto-cor.	.782	.002	.324	.331	.001	.000	.179	.179
2. auto-cor.		.479			.899	.854	.743	.771
Hansen-test		.160			.046	.272	.109	.100

The maximum lag is restricted to 10 years in order to reduce the size of the IV matrix. 1970-2000 yearly data. Heteroscedasticity robust s.e. t-statistics in parenthesis. ***, **, * significant at 1%, 5%, 10%.

4. Conclusions

- Model rationalizes negative causation from inflation to TFP-growth
- Intuitively, link between inflation and TFP-growth in case of incomplete financial markets due to allowance for firm-level heterogeneous investment projects with respect to a risk-productivity tradeoff
- Partially endogenized TFP(-growth) via investment composition effect
- Countries/periods that feature high inflation suffer from reduced long-run productivity growth
- Not appropriate to treat shocks to policy and technology as orthogonal
- Specific microeconomic mechanism consistent with firm/industry data
- Macro- and microeconomic empirical evidence suggest that effect also relevant in relatively developed economies (OECD, USA)

Aggregate empirical relation

- **Confirm** Fisher's result applying a dynamic panel estimation for 86 countries from 1970-1999:

$$y_{i,t} - y_{i,t-1} = \alpha y_{i,t-1} + \beta X_{i,t} + \mu_t + \eta_i + \epsilon_{i,t},$$

$y_{i,t}$: TFP, $X_{i,t}$: matrix of inflation and standard growth determinants,
 μ_t : unobserved common factors, η_i : country-specific effects

- Use of **internal IVs** (lags) following Blundell and Bond (1998): valid in absence of 2. order serial correlation \Rightarrow testable
- TFP residual from human capital augmented production function following Caselli (2005)
- Employ 5-year-averages to smooth out business cycle effects

Table 2: Aggregate data: 5-year-averages: Inflation & TFP growth

	TFP growth OLS	LSDV	GMM-sys	GMM-sys	GMM-sys	GMM-sys	GMM-sys
infl	-.0014*** (-7.33)	-.0009*** (-4.17)	-.0020*** (-2.74)	-.0016** (-2.44)	-.0022*** (-2.96)	-.0059** (-2.05)	-.0646*** (-2.85)
infl-vol						.0026* (1.66)	
credit	.2479 (.54)	-.7932 (-.93)	.7770 (.69)	-.5247 (-.46)	.8965 (.81)	.0139 (.01)	.4846 (.58)
trade	.0021 (.82)	.0154 (.96)	.0066 (1.05)	.0027 (.35)	.0079 (1.22)	.0076 (1.38)	
ki				.1309*** (2.21)			
ppr	.3130*** (3.58)	.1759 (1.26)	.4452*** (2.94)	.3656** (2.53)	.4182** (2.81)	.4779*** (3.32)	-.2293* (-1.71)
kg	-.0113 (-.59)	-.0687 (-.79)	-.0243 (-.87)	-.0145 (-.54)	-.0214 (-.81)	-.0145 (-.54)	-.0606 (-1.07)
tot	-.0066 (-.87)	-.0013 (-.12)	-.0055 (-.59)	-.0164 (-1.54)	-.0058 (-.66)	-.0047 (-.51)	.2247** (2.18)
lag dep. var.	-.0049*** (-3.24)	-.0229*** (-5.28)	-.0180*** (-5.53)	-.0183*** (-5.07)	-.0162*** (-5.52)	-.0151*** (-5.65)	-.6202*** (-4.20)
time-FE	-	-	-	-	yes	-	-
Cou./Obs.	86/363	86/363	86/363	86/363	86/363	86/362	22/107
1. auto-cor.	-	-	0.001	0.002	0.001	0.001	0.034
2. auto-cor.	-	-	0.127	0.129	0.175	0.211	0.385
Hansen-test	-	-	0.122	0.287	0.161	0.195	0.939

We specify inflation, inflation-volatility, credit, trade, investment share as endogenous and property rights, government share, terms of trade as exogenous variables in the GMM system estimation. Inflation volatility is measured by the average standard deviation of yearly inflation rates. Predetermined lagged level of TFP as lagged dependent variable apart from OECD sub-sample.

Incomplete financial markets - second best **contract**

- Second best contract ($\mathcal{C}_t = \{z_t, l_t^z, \Gamma_t(\xi_t), \tau_t(\xi_t)\}$) trades off scale of investment (z_t, l_t^z) and insurance ($\hat{\xi}_t$) - implies optimal cutoff value ξ_t^* :

$$\max_{\mathcal{C}_t} \int \{ \Gamma_t(\xi_t) P_t^z \tilde{y}_t^z - \tau_t(\xi_t) C(W_t, R_t^z; \tilde{y}_t^z) \} dG(\xi_t) - \mathbf{E}_t \quad (2)$$

subject to PC:

$$\int \left\{ \tau_t(\xi_t) C(W_t^z, R_t^z; \tilde{y}_t^z) - \Gamma_t(\xi_t) \xi_t \tilde{\mathbf{R}}_t P_t^z \tilde{y}_t^z \right\} dG(\xi_t) \geq C(W_t^z, R_t^z; \tilde{y}_t^z) - E_t$$

and IC:

$$\Gamma_t(\xi_t) P_t^z \tilde{y}_t^z - \tau_t(\xi_t) C(W_t^z, R_t^z; \tilde{y}_t^z) \geq \Gamma_t(\xi_t) \mathbf{b} P_t^z \tilde{y}_t^z \quad \forall \xi_t,$$

where:

$$\begin{aligned} \tilde{y}_t^z &= \mathcal{I}_t \mathcal{V}_t(z_t)^{\alpha^z} (l_t^z)^{1-\alpha^z} \\ C(W_t^z, R_t^z; \tilde{y}_t^z) &= MC_t^z(W_t^z, R_t^z) \tilde{y}_t^z = R_t^z z_t + W_t^z l_t^z \end{aligned}$$

