Production, Trade, and Cross-Border Data Flows

Qing Chang[1] Lin William Cong[2] Liyong Wang[3] Longtian Zhang[3]

1. School of Statistics and Mathematics, Central University of Finance and Economics
2. Cornell University SC Johnson College of Business and NBER
3. School of International Trade and Economics, Central University of Finance and Economics

2024 North American Winter Meeting of the Econometric Society

January 5, 2024

Outline

1. Introduction
2. The Model
3. Steady States Solution
4. Transition Dynamics
5. Conclusion

- Data as the "new oil" in the information age.
- The unrestricted flow of data factor truly creates values.
- Countries across every stage of development have recently erected barriers to them.
  - "data localization"

A general equilibrium model of production and trade in a global economy.

- Comparisons:
  - A closed economy;
  - Partially open economies;
    - with only goods trade,
    - with goods trade and unilateral data flows.
  - Open economies with free data flows.
- Data
  - generated as byproducts of the consumption of households.
  - play crucial roles as input factors in production.

- Welfare analysis:
  - Latecomer's advantage: International data flows significantly improve welfare, especially for countries more backward in data economy.
  - Facilitate trade, when the data divide between the two countries is not very large;
  - Working data (useful information) vs. Raw data
    - Data-efficient country uses more working data,
    - Data-inefficient country contributes more raw data.
- The transition dynamics:
  - After a productivity shock, the cyclicity of working data reverses going from closed to open economies;
  - shocks to data privacy and to flow costs have opposite effects on domestic and foreign data sectors.

- Data divde trap:
  - Though the country with low importance of data can gain large welfare improvements from trading goods and data flows in most cases,
  - the foreign country with high data importance refuses to trade since it faces a welfare loss.
  - The developing country in data economy should keep up with the pace of the developed country.

- Different paths to the economics of data:
  - Jones and Tonetti (2020): Horizontal nonrivalry & production process;
  - Cong, Xie, and Zhang (2021): Dynamic nonrivalry & innovation process;
  - Cong, Wei, Xie, and Zhang (2022): Vertical nonrivalry & both production process and innovation process simultaneously;
  - Xie and Zhang (2023): "producer data" lead to higher growth rate than "consumer data."
- Data do not always lead to sustained economic growth: Farboodi and Veldkamp (2020, 2021); Hou et al., (2022); Veldkamp, (2023).

Introduction

Literature: Microeconomics of Data Privacy, Intermediaries, Markets and Valuing Data

- Data privacy: Abowd and Schmutte (2019); Fainmesser et al. (2019); Ichihashi (2020).
- Data intermediary and markets: Bergemann and Bonatti (2019); Acemoglu et al. (2022); Ichihashi (2021a, b).
- Valuing data: Sun et al. (2021); Farboodi et al. (2022); Veldkamp (2023).

