Intangible Assets and Inter-firm Linkages over the Lifecycle of Firms: Theory and Firm-level Evidence

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Motivation

- Why do firms grow over time?
  - Typically, accumulation of factor inputs or exogenous productivity growth
  - Quantitatively trivial role in driving firm growth

We advance the idea that firms gradually accumulate organization capital as a technology

Motivation

Research Questions

- What is the role of intangible assets over firm lifecycle dynamics?
- Resource allocations and aggregate productivity in the presence of intangible assets?
- Aggregate dynamics following exogenous shocks?

We provide a firm dynamics model with intangible assets to quantitatively investigate the role of inter-firm linkages

Intangible Assets

Literature: Interpretations and Applications

- Organization capital/technology Syverson (2011), Atkeson and Kehoe (2005), McGrattan and Prescott (2008), Eisfeldt and Papanikolaou (2014), Joel (2017)
- Customer base and firm dynamics Gourio and Rudanko (2014), Sedlacek and Sterk (2017), Kaas and Kimasa (2018), Rouldan and Gilbukh (2018)
- Managerial skills and firm productivity Bloom, Sadun, and Van Reenen (2017), Bhattacharya, Guner, and Ventura (2013)
- Intangibles and aggregate dynamics McGrattan and Prescott (2015), DeLoecker and Eeckhout (2017), Koh, Santaeulalia-Llopis, and Zheng (2018)
- Input-output networks/trading partners Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Saleh (2012), Carvalho, Nirei, Saito, and Tahbaz-Saleh (2018), Liu (2017), Miyauchi (2018), Bigio and LaO (2018), Fujii, Saito, and Senga (2017)

Model of Firm Dynamics and Intangible Assets

Model Overview

- An equilibrium model of industry dynamics
  - Heterogeneous firms with persistent shocks
  - Exogenous firm entry and exit
- Intangible assets
  - Costly adoption and maintenance for gradual accumulation
  - Non-marketable and firm-specific nature
  - Endogenous component of firm productivity

Production and Costs

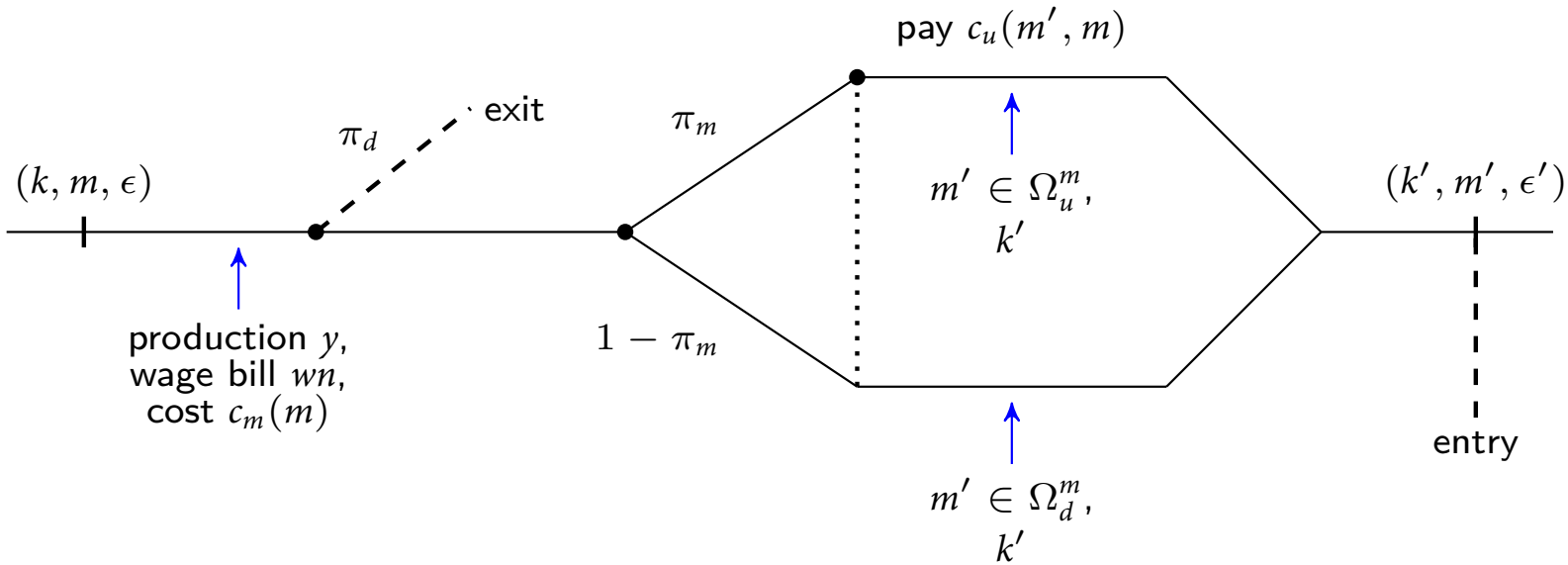
- Production technology, $y = \epsilon \cdot f(k, n) \cdot g(m)$
  - ϵ exogenously following a Markov chain, with $\epsilon \in \mathbf{E}$
  - m as the level of intangible assets, $m \in \Omega^m \subseteq \mathbb{R}_+$
  - Separable contribution of m to output (or, sales)

- Adjustments of intangible assets
  - Convex maintenance cost, $c_m(m)$
  - Random (positive) investment opportunity with π_m
  - Cost of upward adjustments, $c_u(m', m)$
  - No external financing for k' and m'

Entry, Exit, and Timing

- Exogenous exit with probability π_d
  - Exit status known after production in each period
  - Exiting firms are exactly replaced by entrants with (k_0, m_0, ϵ_0)
  - m disappears when a firm exits

- Timing within a period



- Note $\Omega_d^m \equiv \{m' | m' \leq m\}$, $\Omega_u^m \equiv \{m' | m' > m\} \subseteq \Omega^m$, given m

Firm's Problem

Value Function

$$V(k,m,\epsilon) = \max_{k',m',n} \Big[y - wn + (1-\delta)k - c_m(m) + (1-\pi_d)\Big[\pi_m \cdot \max\{V^u, V^n\} + (1-\pi_m)\cdot V^n\Big]\Big] \tag{1}$$

subject to

$$0 \leq y - wn + (1-\delta)k - c_m(m) - k' - \mathbb{I}_{m'>m}\cdot c_u(m',m)$$

$$V^u = -c_u(m',m) - k' + \beta \mathbb{E}_{\epsilon'|\epsilon} V(k',m',\epsilon'), \quad m' \in \Omega_u^m \tag{2}$$

$$V^n = -k' + \beta \mathbb{E}_{\epsilon'|\epsilon} V(k',m',\epsilon'), \quad m' \in \Omega_d^m \tag{3}$$

Application to Inter-firm Linkages

Inter-firm Linkages as Intangibles

- In data, substantial heterogeneity in transaction relationships
  - Trading partners, buyers and sellers, at firm-level
  - Lifecycle patterns and firm growth

- We regard such inter-firm linkages as intangible assets or organization capital in our model
  - Let m be discrete with $\Omega^m \equiv \{1, 2, \ldots, \bar{m}\}$
  - Step-wise upward adjustments, while flexible downward
  - For now, we do not distinguish buyers and sellers

Empirical Evidence

Data

We use Japanese firm-level data on inter-firm linkages

- An unbalanced panel constructed from Tokyo Shoko Research (TSR) dataset
  - Annual from 2007 to 2016, with total 1,899,437 firms covered
  - Firm-level information: sales, employment, credit rating, age, location
  - Linkage information: list of suppliers and customers up to 24 counterparts

- Existing studies using the same dataset, but mostly in cross-sectional
  - Static analyses for input-output networks
  - Bernard et al. (2017), Carvalho et al. (2016)

Empirical Evidence

Summary Statistics, FSS (2017)

