Housing Rent, Inelastic Housing Supply and International Business Cycles

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October 31, 2023

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Housing and the Real Exchange Rates (*RER*)

- **Importance and Uniqueness of Housing Service** ⏩ Graphs

  Housing is a Big Expenditure Category ($15 \sim 25\%$)

  Inelastic Supply

- **Limited Focus on Housing in International Macro Literature**

  Considered as Just Another Nontradable

⋆ **However, I show that**

\- Both in data and model, ***housing*** is important to understand

1) **Cross-sectional** and **Time-series** Variations of *RER*
2) **Balassa-Samuelson Effect & Hypothesis** ⏩ Detail
3) **Backus-Smith Correlation & Puzzle** ⏩ Detail

Overview of Main Findings

- **Data**: *RER* (Trad/Nontrad/Rent), Real GDP per capita, Real Consumption.
  [Eurozone/2000-2019] (Why Eurozone Countries? Berka, Devereux and Engel (2018), Devereux and Hnatkovska (2020))

(1) **Rent component of *RER* is the most volatile both in cross-country and times-series.**
  → It accounts for large portion of the *RER* variation in both cross-section and time-series

(2) **Balassa-Samuelson Effect works predominantly through the housing rent**

(3) **Negative Backus-Smith correlation exists and relative rent is a main driver.**

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- **Model**: Two-Country Model + Housing Sector + Incomplete Market
  (Berka, Devereux and Engel 2018 + Davis and Heathcote 2005 + Corsetti, Dedola and Leduc 2008)

(1) **To generate the quantitatively volatile relative rents, incomplete market is necessary.**

(2) **Housing sector amplifies the model-generated Balassa-Samuelson Effect**

Unique housing characteristics (Land & Stock/Flow) VS $Corr(\bar{A}_j^T, \bar{A}_j^{CR}) < 0$

(3) **Housing sector improves the model prediction on the Backus-Smith correlations.**

Realistically calibrated housing sector makes model's aggregate supply much more inelastic

Literature Review

1. International Business Cycles and Real Exchange Rates

Variation of the Real Exchange Rates in Cross-section/Time-series

Engel (1999), Mussa (1986), Burstein, Neves and Rebelo 2003, Burstein, Eichenbaum and Rebelo 2005, Betts and Kehoe 2006, Atkeson and Burstein (2008), Gopinath and Itskhoki (2010)

Balassa-Samuelson Effect

Rogoff (1996), Bordo et al. (2017), Lee and Tang 2007, Choudhri and Schembri 2014, Gubler and Sax 2019). Berka, Devereux and Engel (2018)

Backus-Smith Puzzle

Cole and Obstfeld (1991), Backus, Kehoe and Kydland (1992), Backus and Smith (1993), Stockman and Tesar (1995), Baxter and Crucini (1995), Chari, Kehoe and McGrattan (2002), Benigno and Thoenissen (2008), Corsetti, Dedola and Leduc (2008), Devereux, Smith and Yetman (2012), Karabarbounis (2014), Bai and Rios-Rull (2015), Jiang (2017), Rouillard (2018), Berka, Devereux and Engel (2018), Lambrias (2020), Devereux and Hnatkovska (2020), Itskhoki and Mukhin (2021), Itskhoki (2021),

- **What's New?**: Distinct Focus on the Role of the **Housing Rent** in *RER* dynamics

2. Role of Housing Sector in (International) Business Cycles

Davis and Heathcote (2005), Iacoviello and Neri (2010), Mendicino and Punzi (2014), **?**, Ferrero (2015), Gete (2020), Cesa-Bianchi, Ferrero and Rebucci (2018)

- **What's New?** : Not House Price and Current Accout but the Rent and Inelastic Housing Supply
  : Rent as a component of *RER*

Empirical Analysis

Data: Real Exchange Rate (Source and Coverage)

- **Eurostat Purchasing Power Parity Database** Data Quality

For 224 items (i) covering the whole consumption basket,

Relative Price Level $(p_{ijt}) = log(\frac{P_{iEU15t}}{P_{ijt}})$ (e.g. Rent in France relative to EU15 in 2011)

Expenditure Share $(\gamma_{ijt}) = \frac{Expenditure_j \ on \ i}{Total \ Expenditure_j}$ (e.g. Rent Exp Share of France in 2011)