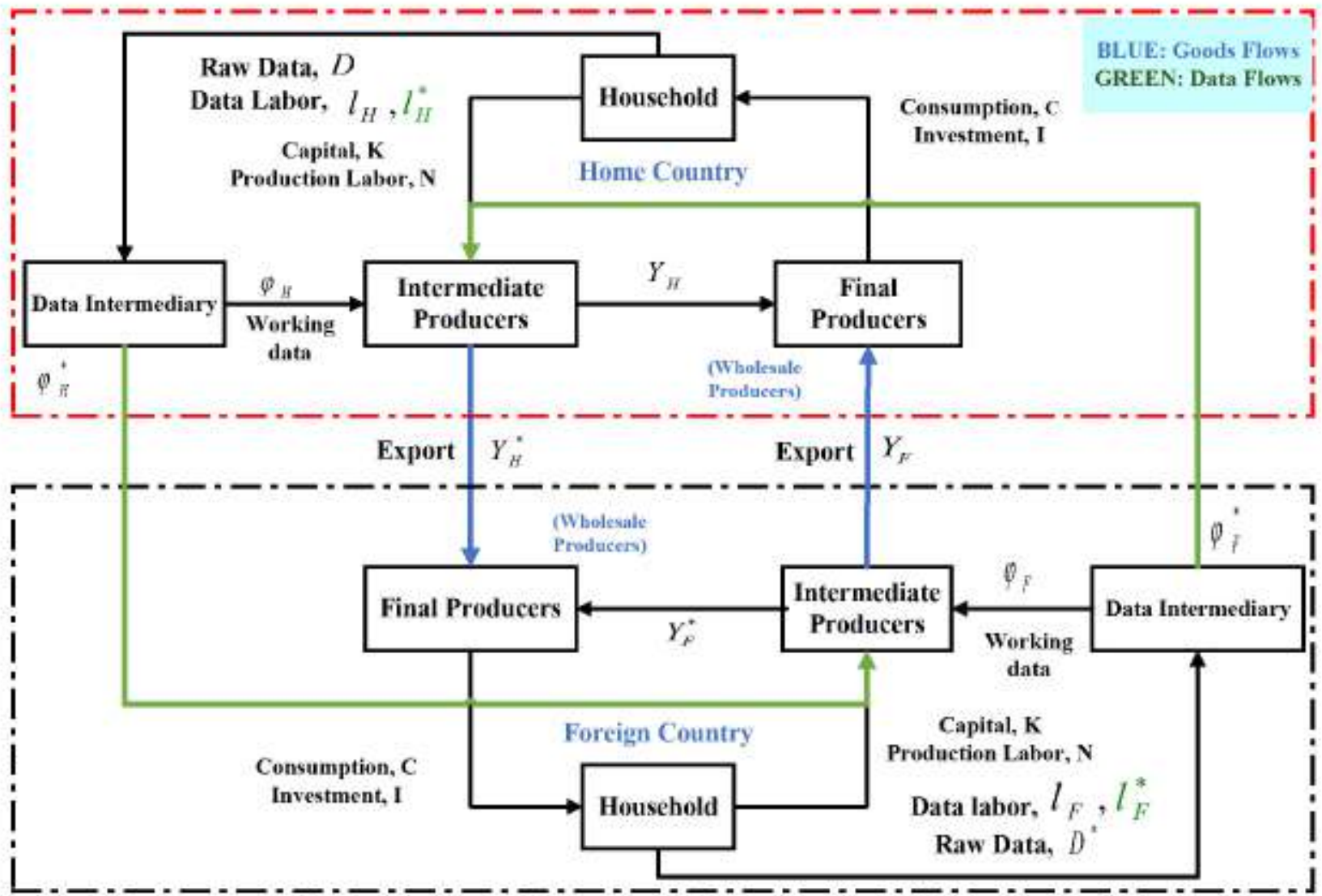
The Model

Setup

- Representative household
  - consumption C_t, labor N_t, and raw data D_t
- Final good producer
  - packs up intermediate goods (from wholesale) to produce output Y_t
- Wholesale good producers
  - assemble domestic and imported intermediate goods ($Y_{H,i,t}$ and $Y_{F,i,t}$) to produce wholesale goods $Y_{i,t}$
- Intermediate good producers (monopolistic with variety i)
  - produce goods $Y_{i,t}$ using labor n_t, capital K_t and data Φ_t
- Data intermediary (monopolist constrained by free entry, i.e. zero profit)
  - buy raw data D_t from household and sell working data φ_t ($\varphi_{H,t}$ and $\varphi^*_{H,t}$) to intermediate producers

A Model of Data Economy

Setup (Cont.)



Utility function:

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \Omega \frac{N_t^{1+\eta}}{1+\eta} - \Pi(1 + b\mathbb{I})\pi_t D_t^2 \right],$$

- π_t is the disutility shock of consumer's data risk, following AR(1):

$$\ln \pi_t - \ln \pi = \rho_\pi (\ln \pi_{t-1} - \ln \pi) + \sigma_\pi \varepsilon, \quad \varepsilon \sim N(0,1),$$

- $\mathbb{I}$ is an indicator function
  - $\mathbb{I} = 1$ when there are cross-border data flows (exporting).
  - In the closed economy, $\mathbb{I} = 0$.

The utility function:

$$U = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \Omega \frac{N_t^{1+\eta}}{1+\eta} - \Pi(1 + b\mathbb{I})\pi_t D_t^2 \right],$$

- Budget Constraint: (We normalize the price of final goods in the home country to 1)

$$C_t + I_t + B_{H,t} + B_{F,t} = w_t N_t + r_t K_t + R_{t-1} B_{H,t-1} + R_{t-1}^* B_{F,t-1} + P_{D,t} D_t.$$

- Capital Accumulation:

$$K_{t+1} = (1 - \delta_K) K_t + I_t.$$

- The final good producer:

$$Y_t = \left[\int_0^1 Y_{i,t}^{\frac{\rho-1}{\rho}} \mathrm{d}i \right]^{\frac{\rho}{\rho-1}},$$

  - $Y_{i,t}$: the wholesale good of variety i (composite intermediate good).
  - Given the prices of each individual variety $P_{i,t}$, the profit maximization problem :

$$\max_{Y_{i,t}} Y_t - \int_0^1 P_{i,t} Y_{i,t} \mathrm{d}i.$$

- Wholesale producers: assemble goods produced domestically and goods imported from abroad using CES technology:

$$Y_{i,t} = \left(Y_{H,i,t}^{\frac{m-1}{m}} + Y_{F,i,t}^{\frac{m-1}{m}} \right)^{\frac{m}{m-1}}. \tag{1}$$

- The profit maximization problem for the wholesale producers:

$$\max_{Y_{H,i,t}, Y_{F,i,t}} Y_{i,t} - P_{H,i,t} Y_{H,i,t} - P_{F,i,t} Y_{F,i,t},$$

where $Y_{i,t}$ is shown in (1).

A Two-country Open Economy

Intermediate Good Producers

- Each producer produces outputs both for domestic use and for exporting, according to the following technology:

$$Y_{H,i,t} + Y^*_{H,i,t} = A_t(\Phi^{\xi}_{i,t} k_{i,t})^{\alpha} n^{1-\alpha}_{i,t}, \tag{2}$$

- A_t is the productivity level, following AR(1) process:

$$\ln A_t - \ln A = \rho_A(\ln A_{t-1} - \ln A) + \sigma_A \varepsilon, \quad \varepsilon \sim N(0,1).$$

- The accumulation process of the data is shown as:

$$\Phi_{i,t+1} = (1-\delta_\Phi)\Phi_{i,t} + \varphi_t, \tag{3}$$

- φ_t here represents a data composite:

$$\varphi_t = \left[\chi^{\frac{1}{o}} \varphi_{H,t}^{\frac{o-1}{o}} + (1-\chi)^{\frac{1}{o}} \varphi_{F,t}^{\frac{o-1}{o}}\right]^{\frac{o}{o-1}}. \tag{4}$$

- The trade cost of importing data.
- Suppose that $P_{\varphi,F,t}$ is the price the foreign country sells its working data to the home country, then the price that the home country should in fact pay is $df_t P_{\varphi,F,t}$.
- Here, d is viewed as the trade cost of foreign working data, and f_t is the shock of this cost, following AR(1) process:

$$\ln f_t - \ln f = \rho_f(\ln f_{t-1} - \ln f) + \sigma_f \varepsilon, \quad \varepsilon \sim N(0,1).$$

- A data intermediary in each country buys raw data from household in domestic country and then sells working data to intermediate producers in both countries.
- It also employ labors ($l_{H,t}$ and $l^*_{H,t}$) to do the collecting and cleaning works, to produce working data for domestic usage and exporting.
- The working data generation functions in the home country:

$$\varphi_{H,t} = BD_t^{\gamma} l_{H,t}^{1-\gamma}, \tag{5}$$

and

$$\varphi^*_{H,t} = BD_t^{\gamma} (l^*_{H,t})^{1-\gamma}. \tag{6}$$

Equilibrium Definition

An allocation in which (both in the home country and foreign country):

- Households maximize the utility ,
- Producers and data intermediaries maximize the profit,
- All markets clear.

  (Final goods market, wholesale goods market, intermediate goods market, labor market, capital market, assets market, and data market.)