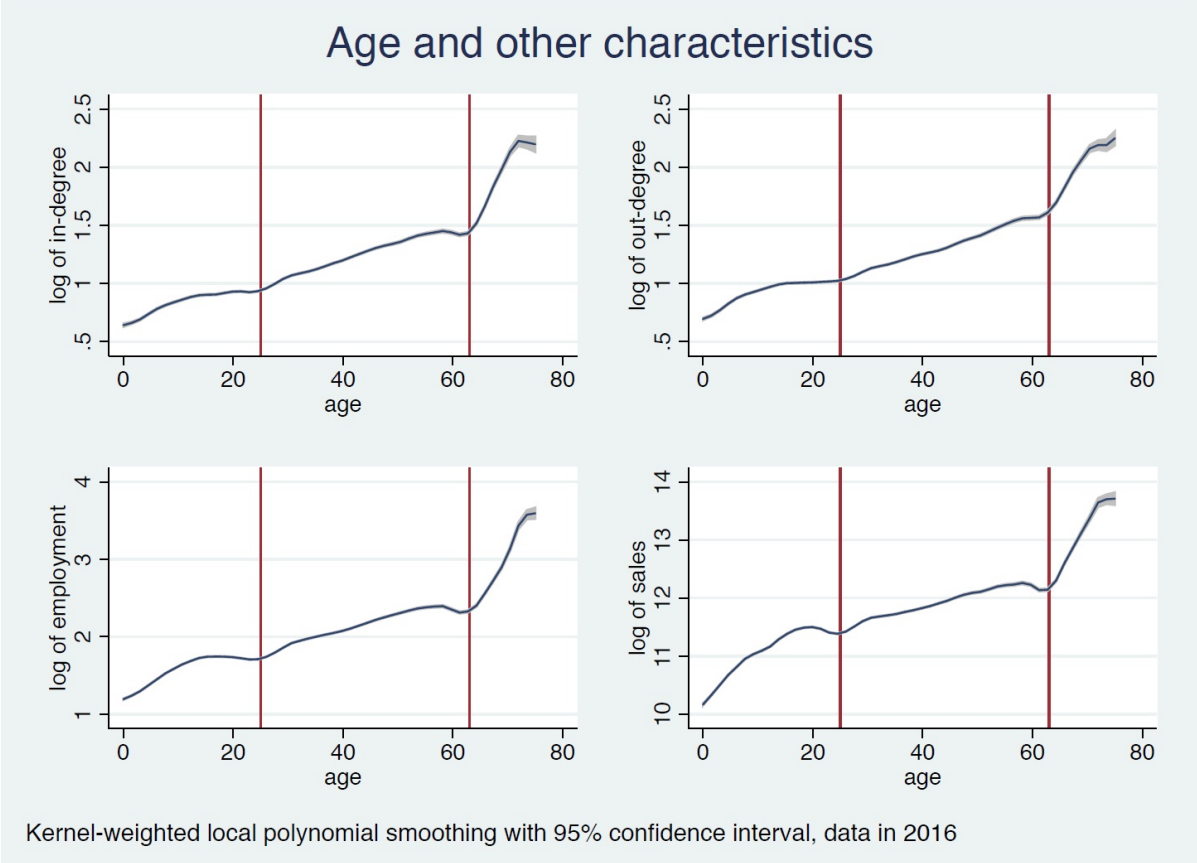
Inter-firm Linkages, TSR 2007-2016

Year	Firms (thous.)	Avg. Age	Links (thous.)	LCR	LTR	Avg. Links/Firm
2007	1006.160	26.5	3117.370	-	-	3.50
2008	1031.324	26.8	3642.342	0.199	0.164	3.53
2009	1075.747	26.6	3799.720	0.204	0.163	3.53
2010	1127.705	26.6	3910.803	0.184	0.155	3.47
2011	1160.461	26.8	3982.640	0.175	0.157	3.43
2012	1201.136	27.0	4015.001	0.168	0.160	3.34
2013	1213.765	27.3	3987.906	0.172	0.179	3.29
2014	1211.590	27.6	3958.519	0.169	0.176	3.27
2015	1198.840	28.0	4117.448	0.203	0.164	3.43
2016	1224.950	28.3	4194.850	0.181	0.163	3.42
2008-2016	1160.613	27.2	3956.581	0.184	0.165	3.41

- Average number of links per firm is stable over time
- Large churnings of total number of links by year (16 to 20 %)

Empirical Evidence

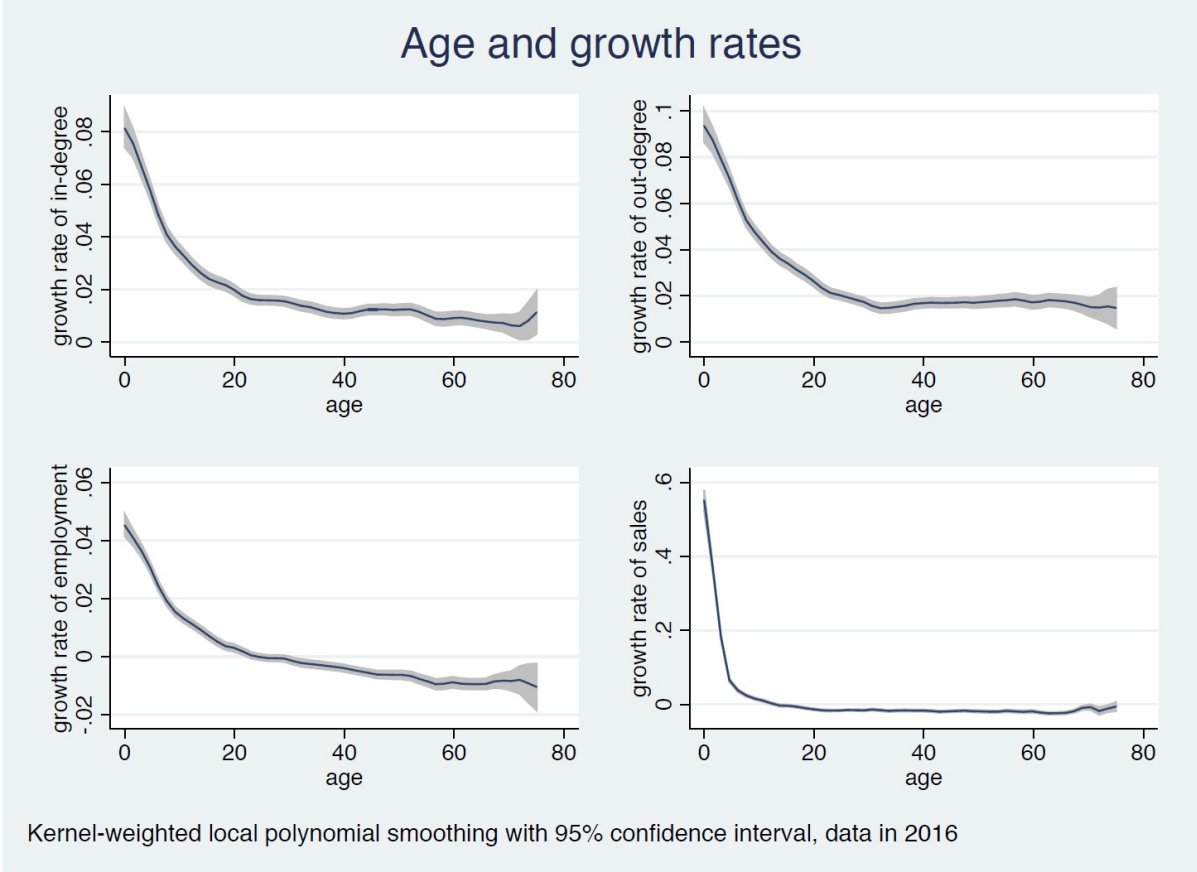
Firm Lifecycle with Linkages, FSS (2017)



- Firm age is positively related with firm size and linkages

Empirical Evidence

Firm Growth, FSS (2017)



- Growth rates fall in firm age

Quantitative Results

Model Parameters

- Functional forms
  - Household utility, $U(C, 1-N) = \log C + \psi(1-N)$
  - Production technology, $f(k,n) = k^{\alpha} n^{\nu}$ and $g(m) = m^{\gamma}$
  - Cost functions, $c_m(m) = x_m \cdot (m-1)^2$ and $c_u(m', m) = \xi_m$
  - Log-normal AR(1) for ϵ with $(\rho_\epsilon, \sigma_{\eta_\epsilon})$

- Parameter values

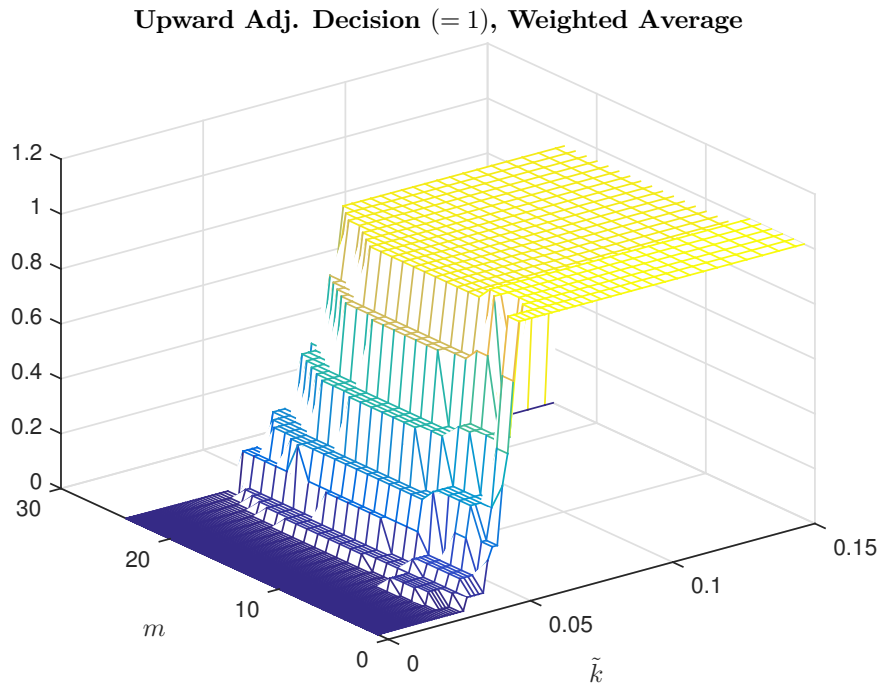
Model Parameters			
α	0.30	x_m	0.0046
β	0.96	ξ_m	0.0120
δ	0.08	χ	0.10
ν	0.60	$\bar{m}$	24
γ	0.20	N_ϵ	7
ψ	2.36	ρ_ϵ	0.75
π_d	0.04	σ_{η_ϵ}	0.10
π_m	0.40		