TFP accounting:

- From CES aggregation of aggregate (final) output:

$$y = \left(\zeta^{\frac{1}{\rho}} y^k \frac{\rho-1}{\rho} + (1 - \zeta)^{\frac{1}{\rho}} y^z \frac{\rho-1}{\rho} \right)^{\frac{\rho}{\rho-1}}$$

$$\hat{y} = \omega_{yk}^y \hat{y}^k + \omega_{yz}^y \hat{y}^z$$

- From sectoral (intermediate) production functions:

$$\hat{y}^k = \hat{A} + \alpha^k \hat{k} + (1 - \alpha^k) \hat{l}^k$$

$$\hat{y}^z = \hat{V} + \omega_{\hat{\xi}^*}^G \hat{\xi}^* + \alpha^z \hat{z} + (1 - \alpha^z) \hat{l}^z$$

- Combine to get measure of aggregate TFP:

$$\hat{T} = \omega_{yk}^y \hat{A} + \omega_{yz}^y \left(\hat{V} + \omega_{\hat{\xi}^*}^G \hat{\xi}^* \right)$$

Table 1: [Sectoral volatility](#) (from Koren & Tenreyro 2005) and mean of growth in value added (correlation coefficient vol-mean: 0.03 (.0057) significant on 1% level)

Industries	volatility	ranking	aver. value added	ranking
Beverages	0.0570	19	7.99E+08	13
Fabricated metal products	0.0610	17	1.95E+09	5
Food products	0.0570	19	2.71E+09	4
Footwear, except rubber or plastic	0.0720	10	1.54E+08	25
Furniture, except metal	0.0650	16	4.26E+08	21
Glass and products	0.0510	22	2.84E+08	23
Industrial chemicals	0.0700	11	1.75E+09	6
Iron and Steel	0.1410	1	1.63E+09	7
Leather products	0.0870	6	1.44E+08	26
Machinery, electric	0.0500	25	2.93E+09	3
Machinery, except electrical	0.0610	17	3.32E+09	1
Misc. Petroleum and coal products	0.0700	11	8.41E+07	27
Non-ferrous metals	0.1410	1	5.39E+08	18
Other manufacturing products	0.0700	11	4.39E+08	20
Other non-metallic mineral products	0.0510	22	9.47E+08	11
Paper and products	0.1080	3	9.53E+08	10
Petroleum refineries	0.0700	11	9.39E+08	12
Plastic products	0.0750	9	6.46E+08	16
Pottery, china, earthenware	0.0510	22	1.74E+08	24
Printing and publishing	0.0460	27	1.38E+09	9
Professional & scientific equipment	0.0660	15	6.60E+08	15
Rubber products	0.0800	8	4.26E+08	22
Textiles	0.0890	5	1.46E+09	8
Tobacco	0.0570	19	5.14E+08	19
Transport equipment	0.0850	7	2.95E+09	2
Wearing apparel, except footwear	0.0500	25	7.85E+08	14
Wood products, except furniture	0.0900	4	5.92E+08	17

Endogeneity problem

- **Dynamic panel estimation**: rely on internal instruments (lags) as suggested by Arellano and Bover (1995) and Blundell and Bond (1998)

– Consider first-differences of the model:

$$y_{i,t} - y_{i,t-1} = (1 + \alpha)(y_{i,t-1} - y_{i,t-2}) + \beta(X_{i,t} - X_{i,t-1}) + (\epsilon_{i,t} - \epsilon_{i,t-1})$$

– Basic assumption following Arellano and Bond (1991):

$$\begin{aligned} E[y_{i,t-s}(\epsilon_{i,t} - \epsilon_{i,t-1})] &= 0, & \text{for } s \geq 2; t = 3, \dots, T \\ E[X_{i,t-s}(\epsilon_{i,t} - \epsilon_{i,t-1})] &= 0, & \text{for } s \geq 2; t = 3, \dots, T \end{aligned}$$

– Assumption: appropriate lags **provide valid instruments** if (i) time-varying disturbance $\epsilon_{i,t}$ is not serially correlated, and (ii) explanatory variables X are weakly exogenous (i.e. uncorrelated with future realizations of $\epsilon_{i,t}$)

- Firm-level: Combine micro- and macroeconomic data: Feedback-effect of R&D expenses by a single firm on aggregate inflation negligible

Corporate liquidity demand

- **Empirical evidence:** [\[Opler et al. \(1997\)\]](#)
 - US nonfinancial firms
 - liquidity = cash + marketable securities
 - corporate liquidity holdings are significant proportion of firm value (average: 18%)
 - higher liquidity holdings in firms with riskier cash flows and higher growth opportunities (market-to-book value, R&D investments)
- **Theoretical setup:** [Holmstrom & Tirole (1998)]
 - microeconomic framework embedded in monetary business cycle model