Alternative Models

Goods Trade Economy, Partially Open Economies, and Closed Economy

- Goods trade model:
  - Intermediate good producers: $\varphi_{H,t} = \varphi_t$.
  - The data intermediary:

$$\max_{D_{H,t}, l_{H,t}} \int_0^1 P_{i,\varphi,H,t}\varphi_{H,t}\mathrm{d}i - P_{D,H,t}D_t - w_t l_{H,t},$$

subject to the working data generation function:

$$\varphi_{H,t} = BD_t^{\gamma} l_{H,t}^{1-\gamma},$$

and the zero-profit condition:

$$\int_0^1 P_{i,\varphi,H,t}\varphi_{H,t}\mathrm{d}i - P_{D,H,t}D_t - w_t l_{H,t} = 0.$$

- Closed economy and economies with unilateral data flow for comparison (without goods traded or data flows).

Steady States Solution

Parameters

Parameters	Meaning	Value	Source
β	Subjective discount factor	0.99	Standard
σ	Reciprocal of elasticity of intertemporal substitution	2	Standard
η	Reciprocal of Frisch labor supply elasticity	1.3	Standard
$1-\alpha$	Contribution of labor in good productions	$2/3$	Standard
δ_k	Capital depreciation rate	0.025	Standard
Ω	Weight on leisure in the utility function	1.315	Christensen and Dib (2008)
ρ	Elasticity of substitution (varieties)	21	Fernandez-Villaverde et al. (2015)
m	Elasticity of substitution (domestic and imported)	5	Alessandria et al. (2021)
ρ_A, ρ_e, ρ_f	Persistence of exogenous shocks	0.95	Alessandria et al. (2013)
δ_Φ	Data depreciation rate	0.025	Discretionary
χ	Availability of domestic data	0.5	Discretionary
B	Efficiency term in working data generation	1	Discretionary
γ	Contribution of raw data in working data generation	0.5	Discretionary

Steady States Solution

Welfare Analyses

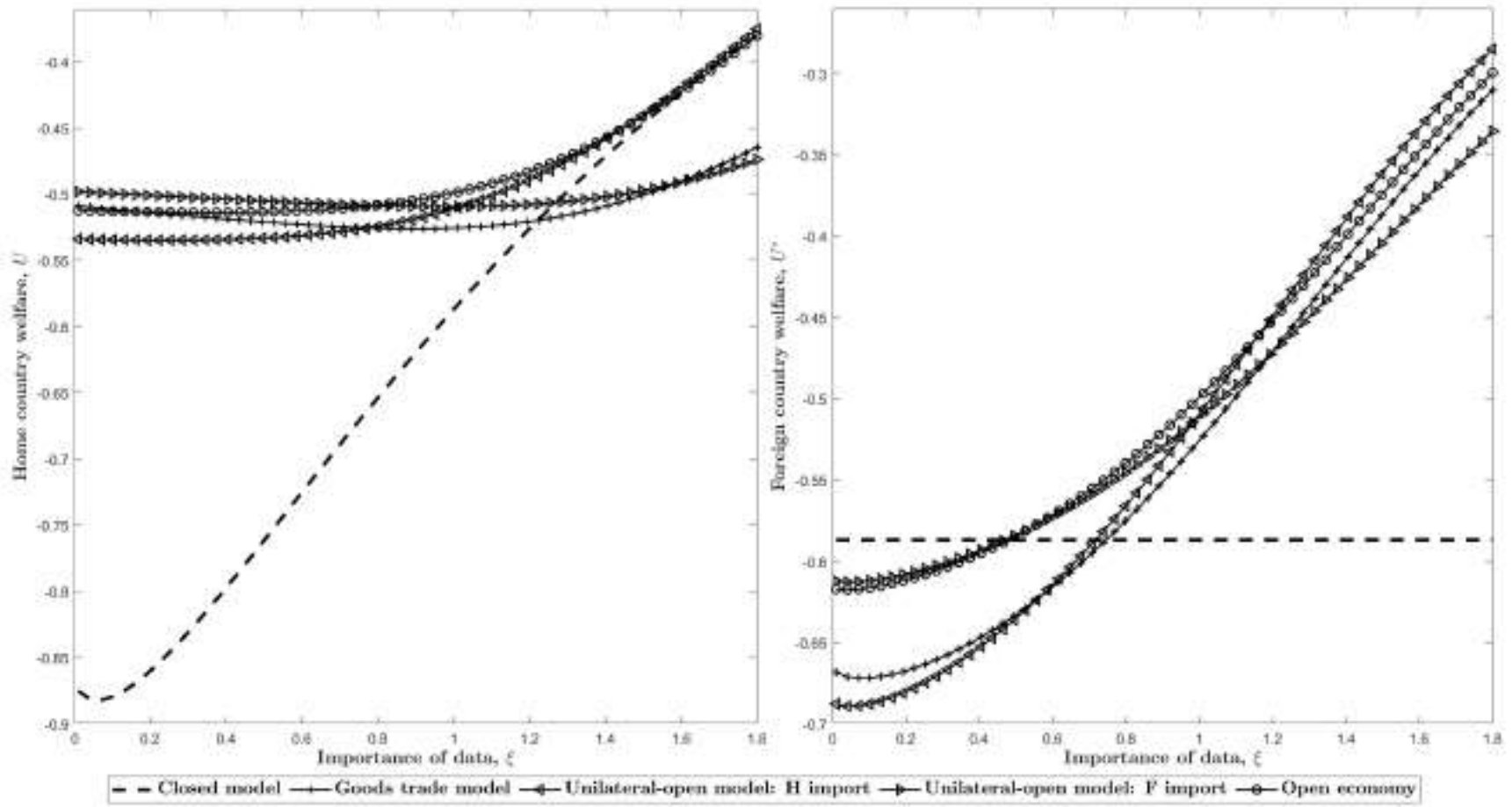


Figure: Welfare Levels with Different Importance of Data in the Two Countries (Fixing $\xi^* = 1$)

Steady States Solution

Welfare Analyses (Cont.)

