Innovation Union: Costs and Benefits of Innovation Policy Coordination

Teodora Borota
University of Uppsala

Fabrice Defever
University of Lille and
LSE-CEP

Giammario Impullitti
University of Nottingham,
CEPR and LSE-CEP

Adam Hal Spencer
University of Nottingham

Fifth INFER / ERMEES Macroeconomics Workshop 2023
Friday December 1st 2023

Roadmap

Question

- What are the growth and welfare effects of innovation policy coordination across regions?

Question

- What are the growth and welfare effects of innovation policy coordination across regions?
  - Subsidy to cost of hiring scientists for R&D.

Motivation

- European Union (E.U.) serves as the policy motivation.

Motivation

- European Union (E.U.) serves as the policy motivation.

- Policy coordination:
  - Ever closer union,
  - Brexit.

Motivation

- European Union (E.U.) serves as the policy motivation.
- Policy coordination:
  - Ever closer union,
  - Brexit.
- Innovation policy: Horizon Europe (2021–2027)
  - Funding of €95.5b for R&D grants across the union.
  - Single innovation market.
  - Builds-off Horizon 2020 (2014–2020): budget €80b.

What We Do

(i) Document empirical facts on asymmetries in innovation performance and policy across the E.U.

What We Do

(i) Document empirical facts on asymmetries in innovation performance and policy across the E.U.

(ii) Develop a general two-country Schumpeterian growth model:

- West (W, old E.U. members) and East (E, new E.U. members).
- Firms compete in quality for market leadership.

What We Do

(i) Document empirical facts on asymmetries in innovation performance and policy across the E.U.

(ii) Develop a general two-country Schumpeterian growth model:

- West (W, old E.U. members) and East (E, new E.U. members).
- Firms compete in quality for market leadership.

(iii) Calibrate to E.U. data and run policy experiments.

- Observed subsidy rates v.s. coordinated.
- Uncoordinated subsidy rates v.s. coordinated.
- Steady state and transition dynamics exercises.

What We Do

- Two model variants:

What We Do

- Two model variants:

  (a) Baseline: semi-endogenous (Jones 1995 JPE) growth.

  - Policy has only transitional effects on growth.

What We Do

- Two model variants:

  (a) Baseline: semi-endogenous (Jones 1995 JPE) growth.

  - Policy has only transitional effects on growth.

  (b) Add FDI and knowledge spillovers through multinational activity.

Qualitative Channels

- Consider moving to the optimal coordinated subsidy rates.

Qualitative Channels

- Consider moving to the optimal coordinated subsidy rates.

- Four key externalities

  a. Strategic motive: business-stealing gives over-investment in R&D.

  b. Inter-temporal effect: under-investment.

  c. Diversification: decreasing returns at country-level.

  d. Consumer surplus: price *level* effects from innovation.

Preview of Results

- Baseline: internalising strategic and diversification dominates inter-temporal effect.
  - Gains to coordination are large.
  - Optimal coordinated rates -39% and 59% for W and E respectively.
  - Rates are 12% and 10% in the data.

Preview of Results

- FDI extension: transfer of knowledge reverses the result.
  - Inter-temporal effect dominates.
  - Optimal coordinated rates 33% and -99%.
  - 7.5% welfare gains in consumption equivalents.

Preview of Results

- Model variants highlight the important role of knowledge spillovers in shaping coordination gains and key externalities.

Roadmap

World

- World with two countries: W and E.
- Continuous time.
- Trade in goods.
- Set of consumed good same across countries.
- Representative households; populations grow at rate n. Details

World

- Horizontal differentiation: continuum of varieties (denoted $\omega \in [0, 1]$).
- Vertical differentiation: vintages of each variety.
- Only the top quality vintage consumed in each variety.
  - Production controlled by firm from either W or E.
- Innovation arrival gives $\lambda > 1$ jump in quality.

Innovation

- Potential entrants i challenge incumbents on each variety.
  - Creative destruction

Innovation

- Potential entrants i challenge incumbents on each variety.
  - Creative destruction

- Arrival rate production function

$$\underbrace{I_i^K}_{\text{Arrival rate firm } i} = \overbrace{(A^K)^{1-\alpha}}^{\text{Productivity for } K} \underbrace{\ell_i^K}_{\text{Resarch emp. firm } i} \overbrace{(L^K)^{-\alpha}}^{\text{Research emp. in } K}$$

for country $K \in \{W, E\}$.