Coverage: Eurozone[1] & 2000-2019 (Yearly Frequency)
(Why Eurozone Countries? Berka, Devereux and Engel (2018), Devereux and Hnatkovska (2020))

[1] Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain

Data: Real Exchange Rate (Construction)

- **Aggregate Real Exchange Rates against the EU15**

$$q_{jt} = \sum_i \gamma_{ijt} p_{ijt} \qquad (q_{jt} < 0 \implies \text{country } j \text{ is more expensive than EU15})$$

- **Sectoral Real Exchange Rates against the EU15** ⏩ Graph of q ⏩ Graph of γ ⏩ Descriptive State of q

$$q_{jt}^T = \frac{\sum_{i \in T} \gamma_{ijt} p_{ijt}}{\sum_{i \in T} \gamma_{ijt}} \quad \text{(159 Items)} \quad \left(\sum_{i \in T} \gamma_{ijt} = \gamma_j^T\right)$$ (e.g. Beef and Veal, Yoghurt, Soft Drinks)

$$q_{jt}^{NT} = \frac{\sum_{i \in NT} \gamma_{ijt} p_{ijt}}{\sum_{i \in NT} \gamma_{ijt}} \quad \text{(63 Items)} \quad \left(\sum_{i \in NT} \gamma_{ijt} = \gamma_j^{NT}\right)$$ (e.g. Dental Services, Cinemas, Theatres, Concerts)

$$q_{jt}^R = \frac{\sum_{i \in H} \gamma_{ijt} p_{ijt}}{\sum_{i \in H} \gamma_{ijt}} \quad \text{(2 Items)} \quad \left(\sum_{i \in H} \gamma_{ijt} = \gamma_j^R = 1 - \gamma_j^T - \gamma_j^{NT}\right)$$ (Actual and Imputed Rentals for Housing)

- **Decomposition of the Real Exchange Rates**

$$\rightarrow \quad q_{jt} = \gamma_j^T q_{jt}^T + \gamma_j^{NT} q_{jt}^{NT} + \gamma_j^R q_{jt}^R \qquad (\gamma_j^T + \gamma_j^{NT} + \gamma_j^R = 1)$$

Data: GDP per capita and Consumption (Source, Coverage and Construction)

- **Eurostat National Account**

  Real GDP per capita (Y_{jt})
  (in PPP-adjusted EU15)

  Real Final Consumption Expenditure of Households (C_{jt})
  (Chain linked volumes (2010), million euro)

  Coverage: Same

- **Relative Real GDP per capita**

  $y_{jt} = ln(Y_{jt}/Y_{EU12t})$ $\quad$ ($y_{jt} > 0 \implies$ country j GDP per capita is higher than EU12)

- **Relative Real Consumption Growth**

  $\Delta c_{jt} = \Delta ln(C_{jt}/C_{EU12t})$ $\quad$ ($\Delta c_{jt} > 0 \implies$ country j growth rate of C is larger than EU12)

Graph of y and Δc

Empirical Analysis

Result

1. Relative Rent is the Most Volatile Component of *RER*

σ	Cross-section	Time-series	Autocorr(1)
q	0.119	0.025	0.764
q^T	0.079	0.022	0.725
q^{NT}	0.144	0.039	0.768
q^R	0.286	0.072	0.851

First column is time-series average of each year's cross-country standard deviation of *RER*. Second column is the cross-country average of each country's time-series standard deviation of *RER*. Last column is average of all countries' first-order auto-correlation. Data period is from 2000 to 2019 and data is in annual frequency. Cross-section is the sample mean of cross-sectional standard deviation of each year. Time-series is the sample mean of time-series standard deviation of each country.

Table 1. Cross-sectional and Time-Series Variations of *RER*

1. How Much Does Rent Contribute to Total Variations of *RER*?

- **Decomposition of Variations**: What's the contribution of rent real exchange rates?

$$Var(q) = Cov(q,q) = Cov(q, \gamma^T q^T + \gamma^{NT} q^{NT} + \gamma^R q^R) = \gamma^T Cov(q, q^T) + \gamma^{NT} Cov(q, q^{NT}) + \gamma^R Cov(q, q^R)$$

$$\rightarrow 1 = \gamma^T Corr(q, q^T)\frac{std(q^T)}{std(q)} + \gamma^{NT} Corr(q, q^{NT})\frac{std(q^{NT})}{std(q)} + \underbrace{\gamma^R Corr(q, q^R)\frac{std(q^R)}{std(q)}}_{\text{Share of } q^R \text{ in } RER \text{ Variation}}$$