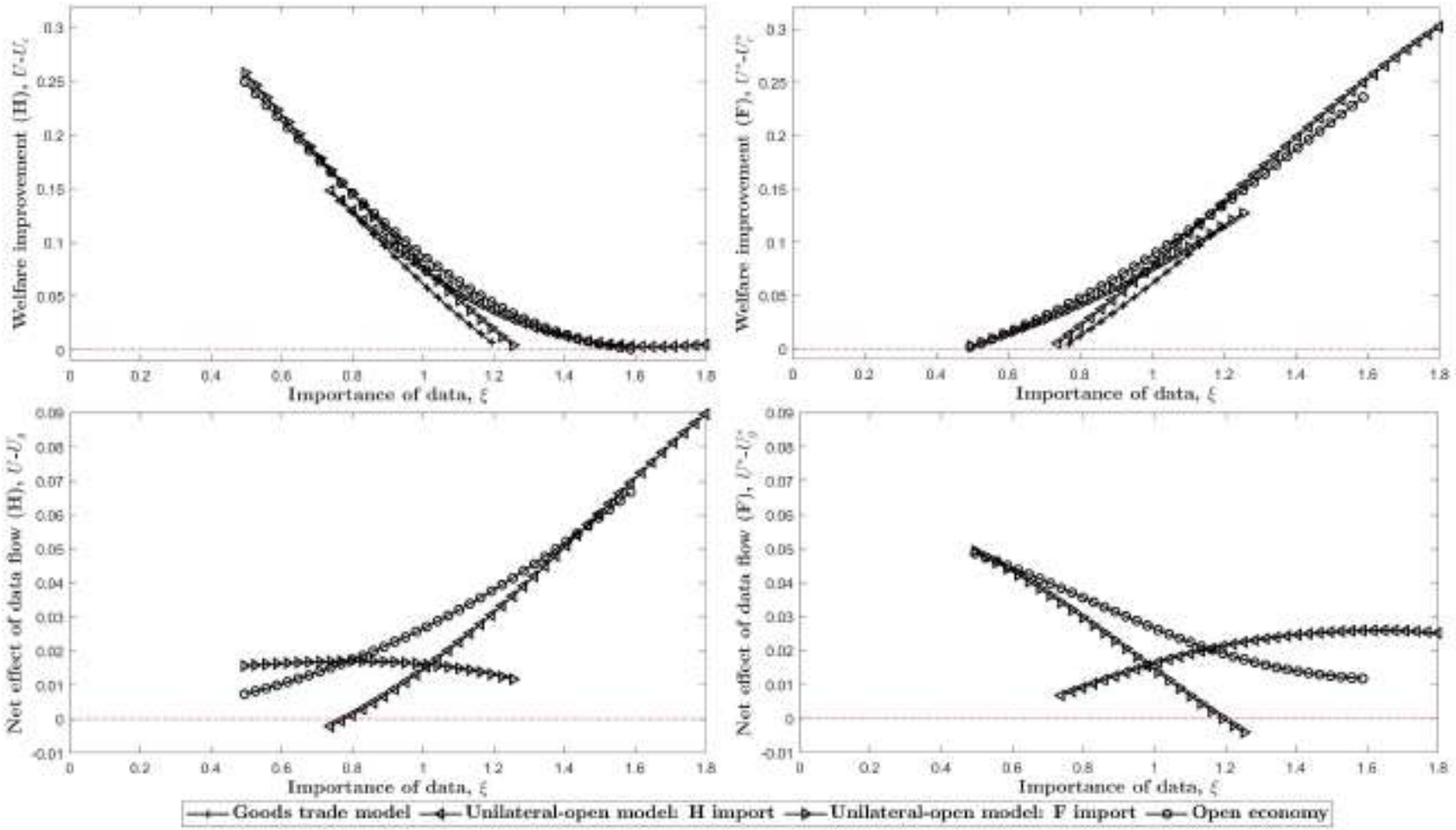


Figure: Welfare Improvements from Trade and Data Flows under Different Importance of Data

Steady States Solution

Welfare Analyses (Cont.)

- The importance of data in the foreign country is fix at $\xi^* = 1.0$.
  - In the home country, welfare improvements are very large when ξ is small.
  - However, in the foreign country, we see welfare loss in these cases.
    - The foreign country will refuse to trade.
- Intuitions
  - Benefits of trade: market expansion and demand increasing
  - Costs for high ξ country: the price of its goods become cheaper
    - High ξ country export more (cheap), but import less (expensive).
    - Goods from different countries are substitutes.
    - In extreme cases where data divide is too large, welfare loss.

Steady States Solution

Welfare Analyses (Cont.)

	Model	Foreign Country: Importance of Data, ξ^*		
		$\xi^* = 0.5$	$\xi^* = 1.0$	$\xi^* = 1.5$
Home Country: Available Interval of Trade, ξ. ($U - U_c > 0$ and $U^* - U_c^* > 0$)	Goods Trade Model	$[0, 0.79]$	$[0.75, 1.22]$	$[1.31, 1.67]$
	Unilateral-Open Model: F import	$[0, 0.80]$	$[0.47, 1.27]$	$[0.88, 1.75]$
	Unilateral-Open Model: H import	$[0, 1.03]$	$[0.72, 1.75]$	$[1.23, 1.75]$
	Open Economy: $d = 1$	$[0, 1.02]$	$[0.48, 1.61]$	$[0.93, 1.75]$
	Open Economy: $d = 1.5$	$[0, 0.91]$	$[0.49, 1.39]$	$[0.94, 1.75]$
	Open Economy: $d = 2$	$[0, 0.87]$	$[0.50, 1.33]$	$[0.96, 1.75]$
Home Country: Positive Net Effect Interval of Data Flow, ξ. ($U - U_g > 0$ and $U^* - U_g^* > 0$)	Unilateral-Open Model: F import	$[0, 0.73]$	$[0.47, 1.19]$	$[0.88, 1.61]$
	Unilateral-Open Model: H import	$[0.29, 1.03]$	$[0.78, 1.75]$	$[1.37, 1.75]$
	Open Economy: $d = 1$	$[0.13, 1.02]$	$[0.48, 1.61]$	$[0.93, 1.75]$
	Open Economy: $d = 1.5$	$[0.15, 0.91]$	$[0.49, 1.39]$	$[0.94, 1.75]$
	Open Economy: $d = 2$	$[0.17, 0.87]$	$[0.50, 1.33]$	$[0.96, 1.75]$