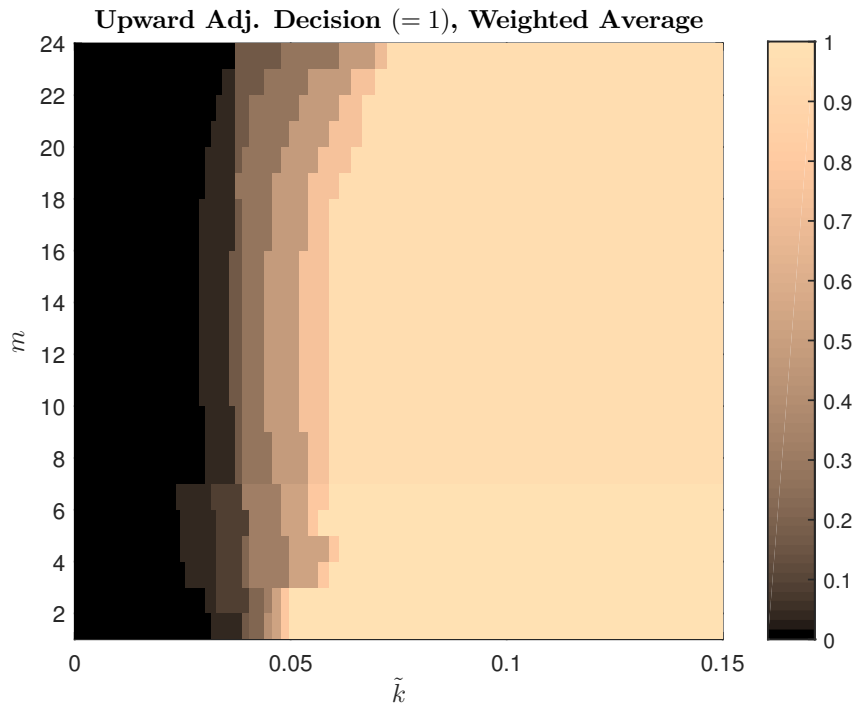
Model Parameters

- Aggregate moments *(preliminary)*

Aggregate Moments		
Description	Data	Model
Average hours worked	-	0.334
Capital to output ratio (CAO, 2008-2016)	1.732	1.818
Average firm age (TSR, 2008-2016)	27.222	23.888
Average # of links per firm (TSR, 2008-2016)	3.412	3.794
Average # of links at age 20 (TSR, 2016)	4.xxx	3.345
Firms with $m' > m$	(TBA)	0.196

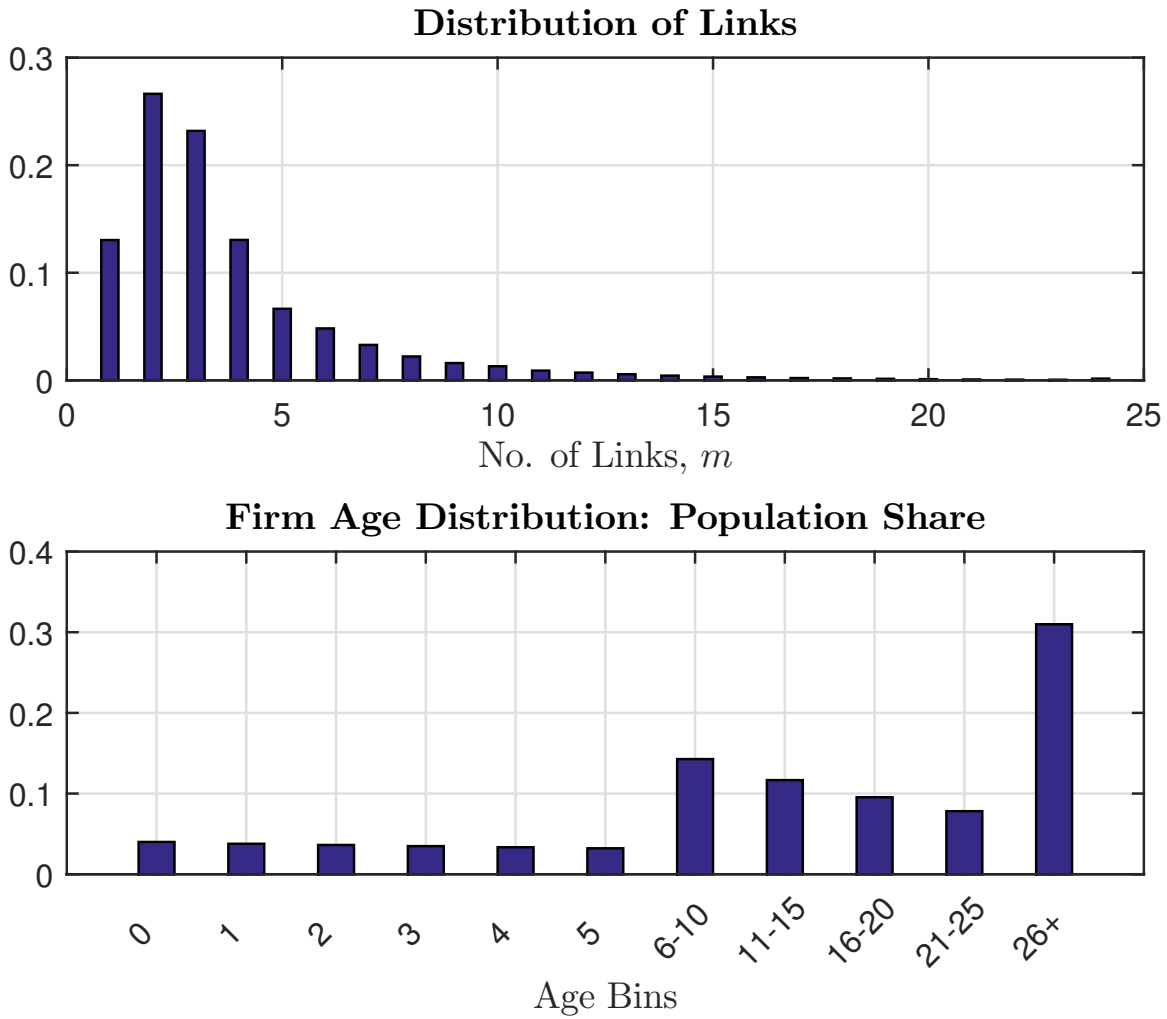
Steady State: Upward Adjustment Decision