1) **Across-Country** ($Var(\bar{q}_j)$)

$$\gamma^R Corr(q, q^R)\frac{std(q^R)}{std(q)} = 0.33 \rightarrow 33\% \text{ of Total Variation}$$

Variance Decomposition of q

2) **Within Country (Across-Time)** ($Var_j(q_{jt})$ for all j)

$\gamma^R Corr(q, q^R)\frac{std(q^R)}{std(q)}$ ranges from 0.00 to 0.58 → from 0 to 58% of Total Variation

Variance Decomposition of q

2. Balassa-Samuelson Effect Works Predominantly through the Rent

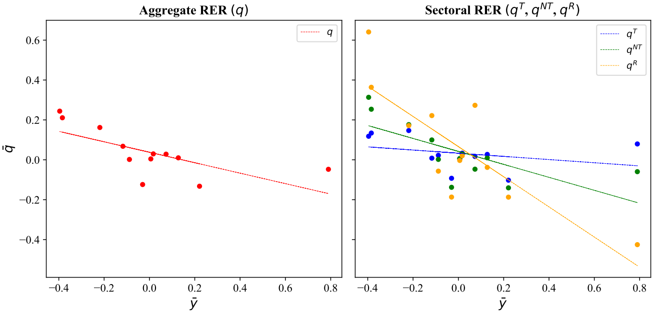

Figure 1. Balassa-Samuelson Effect

- **Balassa-Samuelson Effect**

  Cross-section (Rogoff 1996)

  $\bar{y} \sim \bar{q}, \bar{q}^T, \bar{q}^{NT}, \bar{q}^R$

→ Balassa-Samuelson Effect exists.

→ q^T shows no slope.

→ q^R shows steep slope.

2. Balassa-Samuelson Effect Regressions and Types of Variations

- Regression Analysis

$q_j = \alpha + \beta y_j + \epsilon_j$ (Cross-section of 1990) (Rogoff 1996)

$q_{jt} = \alpha + \beta y_{jt} + \epsilon_{jt}$ (Cross-section/Time-series) (What We Have: Panel Data)

- Regressions Capturing Different Variations

(1) Regression Analysis for Cross-section Variations**

$\bar{q}_j = \beta \bar{y}_j + \epsilon_j$ (Country Average)

$q_{jt} = \beta y_{jt} + \eta_t + \epsilon_{jt}$ (Time Fixed Effect)

(2) Regression Analysis for Time-series Variations

$\Delta q_{jt} = \beta \Delta y_{jt} + \epsilon_{jt}$ (Growth Rate)

$q_{jt} = \beta y_{jt} + \eta_j + \epsilon_{jt}$ (Entity Fixed Effect)

2. Decomposition of Balassa Samuelson Effect via Regressions

- **Regression-based Decomposition**

  $q = \alpha + \beta y + \epsilon \quad \rightarrow \quad \beta =$ Summary Statistics of the Balassa-Samuelson Effect

  $$q^T = \alpha + \beta^T y + \epsilon$$
  $$q^{NT} = \alpha + \beta^{NT} y + \epsilon$$
  $$q^R = \alpha + \beta^R y + \epsilon$$

  $$\implies \beta = \gamma^T \beta^T + \gamma^{NT} \beta^{NT} + \gamma^R \beta^R$$

  $(q = \gamma^T q^T + \gamma^{NT} q^{NT} + \gamma^R q^R$ & $\beta = \frac{Cov(q,y)}{Var(y)}$ (Linearity of the OLS estimator))

- **How much does q^R contribute to the total Balassa-Samuelson Effect?**

  $\rightarrow \gamma^R \beta^R$

2. Balassa-Samuelson Effect Works Predominantly through the Rent

		$\bar{q}$	$\bar{q}^T$	$\bar{q}^{NT}$	$\bar{q}^R$
Country Average	$\bar{y}$	-0.26*	-0.08	-0.33*	-0.76***
		(0.14)	(0.13)	(0.18)	(0.19)
	R^2	0.43	0.08	0.45	0.64
	N	12	12	12	12
	$\gamma\beta$	-0.26	-0.04	-0.11	-0.12

		q	q^T	q^{NT}	q^R
Time-FE	y	-0.26***	-0.07***	-0.31***	-0.75***
		(0.01)	(0.01)	(0.01)	(0.03)
	R^2	0.45	0.08	0.45	0.64
	N	240	240	240	240
	$\gamma\beta$	-0.26	-0.04	-0.10	-0.12