Innovation

- Potential entrants i challenge incumbents on each variety.
  - Creative destruction

- Arrival rate production function

$$\underbrace{I_i^K}_{\text{Arrival rate firm } i} = \overbrace{(A^K)^{1-\alpha}}^{\text{Productivity for } K} \underbrace{\ell_i^K}_{\text{Resarch emp. firm } i} \overbrace{(L^K)^{-\alpha}}^{\text{Research emp. in } K}$$

  for country $K \in \{W, E\}$.

- Decreasing returns in research employment L^K: $\alpha \in (0, 1)$

Innovation

- Productivity country $K \in \{W, E\}$

$$\underbrace{A^K}_{\text{Innov. productivity}} = \overbrace{\gamma^K}^{\text{Exogenous prod.}} \underbrace{(\widehat{Q}^K)^{\phi}}_{\text{Knowledge spillovers}} \overbrace{q^{-1}}^{\text{Quality of variety leader}}$$

- $\widehat{Q}^K$ is country-specific average of aggregate quality from each K.

Innovation

- Productivity country $K \in \{W, E\}$

$$\underbrace{A^K}_{\text{Innov. productivity}} = \overbrace{\gamma^K}^{\text{Exogenous prod.}} \underbrace{(\widehat{Q}^K)^{\phi}}_{\text{Knowledge spillovers}} \overbrace{q^{-1}}^{\text{Quality of variety leader}}$$

- $\widehat{Q}^K$ is country-specific average of aggregate quality from each K.

- $\phi < 1$: semi-endogenous growth
  - Decreasing returns to knowledge spillovers

Innovation

- Knowledge spillovers affecting R&D productivity:

$$\underbrace{\widehat{Q}^K(t)}_{\text{Knowledge spillovers}} = \underbrace{Q^K(t)^{\beta}}_{\text{Local quality aggregate}} \overbrace{Q(t)^{(1-\beta)}}^{\text{Global quality aggregate}}$$

where

$$Q(t) = \int_0^1 q(\omega, t) d\omega$$

$$Q^K(t) = \int_{\omega \in \omega^K} q(\omega, t) d\omega.$$

- Parameter $\beta \in [0.5, 1]$ captures local bias.

Subsidy Instruments

- Subsidy to wage bill of hiring scientists $s^K \in [0, 1]$.

- Scientist wage bill post-subsidy:

$$(1 - s^K) \underbrace{\ell_i^K w^K}_{\text{Scientist wage bill firm } i}$$

Equilibrium Innovation

- Potential entrants maximise expected profits

$$\max_{I_i^K} \overbrace{I_i^K}^{\text{Arrival rate firm } i} \underbrace{v}_{\text{Present value of incumbency}} - (1 - s^K)\ell_i^K w^K$$

subject to arrival rate production function.

Incumbent value

Equilibrium Definition

- Equilibrium is a set of endogenous aggregate objects such that
  - Households optimise in each country Show,
  - Potential entrants make zero expected profits in each country Show,
  - Labour markets clear in each country Show,
  - Aggregate growth determined by innovation intensity in each K and quality improvement λ Show.

Roadmap

Exercise Design

- Observed scenario
  - Equilibrium with subsidies fixed at rates in the data.

Exercise Design

- Observed scenario
  - Equilibrium with subsidies fixed at rates in the data.
- Coordinated scenario:
  - Choose 2 subsidy rates to maximise total E.U. welfare.

Moments | Parameters

Exercise Design

a. Steady state exercises.

b. Transition exercises:

- Initial steady state at observed subsidy rates.
- Set alternative counterfactual rate once and for all at $t = 0$.
- Map transition path to counterfactual steady state.
- Account for transition path in welfare computations.

Optimal R&D Subsidy Rates

	Transition		Steady State	
	s^W	s^E	s^W	s^E
Observed	0.12	0.10	0.12	0.10
Coordinated	-0.39	0.59	-0.99	0.55

Gains from Coordination

	Transition			Steady State		
	W	*E*	*EU*	*W*	*E*	*EU*
Coordinated vs observed	-0.07	0.23	0.16	-0.09	0.41	0.32

Gains from Coordination

	Transition			Steady State		
	W	*E*	*EU*	*W*	*E*	*EU*
Coordinated vs observed	-0.07	0.23	0.16	-0.09	0.41	0.32
Strategic motive	0.02	0.32	0.34	0.02	0.51	0.53