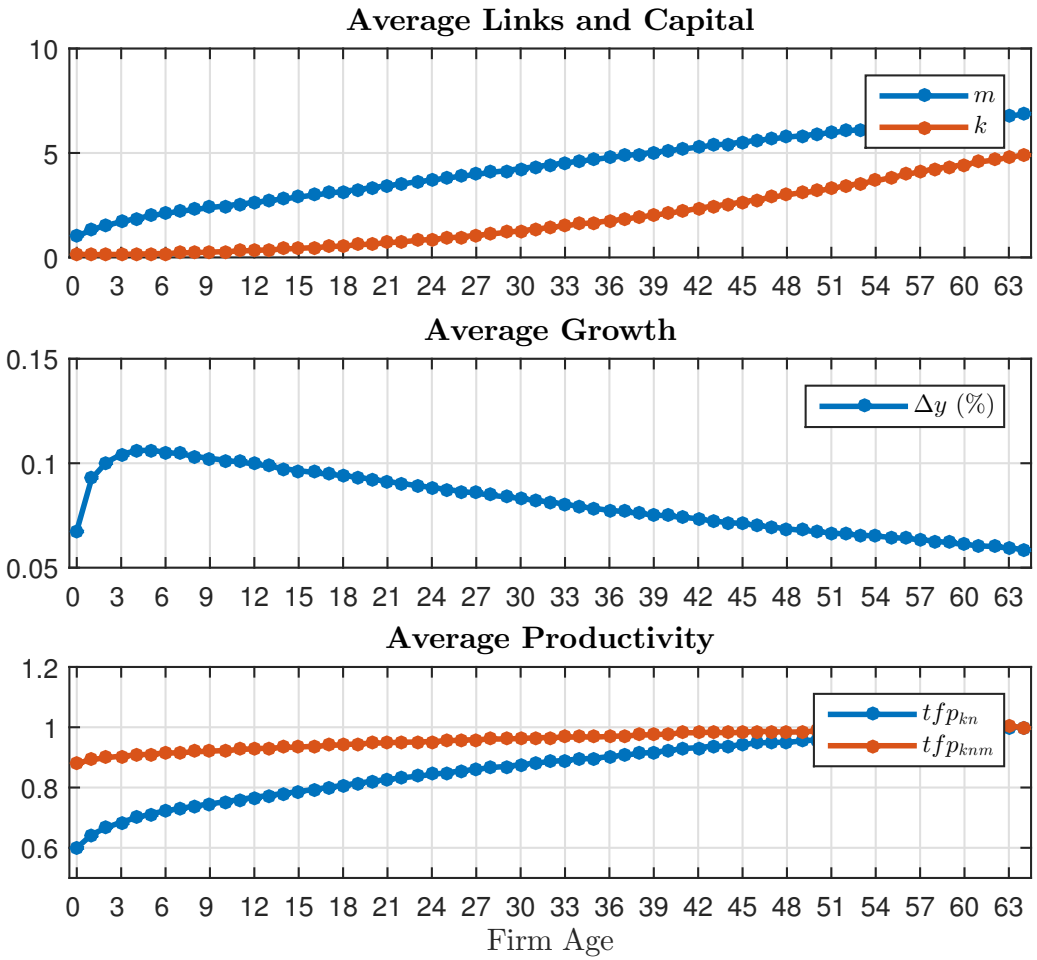


- $V(\tilde{k}, m, \epsilon)$ and $\mu(\tilde{k}, m, \epsilon)$

Steady State: Link and Age Distributions



Steady State: Firm Lifecycle



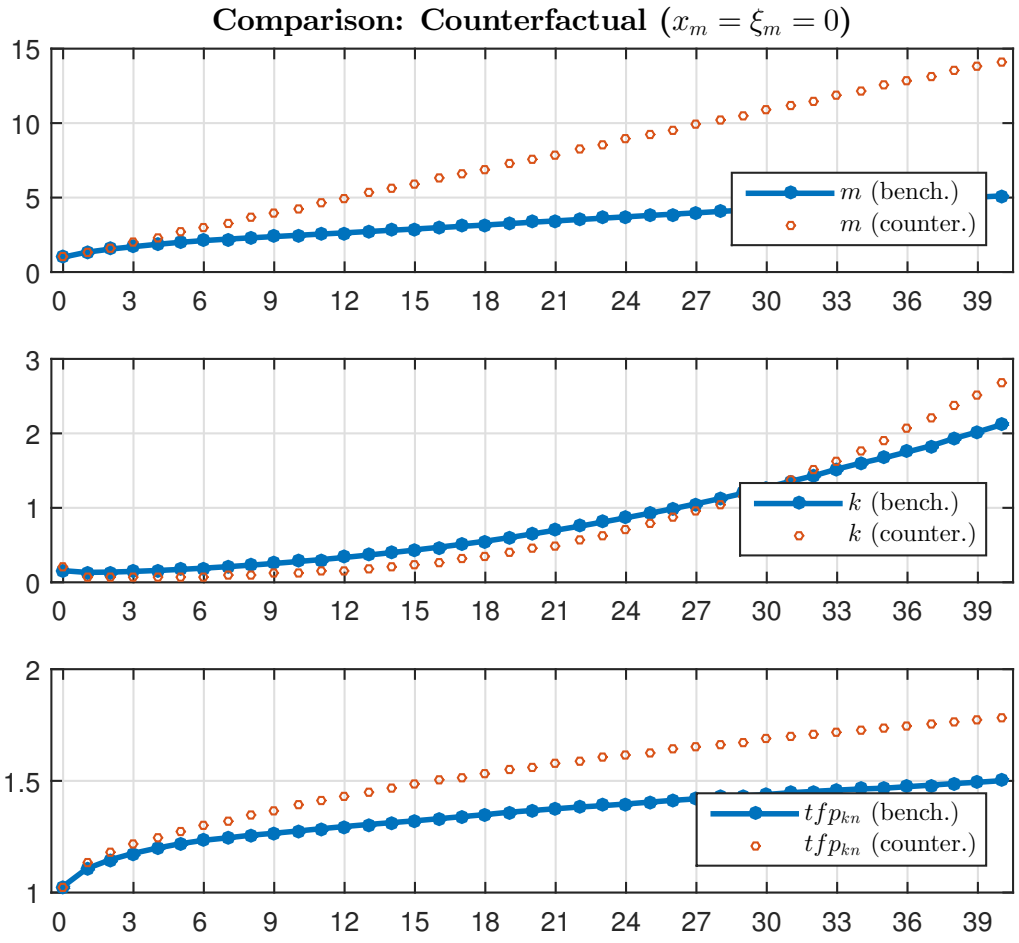
Comparative Statics: Role of x_m and ξ_m

Aggregate changes when setting $x_m = \xi_m = 0$

Counterfactual: Aggregates, $x_m = \xi_m = 0$		
	Benchmark	No Cost
consumption	100.00	132.15
capital	100.00	126.28
output	100.00	118.88
employment	100.00	89.98
avg. links	3.7935	9.5989
links at age 20	3.3450	7.5800
$\Delta TFP_{KN}(\%)$	(1.4637)	18.6489
$\Delta TFP_{KNM}(\%)$	(1.1211)	-1.4567
$\Delta MPN(\%)$	(1.5424)	32.1243
CEV(%)	-	43.0239

Comparative Statics: Role of x_m and ξ_m

Firm dynamics when $x_m = \xi_m = 0$



▶ Extreme π_m

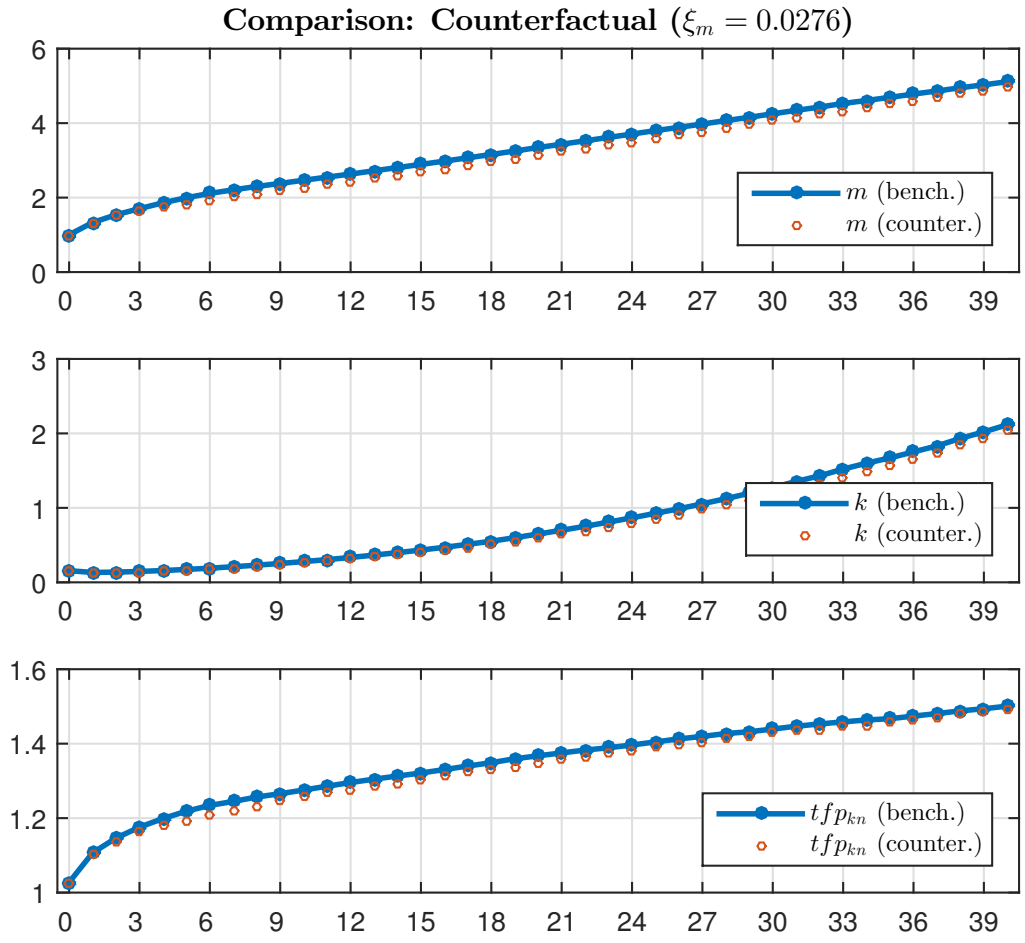
Comparative Statics: Raising Costs, ξ_m or x_m

Note the average no. of links in Japan fell by 4% between 2011 and 2014

Counterfactual: Aggregates, Raising ξ_m or x_m			
	Benchmark	$\xi_m \uparrow$ ($\xi_m = 0.0276$)	$x_m \uparrow$ ($x_m = 0.0051$)
consumption	100.00	99.31	98.78
capital	100.00	99.29	98.94
output	100.00	99.17	98.75
employment	100.00	99.88	100.00
avg. links	3.7935	3.6445	3.6412
links at age 20	3.3450	3.1390	3.2650
$\Delta TFP_{KN}(\%)$	(1.4637)	-0.5567	-0.9495
$\Delta TFP_{KNM}(\%)$	(1.1211)	0.2434	-0.1344
$\Delta MPN(\%)$	(1.5424)	-0.7076	-1.2455
CEV(%)	-	-0.5990	-1.2214