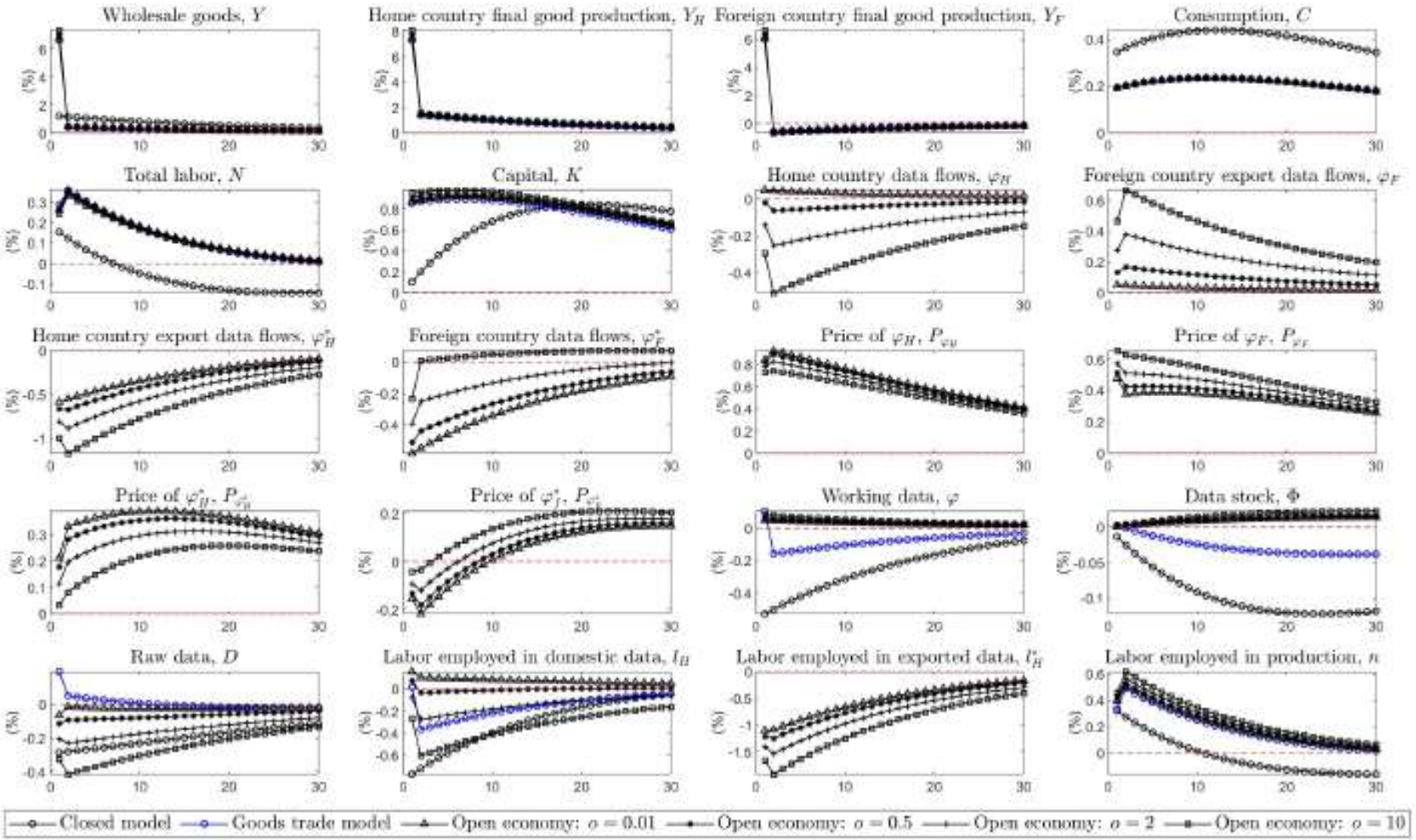
Steady States Solution

Welfare Analyses (Cont.)

- Further observations
  - Data flows help mitigate the welfare loss of high ξ country.
    - Available interval becomes larger.
  - Positive net effect of data flows in most of the cases.
    - Unilateral data flows to foreign country also have positive net effects.
    - Unilateral data flows to home country enlarges the interval.
  - Increasing trade costs of data reduces the feasible interval.
    - The interval of positive net effect of data flows also become narrower.

Transition Dynamics

Analysis on Symmetric Countries—Productivity Shock A_t



Transition Dynamics

Analysis on Symmetric Countries

Main Observations.

- Productivity shock.
  - Working data (used by firms) cyclicity reverses when we change from closed model to open economy.
  - Intuition: When a productivity shock occurs in the home country, data concentrate in the high-productivity country. Less exporting, more importing....
- Disutility shock.
  - The closed model and the goods trade model behave similarly for data-related variables.
- Price shock.
  - Acts similarly with disutility shock in the open economies, but has different mechanisms (supply side vs. demand side)