Gains from Coordination

	Transition			Steady State		
	W	*E*	*EU*	*W*	*E*	*EU*
Coordinated vs observed	-0.07	0.23	0.16	-0.09	0.41	0.32
Strategic motive	0.02	0.32	0.34	0.02	0.51	0.53
Consumer surplus effect	-0.06	-0.06	-0.12	-0.11	-0.11	-0.22

Gains from Coordination

	Transition			Steady State		
	W	*E*	*EU*	*W*	*E*	*EU*
Coordinated vs observed	-0.07	0.23	0.16	-0.09	0.41	0.32
Strategic motive	0.02	0.32	0.34	0.02	0.51	0.53
Consumer surplus effect	-0.06	-0.06	-0.12	-0.11	-0.11	-0.22
Intertemporal spillovers	-0.03	-0.03	-0.06	0.00	0.00	0.00

Roadmap

Model Variants and Other Exercises

1. FDI: include multinationals. Show

2. Policy Horizons. Show

Roadmap

Summary

- What are the gains to innovation policy coordination?

Summary

- What are the gains to innovation policy coordination?
- Develop a quantitative framework:
  - Can study steady states and the transition.
  - Extended to include knowledge transfer through multinationals.

Summary

- What are the gains to innovation policy coordination?
- Develop a quantitative framework:
  - Can study steady states and the transition.
  - Extended to include knowledge transfer through multinationals.
- Gains are lower when accounting for the transition.

Summary

- What are the gains to innovation policy coordination?
- Develop a quantitative framework:
  - Can study steady states and the transition.
  - Extended to include knowledge transfer through multinationals.
- Gains are lower when accounting for the transition.
- Takeaways:
  - Spillovers matter!
  - Gains are large: 7% in FDI variant.

Addition of FDI: Model

- W leaders can offshore production to save on manufacturing costs.

Addition of FDI: Model

- W leaders can offshore production to save on manufacturing costs.

- Product cycles
  - Ideas start in W ($\omega \in \omega^W$),
  - W firms choose to offshore as multinationals ($\omega \in \omega^M$),
  - Once offshored, E can start innovating on that variety,
  - E leadership ($\omega \in \omega^E$),
  - W leadership.

Addition of FDI: Model

- Innovation productivity terms for sector $K \in \{W, M, E\}$

$$A^W = \gamma^W \, \widehat{Q}^W(t)^\phi \, q^{-1}$$
$$A^M = \gamma^M \, \widehat{Q}^W(t)^\phi \, q^{-1}$$
$$A^E = \gamma^E \, \widehat{Q}^E(t)^\phi \, q^{-1}$$

Addition of FDI: Model

- Innovation productivity terms for sector $K \in \{W, M, E\}$

$$A^W = \gamma^W \, \widehat{Q}^W(t)^\phi \, q^{-1}$$
$$A^M = \gamma^M \, \widehat{Q}^W(t)^\phi \, q^{-1}$$
$$A^E = \gamma^E \, \widehat{Q}^E(t)^\phi \, q^{-1}$$

where

$$\widehat{Q}^W(t) = Q^W(t)^\beta \, Q(t)^{1-\beta}$$
$$\widehat{Q}^E(t) = Q^{E+M}(t)^\beta \, Q(t)^{1-\beta}$$

and

$$Q^{E+M}(t) = \int_{\omega \in \omega^M \cup \omega^E} q(\omega, t) d\omega.$$

Addition of FDI: Results

	Baseline			With FDI		
	s^W	s^E		s^W	s^E	
Observed	0.12	0.10				
Coordinated	-0.39	0.59				
Welfare gains	W	E	W+E	W	E	W+E
Coordinated vs observed (CEV)	-0.07	0.23	0.16			
Strategic motive	0.02	0.32	0.34			
Consumer surplus	-0.06	-0.06	-0.12			
Intertemporal spillovers	-0.03	-0.03	-0.06			

All inclusive of transition

Back to **extensions**

Addition of FDI: Results

	Baseline			With FDI		
	s^W	s^E		s^W	s^E	
Observed	0.12	0.10		0.12	0.10	
Coordinated	-0.39	0.59		0.33	-0.99	
Welfare gains	W	E	W+E	W	E	W+E
Coordinated vs observed (CEV)	-0.07	0.23	0.16	0.05	0.02	0.07
Strategic motive	0.02	0.32	0.34	-0.01	-0.04	-0.05
Consumer surplus	-0.06	-0.06	-0.12	0.00	0.00	0.00
Intertemporal spillovers	-0.03	-0.03	-0.06	0.06	0.06	0.13

All inclusive of transition

Back to **extensions**

Fully Endogenous Variant: Model

- Remove decreasing returns to knowledge spillovers:

$$A^K = \overbrace{\gamma^K}^{\text{Exogenous prod.}} \underbrace{(\widehat{Q}^K)^{\phi}}_{\text{Knowledge spillovers}} \overbrace{q^{-1}}^{\text{Quality of variety leader}}$$

  with $\phi = 1$.