Comparative Statics: Raising Costs, ξ_m or x_m

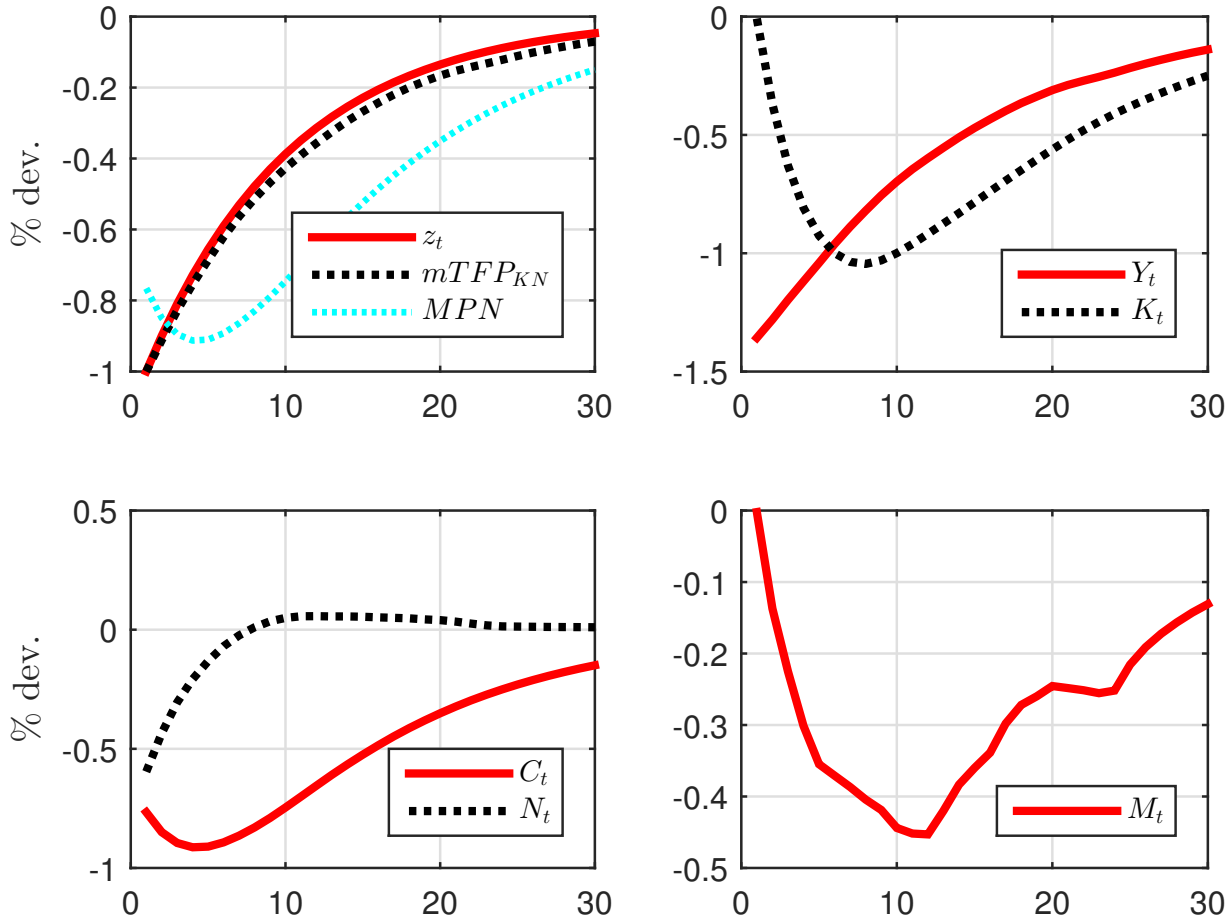
The case of raising ξ_m



▶ Case of x_m ↑

Transitional Dynamics: Aggregate Productivity Shock

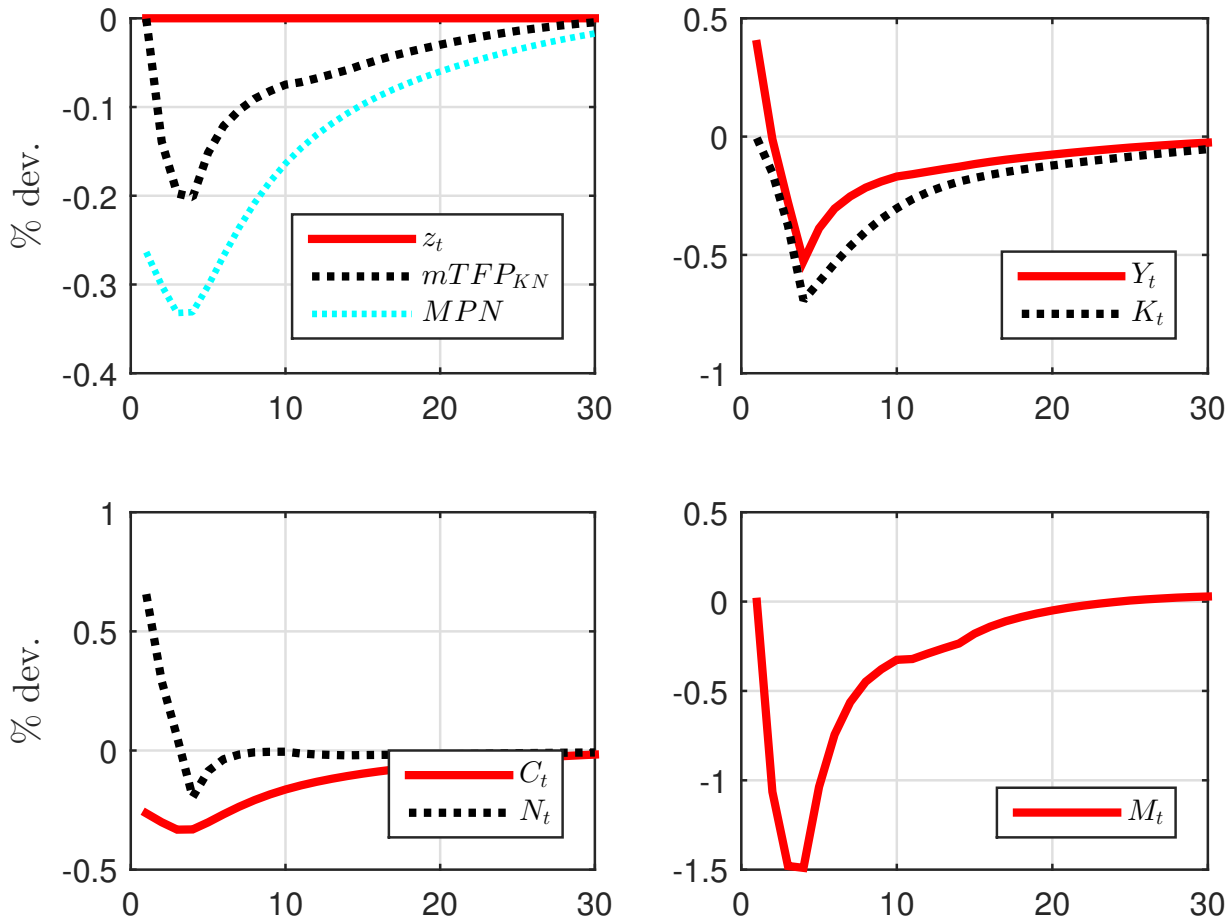
A persistent negative shock on z with $\rho_z = 0.9$



▸ No Costs ▸ Labor Wedge ▸ Combined with $\pi_m \downarrow$

Transitional Dynamics: Linkage Cost Shock

A sudden increase in x_m for 3 periods



▸ Comparing x_m vs. ξ_m

Takeaways

- We study the macroeconomic implications of firm dynamics in the presence of intangible assets
  - Intangibles in relation with firm growth and productivity
  - Potential amplification channel of aggregate productivity shocks
  - Recessions triggered by a sudden deterioration of intangibles

- Our focus is on the inter-firm linkages as a new mechanism
  - Empirical evidence on lifecycle patterns
  - Micro-to-macro approach on allocative efficiency and business cycles