Table 2. Balassa-Samuelson Effect Regressions (Cross-section) Time Series

2. Balassa-Samuelson Effect Works Predominantly through the Rent

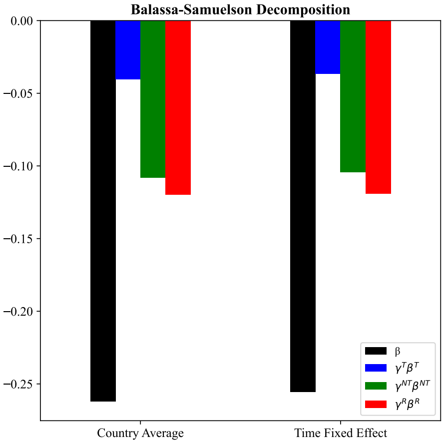

Figure 2. Decomposition of β

3. Negative Backus-Smith Correlation Exists and Housing Rent is a Main Driver

- **The Backus-Smith Correlation** ⏩ Level Corr ⏩ Growth Corr

$Corr_j(c_{jt}, q_{jt}) < 0$ & $Corr_j(\Delta c_{jt}, \Delta q_{jt}) < 0$ (Time-series) (Backus and Smith 1993)

cf) Backus-Smith and Fixed Exchange Rates? (Devereux and Hnatkovska 2020)

- **Regressions Capturing Different Variations** ⏩ Correlation vs β

(1) **Regression Analysis for Cross-sectional Variations**

$\bar{q}_j = \beta \bar{y}_j + \epsilon_j$ (Country Average)

$q_{jt} = \beta y_{jt} + \eta_t + \epsilon_{jt}$ (Time Fixed Effect)

(2) **Regression Analysis for Time-series Variations****

$\Delta q_{jt} = \beta \Delta y_{jt} + \epsilon_{jt}$ (Growth Rate)

$q_{jt} = \beta y_{jt} + \eta_j + \epsilon_{jt}$ (Entity Fixed Effect)

3. Negative Backus-Smith Correlation Exists and Housing Rent is a Main Driver

		Δq	Δq^T	Δq^{NT}	Δq^R
Growth Rate	Δc	-0.14**	0.02	-0.15***	-0.53***
		(0.07)	(0.05)	(0.06)	(0.23)
	R^2	0.03	0.00	0.01	0.06
	N	240	240	240	240
	$\gamma\beta$	-0.14	0.01	-0.05	-0.08
		q	q^T	q^{NT}	q^R
Country-FE	c	-0.17**	0.10*	-0.22	-0.72**
		(0.07)	(0.06)	(0.14)	(0.37)
	R^2	0.09	0.05	0.06	0.17
	N	240	240	240	240
	$\gamma\beta$	-0.17	0.05	-0.07	-0.12

Table 3. Backus-Smith Regressions (Time-Series) Cross-section

3. Negative Backus-Smith Correlation Exists and Housing Rent is a Main Driver

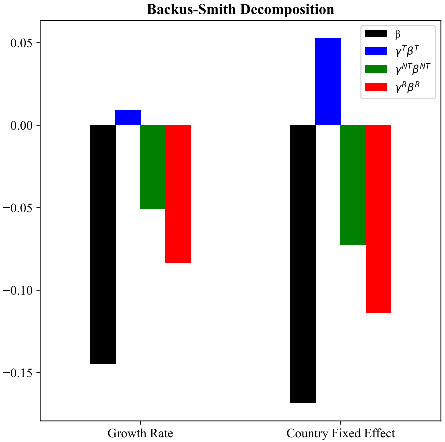

Figure 3. Balassa-Samuelson Effect

Model

Summary of Empirical Findings

(1) **Rent component of *RER* is the most volatile both in cross-country and times-series.**

33% of Total *RER* Cross-sectional Variation

0-60% of Total *RER* Time-series Variations of Countries

(2) **Balassa Samuelson Effect works predominantly through the housing rent**

Country with 1% higher GDP per capita than EU shows 0.25% higher price level than EU.
(0.76% higher rent level) .