- Also some adjustment to arrival rate production function.

Fully Endogenous Variant: Results

	Baseline			Fully endogenous		
	s^W	s^E		s^W	s^E	
Observed	0.12	0.10				
Coordinated	-0.39	0.59				
Welfare gains	W	E	W+E	W	E	W+E
Coordinated vs observed (CEV)	-0.07	0.23	0.16			
Strategic motive	0.02	0.32	0.34			
Consumer surplus	-0.06	-0.06	-0.12			
Intertemporal spillovers	-0.03	-0.03	-0.06			

All inclusive of transition

Fully Endogenous Variant: Results

	Baseline			Fully endogenous		
	s^W	s^E		s^W	s^E	
Observed	0.12	0.10		0.12	0.10	
Coordinated	-0.39	0.59		0.83	0.83	
Welfare gains	W	E	W+E	W	E	W+E
Coordinated vs observed (CEV)	-0.07	0.23	0.16	0.07	0.07	0.14
Strategic motive	0.02	0.32	0.34	-0.15	-0.15	-0.30
Consumer surplus	-0.06	-0.06	-0.12	0.00	0.00	0.00
Intertemporal spillovers	-0.03	-0.03	-0.06	0.22	0.22	0.44

All inclusive of transition

Back to **extensions**

Zero Profit Condition

$$\underbrace{\overbrace{v^K(\omega,t)}^{\text{Gain in success}}\ \overbrace{A^K(\omega,t)I^K(\omega,t)^{\frac{\alpha}{\alpha-1}}}^{\text{Rate of success}}}_{\text{Expected gain to innovation}} = \underbrace{(1-s^K)w^K(t)}_{\text{Cost of innovation}}$$

Back to **equilibrium definition**

Labour Market Clearing Conditions

$$\underbrace{\ell^W}_{\text{Labour supply in W}} = \overbrace{\left(\frac{\sigma}{\sigma-1}\right)^{-\sigma} a^{W(1-\sigma)} q^W \left(\frac{c^W \ell^W}{\bar{P}^{W(1-\sigma)}} + \frac{c^E(1-\ell^W)}{\bar{P}^{E(1-\sigma)}}\tau^{W(1-\sigma)}\right)}^{\text{Manufacturing labour demand in W}} + \underbrace{\frac{I^{W\frac{1}{1-\alpha}}}{\gamma^W} \frac{Q(t)}{\widehat{Q}^W(t)^\phi L(t)}}_{\text{Innovation labour demand in W}}$$

Back to **equilibrium definition**

Additional Terms in Household Budget Constraint

- Government budget constraint

$$T^K(t) = \underbrace{s^K w^K(t) \int_0^1 L_R^K(\omega, t)}_{\text{Total expenditure on R\&D by firms from } K}$$

- Asset holdings:

$$A^K(t) = \int_{\omega^K} \frac{v^K(\omega, t)}{L^K(t)} d\omega$$

Back to **household**

Innovation

- Present value of incumbency

$$v^K(\omega,t) = \frac{\overbrace{\pi^K(\omega,t)}^{\text{Period profits}}}{r(t) + \underbrace{I^W(\omega,t) + I^E(\omega,t)}_{\text{Schumpeterian creative destruction}} - \frac{\dot{v}^K(\omega,t)}{v^K(\omega,t)}}$$

Innovation

- Present value of incumbency

$$v^K(\omega,t) = \frac{\overbrace{\pi^K(\omega,t)}^{\text{Period profits}}}{r(t) + \underbrace{I^W(\omega,t) + I^E(\omega,t)}_{\text{Schumpeterian creative destruction}} - \frac{\dot{v}^K(\omega,t)}{v^K(\omega,t)}}$$

where

$$I^K(\omega,t) = \underbrace{\sum_i}_{\text{Over firms } i \text{ in sector}} I_i^K(\omega,t) \overbrace{= I^K(t)}^{\text{By symmetry}}$$