Moving Forward

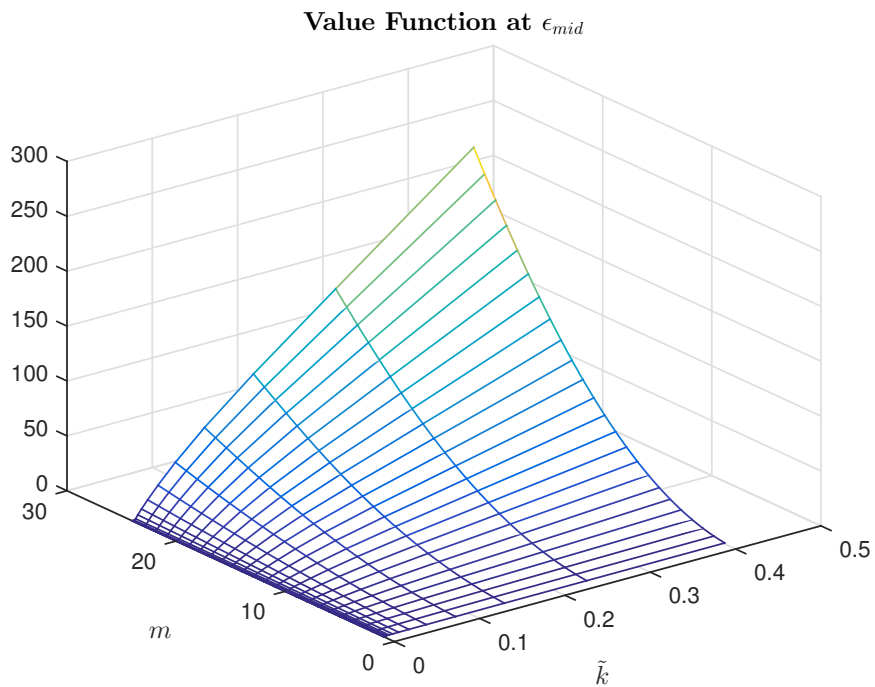
Directions

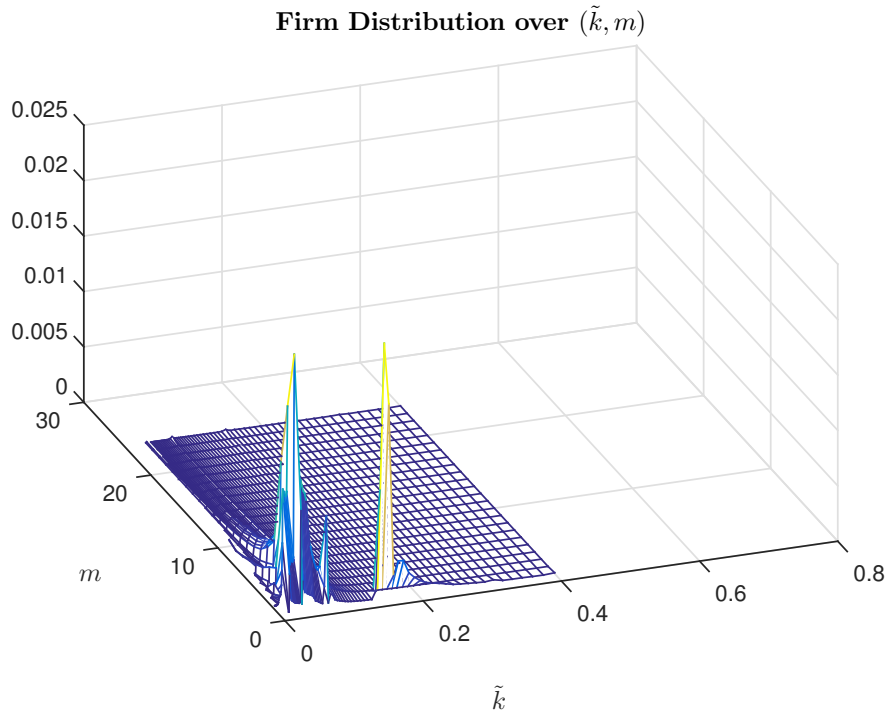
- Macroeconomic implications of intangible assets at firm-level
  - Business cycles with job flows and firm age (Fort et al. (2013), Sedlacek and Sterk (2017))
  - Transitional dynamics and decreasing labor income share (DeLoecker and Eeckhout (2017), Koh et al. (2018))
  - Industry equilibrium with endogenous entry/exit and firm growth/aging (Arkolakis (2016), Fattal-Jaef (2018), Jo and Senga (2018))
- Role of uncertainty across inter-firm relationships
  - Theory on link survival rates, sorting, asymmetry between buyers and sellers (Jovanovic (1982), Foster et al. (2015), Senga (2018))
  - Linkage adjustments across firm age with endogenous link matching (Kaas and Kimasa (2018))

Backup Slides

Steady State: Value Function and Firm Distribution

Note $\tilde{k} \equiv \frac{k}{m^{\frac{\gamma}{1-\alpha-\nu}}}$



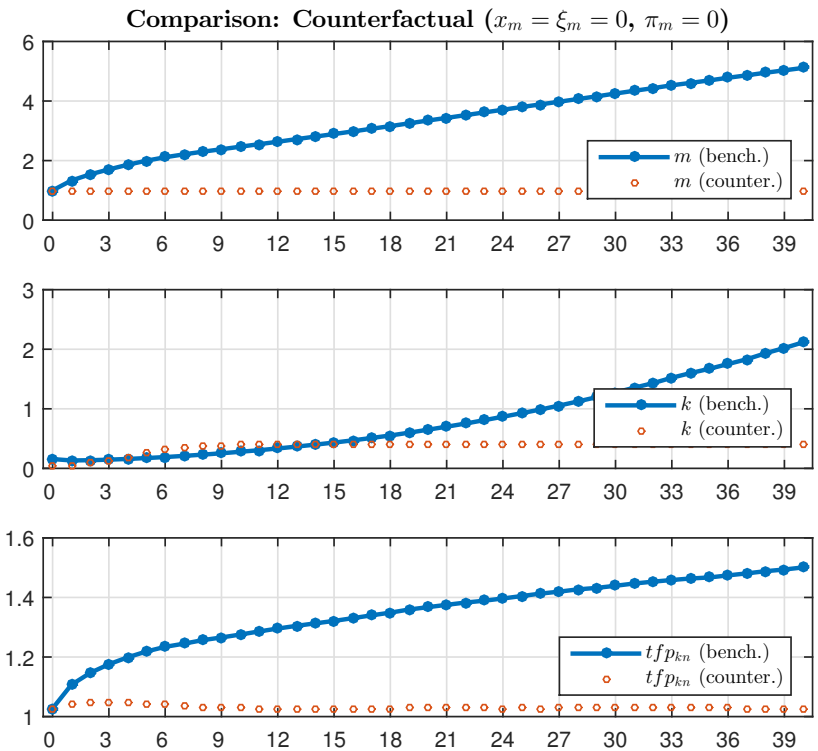


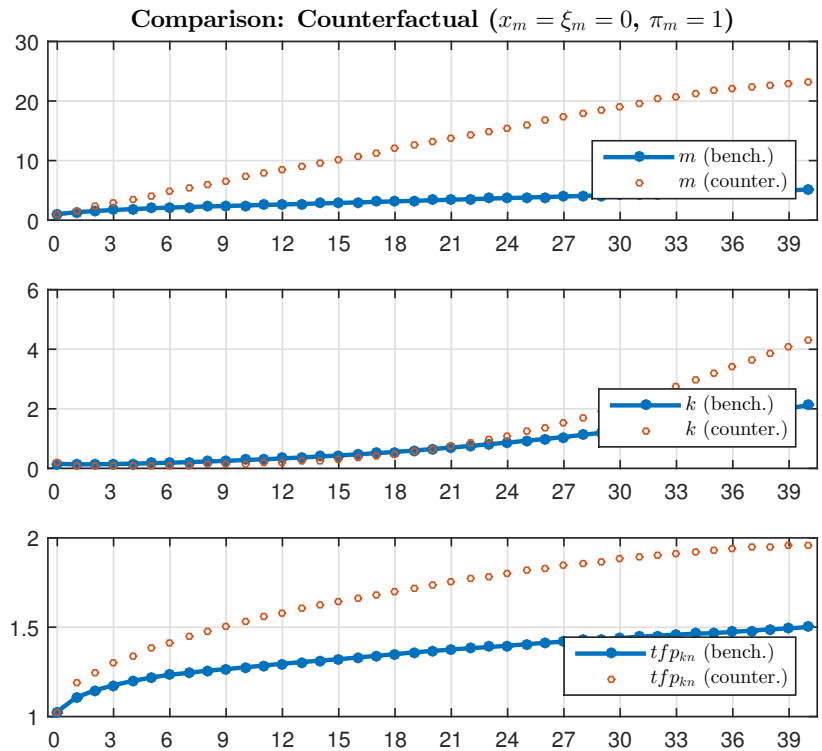
Return

Comparative Statistics: Role of π_m

References for Firm Dynamics

When π_m is either 0 or 1, in addition to $x_m = \xi_m = 0$





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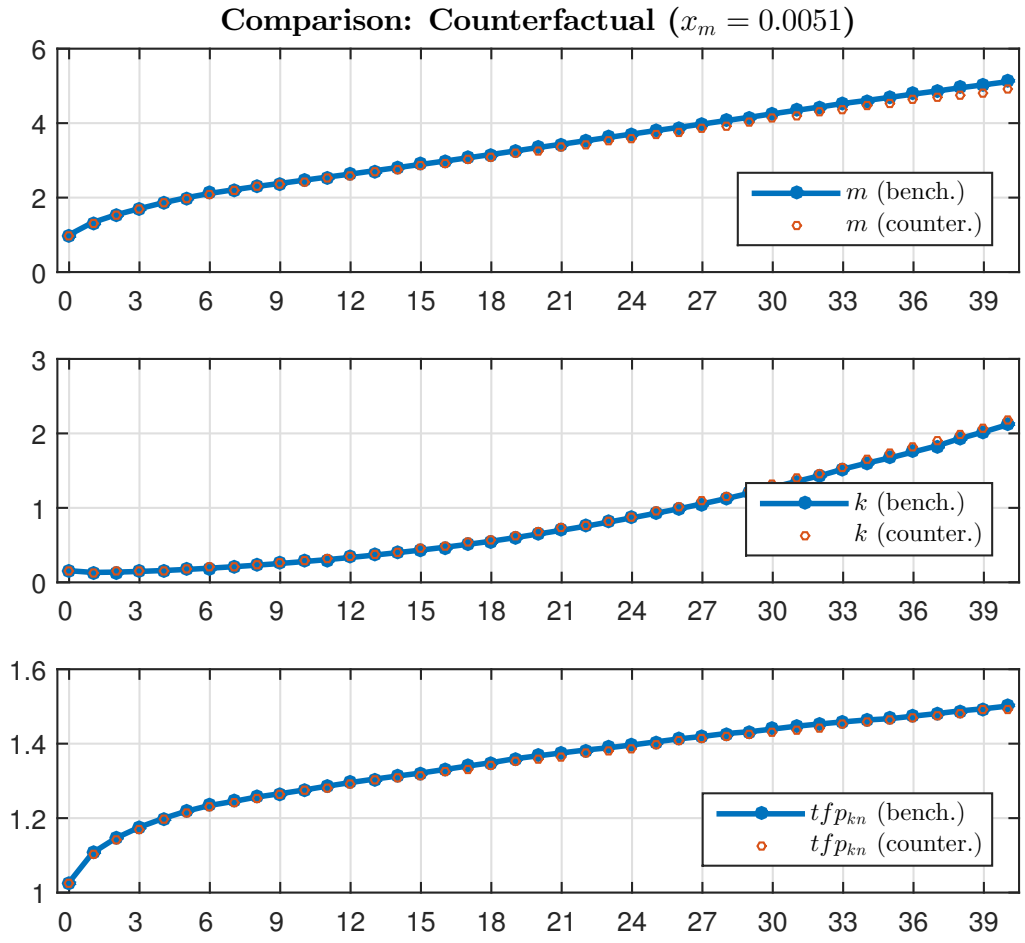
Comparative Statics: Raising Costs, ξ_m or x_m