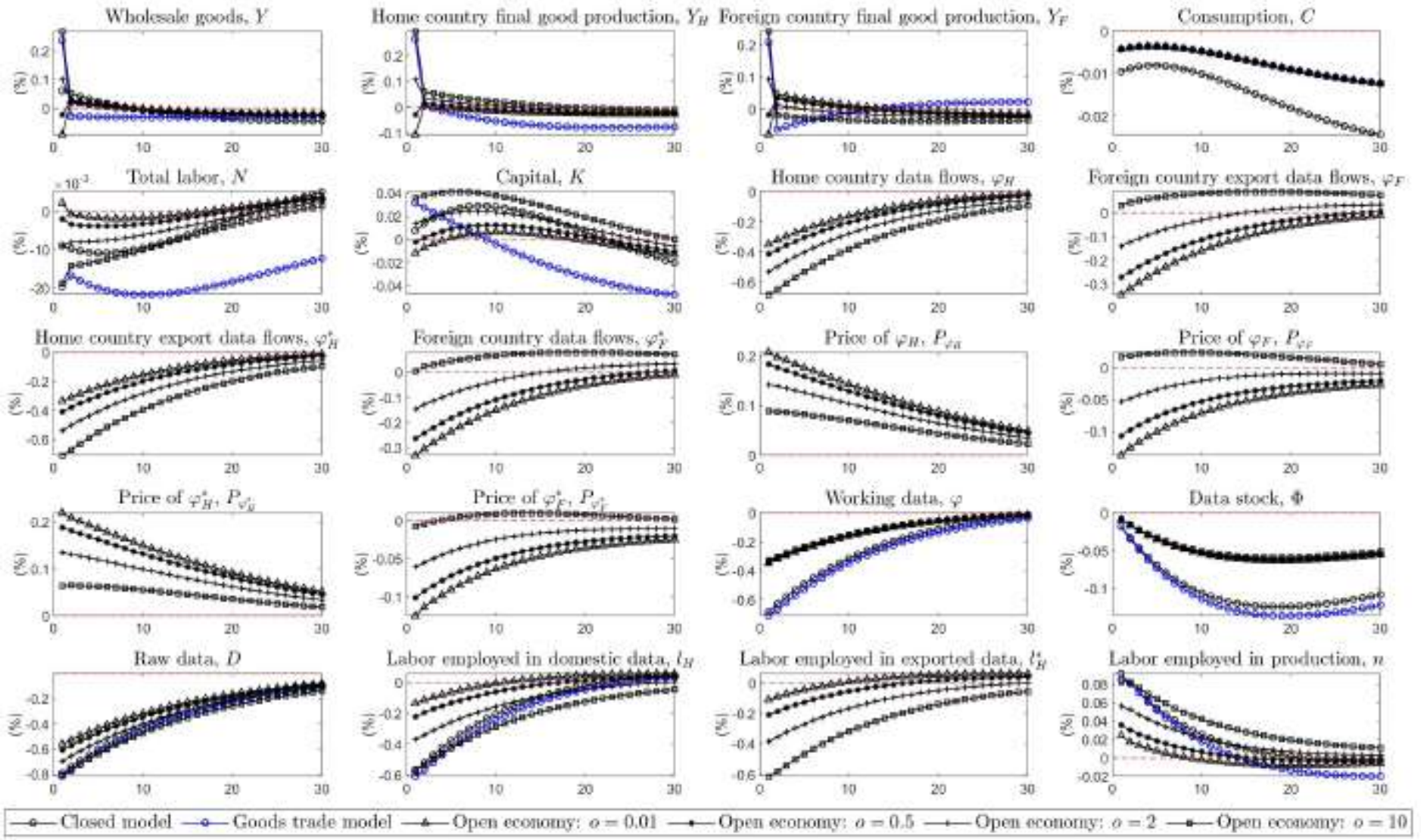
Conclusion

- We contribute to the emerging literature on the data economy by extending the discussion to the international context in a dynamic general equilibrium framework.
  - Latecomer's advantage: welfare improvements from trade are large in the data-inefficient country.
  - However, trade liberalization may come to a halt when the data divide between two countries is too large.
  - Working data tends to concentrate in the data-efficient country.
  - A reversed cyclical pattern in working data following aggregate productivity shocks.
- Policy guidance on the development of data-related industries, cross-border data flows, and the mitigation of aggregate shocks.

Thanks for your attention!

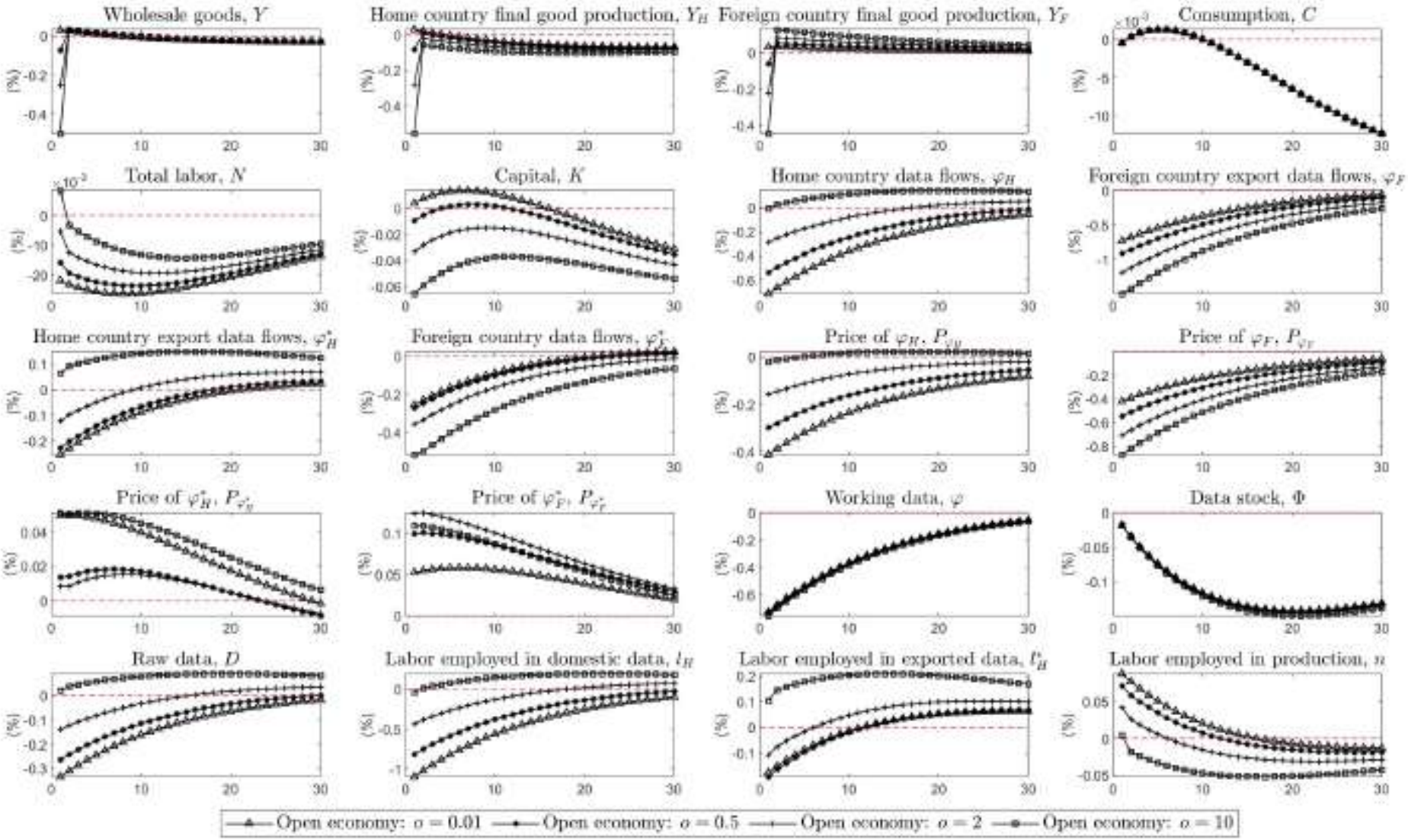
Transition Dynamics (Appendix)