Profits

$$\pi^K(\omega,t) = \overbrace{\frac{1}{\sigma}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}(a^K w^K(t))^{1-\sigma}}^{\text{Preference, production parameters \& labour cost}} \underbrace{q(\omega,t)}_{\text{Incumbent's quality}}$$

$$\left(\underbrace{\frac{c^K(t)L^K(t)}{P^K(t)^{1-\sigma}}}_{\text{Demand from market } K} + \underbrace{\frac{c^{K*}(t)L^{K*}(t)}{P^{K*}(t)^{1-\sigma}}\tau^{1-\sigma}}_{\text{Demand from market } K*} \right)$$

Back to **equilibrium innovation**

Household

- Lifetime utility

$$U = \int_0^{\infty} \underbrace{L_0}_{\text{Starting population}} \overbrace{e^{-(\rho-n)t}}^{\rho \text{ discount rate; } n \text{ population growth}} \underbrace{\log[u(t)]}_{\text{Instantaneous utility}} \; dt$$

Household

- Lifetime utility

$$U = \int_0^{\infty} \underbrace{L_0}_{\text{Starting population}} \overbrace{e^{-(\rho-n)t}}^{\rho \text{ discount rate; } n \text{ population growth}} \underbrace{\log[u(t)]}_{\text{Instantaneous utility}} \, dt$$

with

$$u(t) = \left(\int_0^1 \left[\overbrace{\sum_{j=0}^{j^{max}(\omega,t)}}^{\text{Top quality vintage}} \underbrace{\lambda^{j(\omega,t)}}_{\lambda > 1 \text{ quality jump}} \overbrace{d(j,\omega,t)}^{\text{Per capita consumption}} \right]^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}}$$

where $\sigma > 0$ elasticity of substitution.

Household

- Supply unit labour endowment inelastically.

- Budget constraint

$$\dot{A}(t) = \underbrace{w(t)}_{\text{Labour income}} + \overbrace{r(t)A(t)}^{A(t)\text{ assets per capita, }r(t)\text{ return}} - \underbrace{c(t)}_{\text{Nominal expenditure per capita}} - \overbrace{nA(t)}^{\text{Pop. growth } n} - \underbrace{T(t)}_{\text{Taxes}}$$

Setup

Households

- Choose vintage with lowest price per unit of quality: $j^{max}(\omega, t)$.

- Love of variety demand curves

$$d(\omega, t) = \underbrace{q(\omega, t)}_{\text{Quality of } j^{max}(\omega,t)} \overbrace{p(\omega, t)^{-\sigma}}^{\text{Price of } j^{max}(\omega,t)} \underbrace{\frac{c(t)}{P(t)^{1-\sigma}}}_{\text{CPI}}$$

Households

- Choose vintage with lowest price per unit of quality: $j^{max}(\omega, t)$.

- Love of variety demand curves

$$d(\omega, t) = \underbrace{q(\omega, t)}_{\text{Quality of } j^{max}(\omega,t)} \overbrace{p(\omega, t)^{-\sigma}}^{\text{Price of } j^{max}(\omega,t)} \underbrace{\frac{c(t)}{P(t)^{1-\sigma}}}_{\text{CPI}}$$

- Consumption Euler equation

$$\frac{\dot{c}(t)}{c(t)} = r(t) - \rho$$

Equilibrium definition

Growth rate

- Aggregate growth

$$\frac{\dot{Q}(t)}{Q(t)} = (\lambda^{\sigma-1} - 1)(I^W(t) + I^E(t))$$

- Semi-endogenous structure implies steady state growth:

$$\frac{\dot{Q}(t)}{Q(t)} = \frac{n}{1-\phi}$$

Equilibrium definition

Moments

Moments	Data (Model)	Source
East relative wage (w^E)	0.60 (0.61)	Eurostat, 2005-2016
MFP growth rate	0.66% (0.66%)	OECD 2005-2016
Share of sectors, West leadership (ω^W)	91% (91%)	OECD*, 2005-2016
West R&D expenditure/GDP	3.87% (3.04%)	Eurostat, 2015
East R&D expenditure/GDP	2.12% (1.85%)	Eurostat, 2015
West share of labour in R&D	3.13% (3.71%)	Eurostat, 2015
East share of labour in R&D	2.22% (4.33%)	Eurostat, 2015
West innovation elasticity to subsidy	[0.7, 3.5] (1.23)	Akcigit et al. (2018)
East innovation elasticity to subsidy	[0.7, 3.5] (1.60)	Akcigit et al. (2018)

* Analytical Activity of Multinational Enterprises database. Gives output of countries by ownership of firms.