The case of raising x_m



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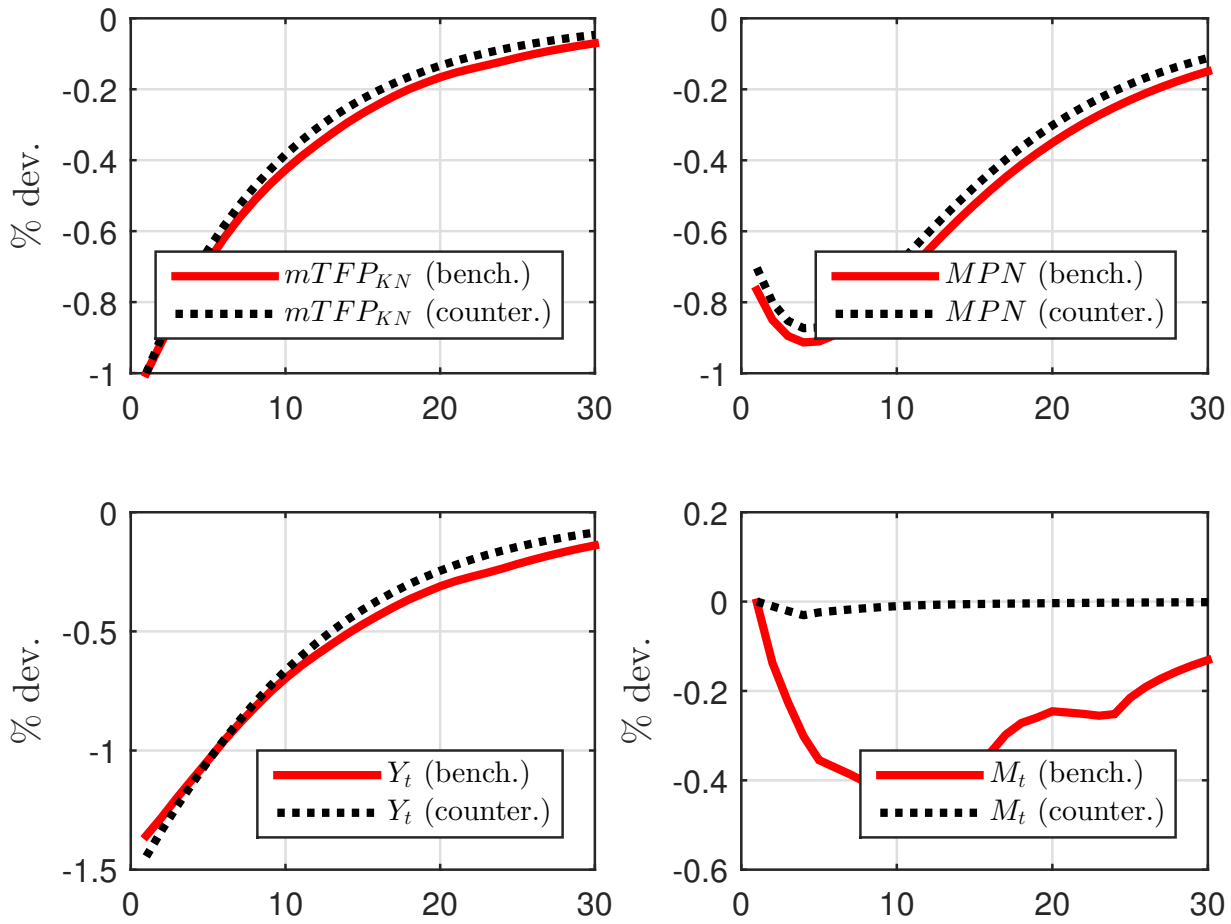
Transitional Dynamics: Aggregate Productivity Shocks

A persistent shock on z with $\rho_z = 0.9$, when $x_m = \xi_m = 0$



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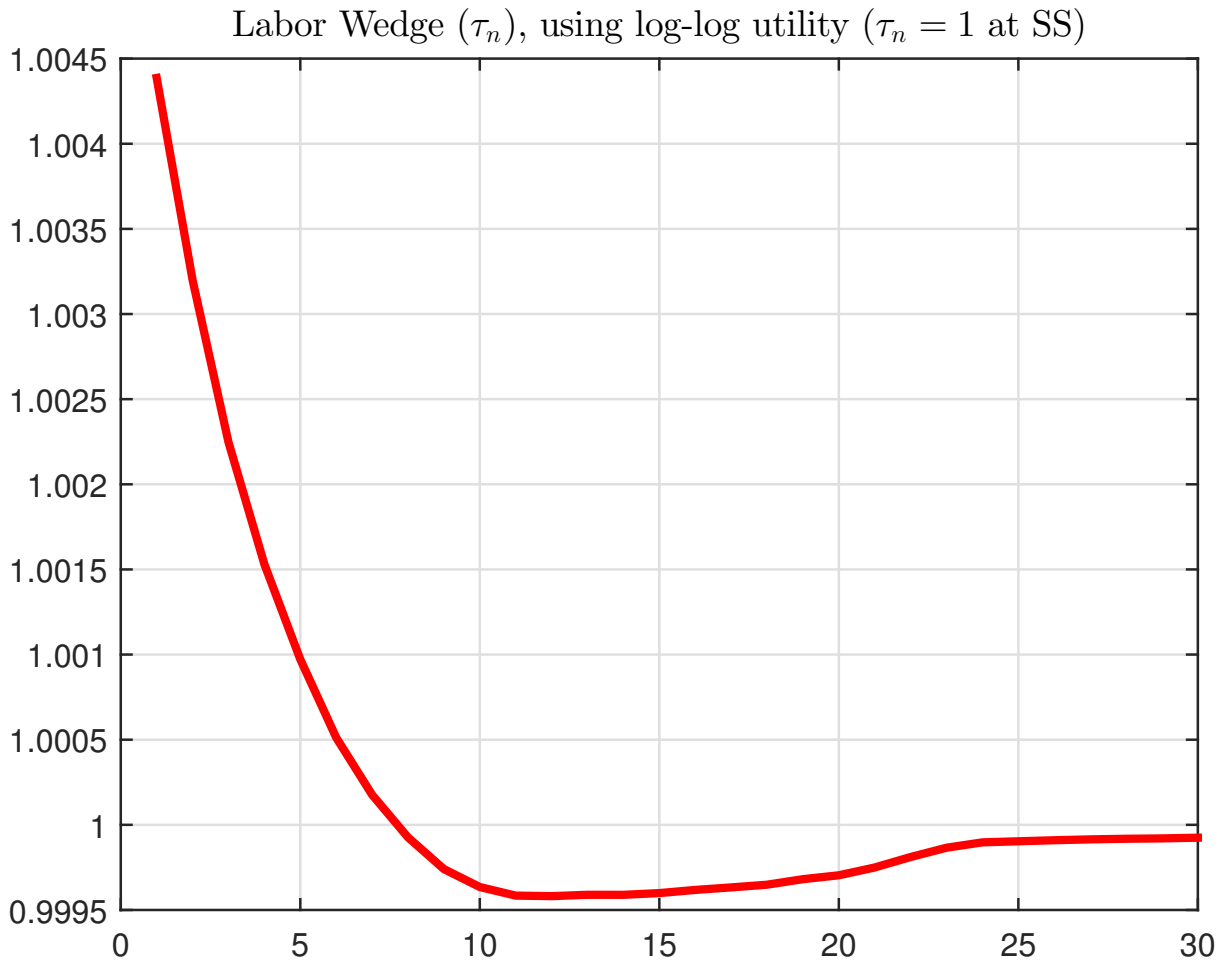
Transitional Dynamics: Aggregate Productivity Shocks