Analysis on Symmetric Countries—Disutility Shock on Raw Data Flows π_t



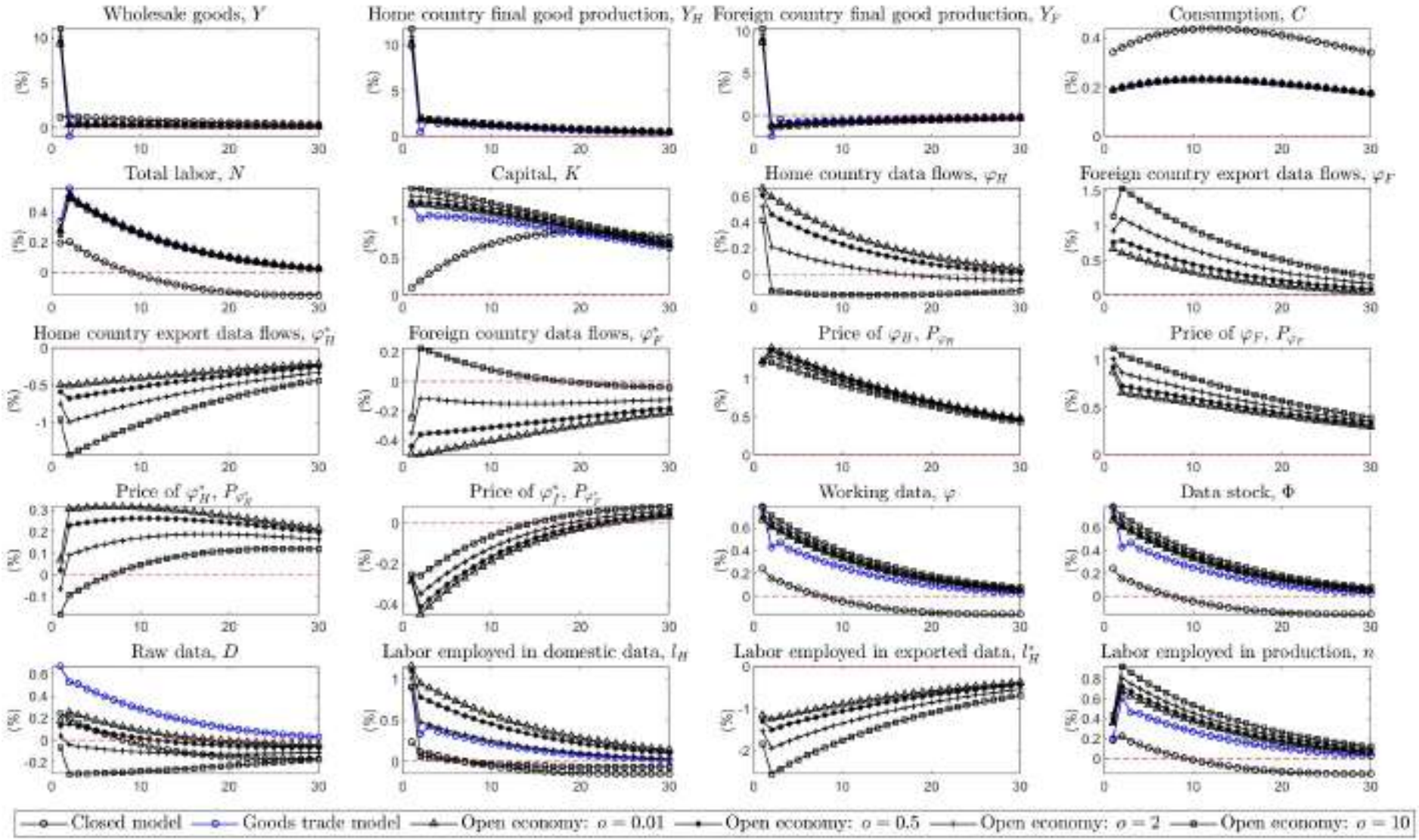
Transition Dynamics (Appendix)

Analysis on Symmetric Countries—Cost Shock on Importing Data Flows in Production f_t



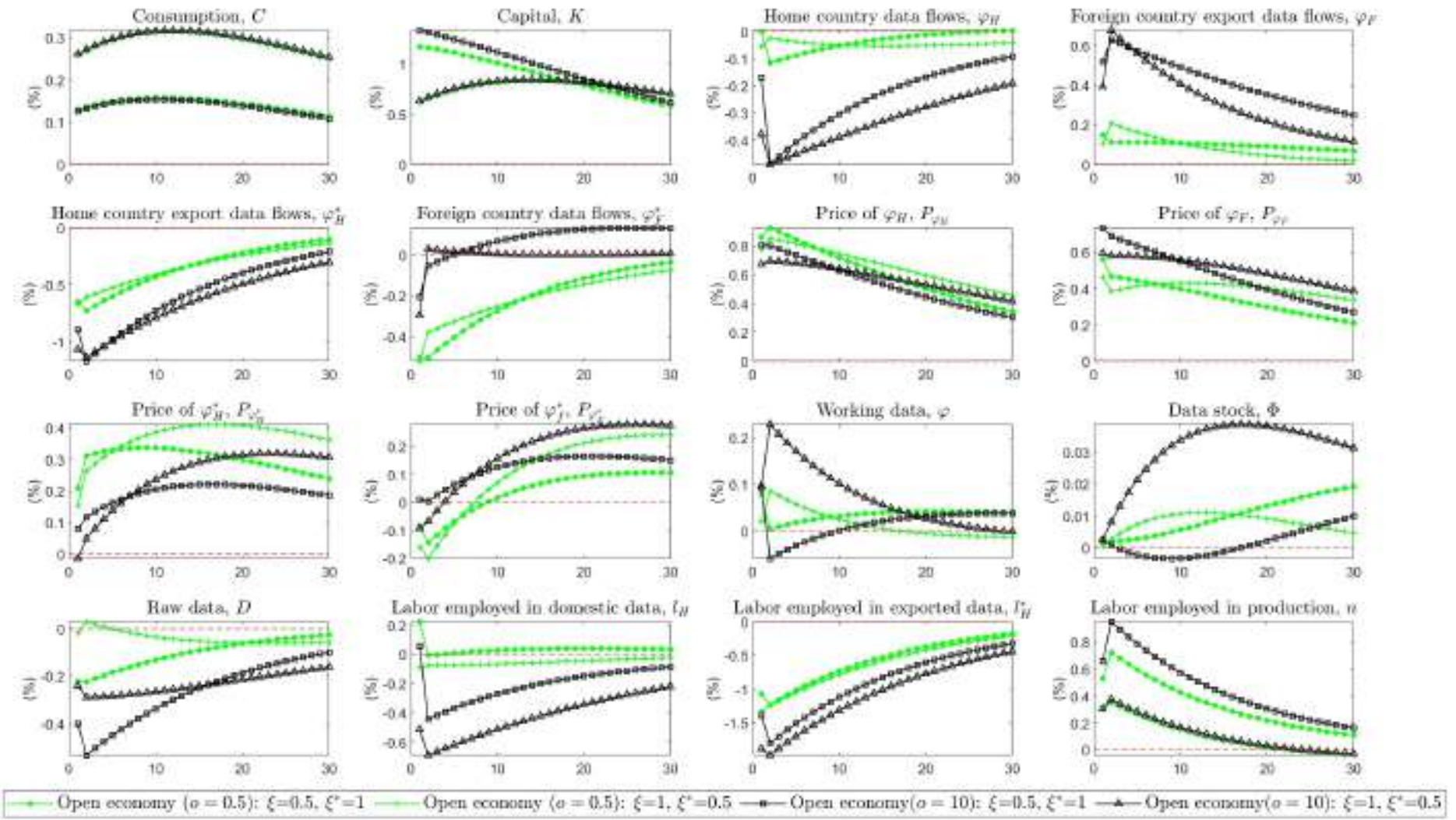
Transition Dynamics (Appendix)