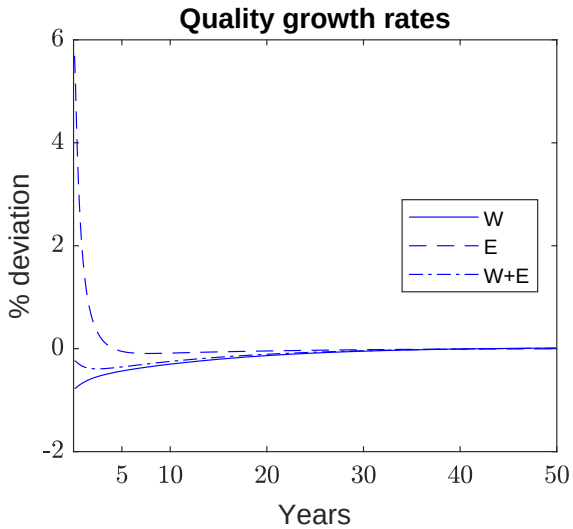
Back to Quantitative

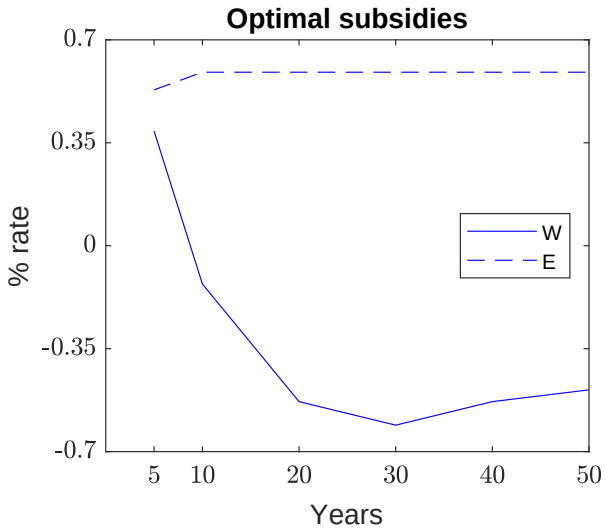
Some Parameters

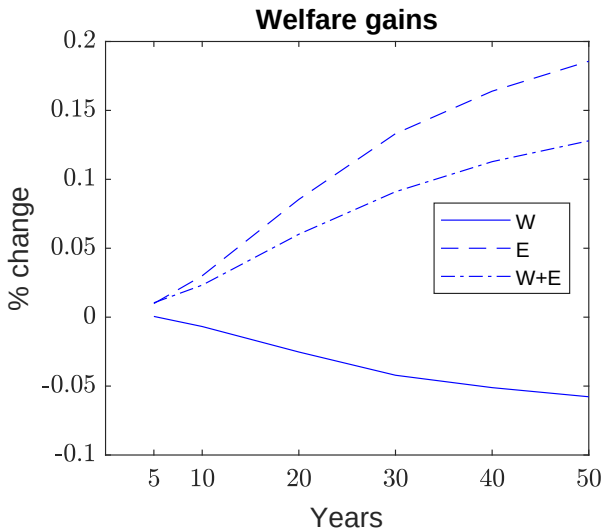
Calibrated parameters	Value
Innovative R&D productivity parameter, West (γ^W)	0.20
Innovative R&D productivity parameter, East (γ^E)	0.10
Spillover parameter (β)	0.60
Quality jump size (λ)	1.80
Decreasing returns (α)	0.20
Spillovers curvature (ϕ)	0.70

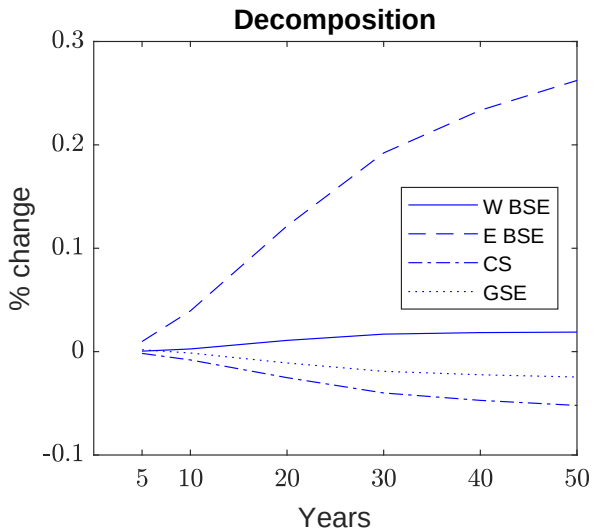
Back to Quantitative

Gains from Coordination: Dynamics









Back to **extensions**