Labor wedge following an aggregate productivity shock



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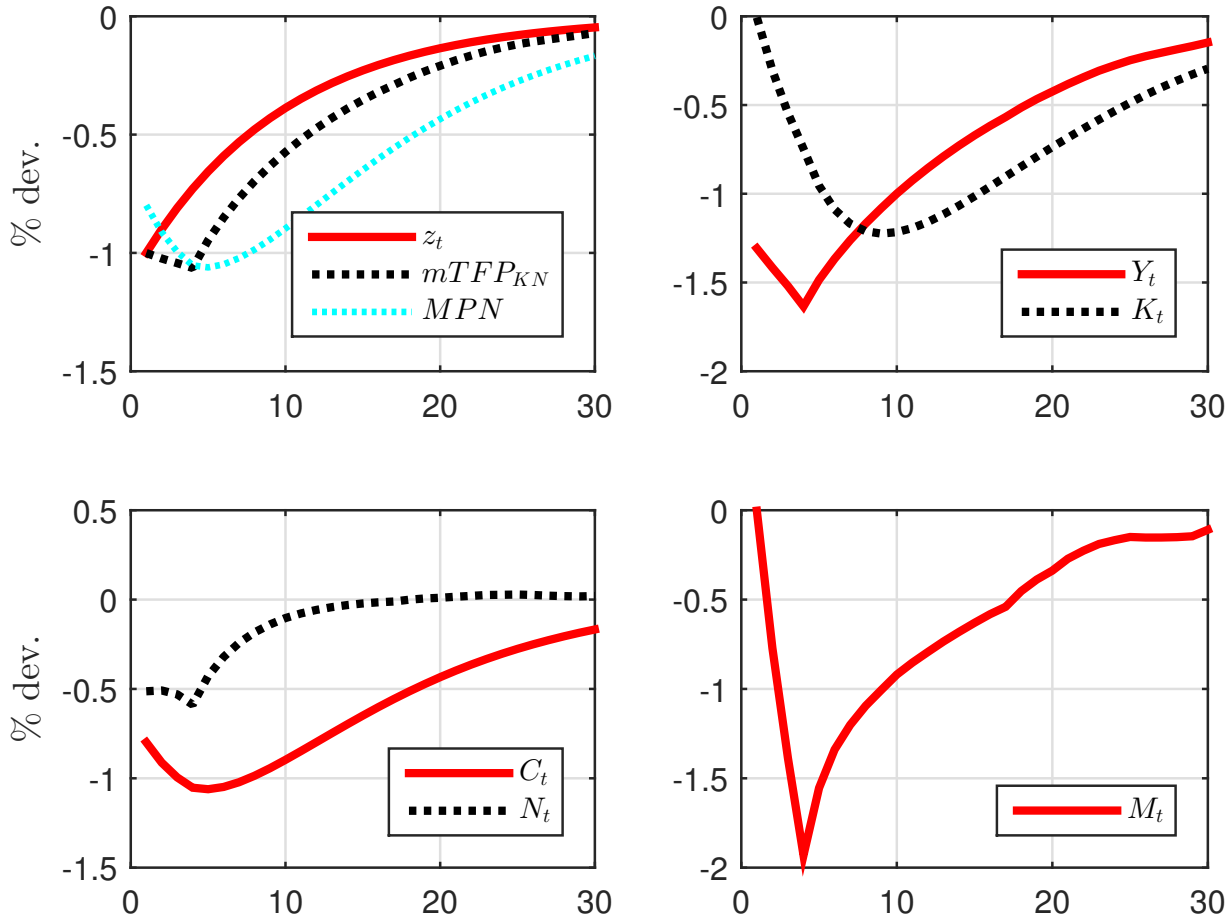
Transitional Dynamics: Aggregate Productivity Shocks

When π_m also falls to 0.32 for 3 periods



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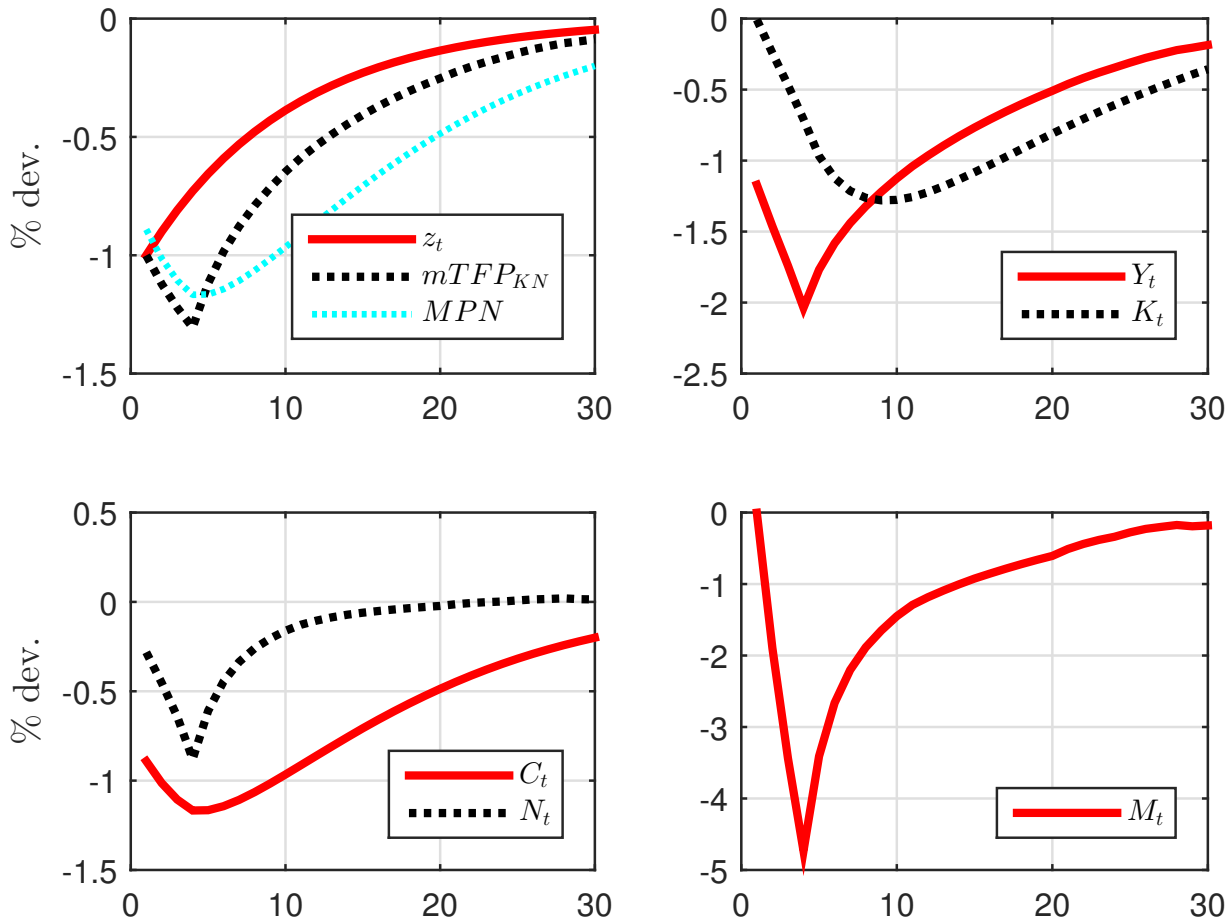
Transitional Dynamics: Aggregate Productivity Shocks

When $\pi_m = 0.32$ and $\xi_m = 0.0276$ for 3 periods, following a negative z shock



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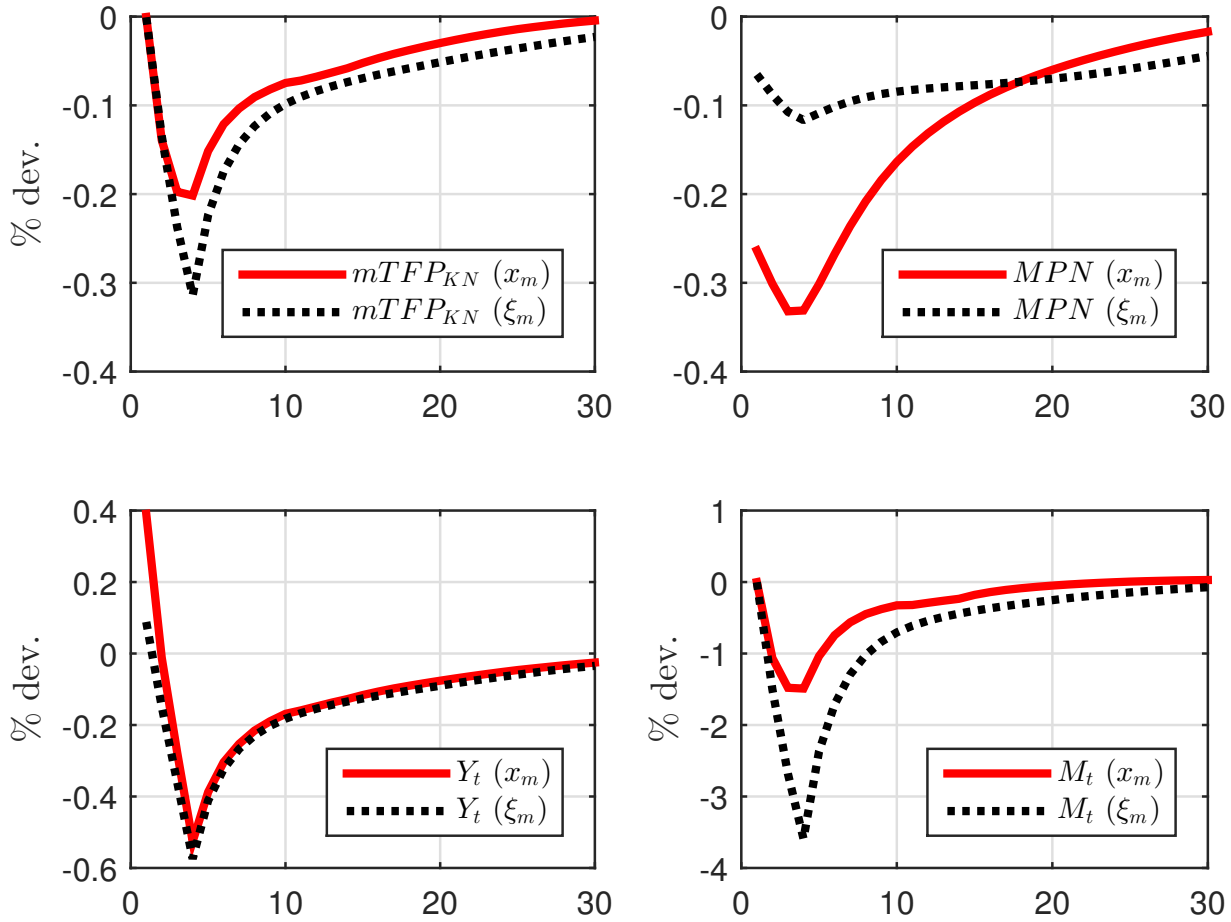
Transitional Dynamics: Linkage Cost Shock

Comparing results between raising x_m and ξ_m



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