Symmetric Countries with Full Data Depreciate—Productivity shock



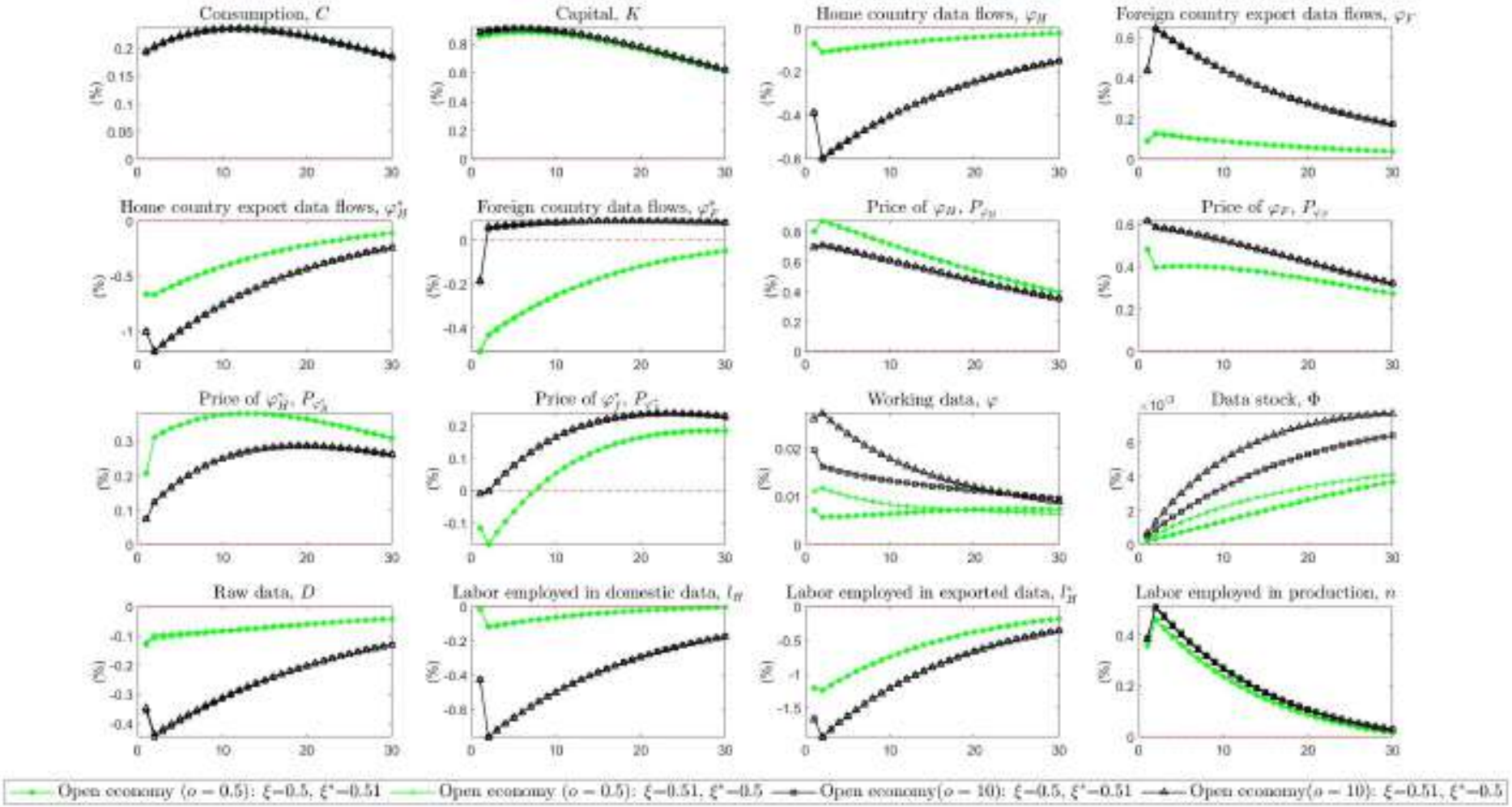
Transition Dynamics (Appendix)

Asymmetric Countries Under Pre-existing Data Divide—Productivity shock



Transition Dynamics (Appendix)

Asymmetric Countries Under Small Pre-existing Data Divide—Productivity shock



Transition Dynamics (Appendix)

Analysis on Symmetric Countries (Cont.)

Main Observations after productivity shocks.

- The gap of data widens even further.
  - When shock happens in low (high) ξ country, working data and data stock decreases (increases).
- Consumption increases in both countries following the shock.
  - A larger variation in the high ξ country.
- Other shocks: no significant conclusions, omitted.