$\rightarrow$ Among 0.25% higher price level, 0.122% is from the higher rents.

(3) **Negative Backus Smith correlation exists and housing rent is a main driver.**

When country's C increases 1% more than EU, price level increases 0.14% more than EU.
(rent level increases 0.72%)

$\rightarrow$ Among 0.14% price level increase, 0.126% is from the higher rents.

Model Overview

- **Two-Country Three-Sector Model** Overview Core Mechanism

  (Berka, Devereux and Engel 2018, Davis and Heathcote 2005)

  Two Symmetric Countries (Home and Foreign)

  Representative Household & **Large Rent Expenditure Share**

  Tradable Sector, Nontradable Sector, Construction Sector, Distribution Margin

  Housing Capital and Residential-Zoned Land $\rightarrow$ **Inelastic Supply of Housing Service**

  Incomplete Market and Portfolio Adjustment Cost

  (Schmitt-Grohé and Uribe 2003)

- Production of Traded/Nontraded/Construction Sectors

$$Y_{H,t} = A_{H,t}N_{H,t}\ (Y^*_{F,t} = A^*_{F,t}N_{F,t}), \quad Y_{N,t} = A_{N,t}N_{N,t}, \quad Y_{CR,t} = A_{CR,t}N_{CR,t}$$

$$ln(A_{X,t}) = ln(\bar{A}_X) + \rho_X(ln(A_{X,t-1}) - ln(\bar{A}_X)) + \epsilon_{X,t} \qquad X \in (H, N, CR)$$

- Housing Production (Real Estate Developer) and Law of Motion for Housing

$$I_{RI,t} = Y^{1-\tau}_{CR,t} l^{\tau}_t \quad (l_t = \bar{l})$$

$$H_t = (1-\delta)H_{t-1} + I_{RI,t}$$

- **Household Problem**

$$U = E[\sum_{t=0}^{\infty} \beta^t (\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\psi}}{1+\psi})], \quad \beta < 1$$

$$s.t. \quad P_t C_t + D_{t+1}/R_{t+1} + P_{RI,t} I_{RI,t} = D_t + W_t N_t + P_{R,t} H_{t-1} + P_{l,t} l_t - \frac{\phi^C}{2} D_{t+1}^2$$

$$H_t = (1-\delta) H_{t-1} + I_{RI,t}$$

- **Incomplete Market**

D_{t+1} : International Non-contingent Bonds

$\frac{\phi^C}{2} D_{t+1}^2$: Portfolio Adjustment Costs

Model 3. Consumption Aggregators

- Consumption Aggregators

$$C_t = (\gamma_R^{\frac{1}{v}} C_{R,t}^{1-\frac{1}{v}} + (1-\gamma_R)^{\frac{1}{v}} C_{NR,t}^{1-\frac{1}{v}})^{\frac{v}{v-1}}$$ (Final Consumption = Housing + Non-Housing)

$$C_{R,t} \ (= H_{t-1})$$ (Housing)

$$C_{NR,t} = (\gamma_{NT}^{\frac{1}{\theta}} C_{NT,t}^{1-\frac{1}{\theta}} + (1-\gamma_{NT})^{\frac{1}{\theta}} C_{T,t}^{1-\frac{1}{\theta}})^{\frac{\theta}{\theta-1}}$$ (Non-Housing = Nontrad + Trad)

$$C_{NT,t}$$ (Nontrad)

$$C_{T,t} = (\omega_H^{\frac{1}{\lambda}} C_{H,t}^{1-\frac{1}{\lambda}} + (1-\omega_H)^{\frac{1}{\lambda}} C_{F,t}^{1-\frac{1}{\lambda}})^{\frac{\lambda}{\lambda-1}}$$ (Trad = Home Trad + Foreign Trad)

$$C_{H,t} = (\chi_{NT}^{\frac{1}{\phi}} V_{H,t}^{1-\frac{1}{\phi}} + (1-\chi_{NT})^{\frac{1}{\phi}} I_{H,t}^{1-\frac{1}{\phi}})^{\frac{\phi}{\phi-1}}$$ (Home Trad)

$$C_{F,t} = (\chi_{NT}^{\frac{1}{\phi}} V_{F,t}^{1-\frac{1}{\phi}} + (1-\chi_{NT})^{\frac{1}{\phi}} I_{F,t}^{1-\frac{1}{\phi}})^{\frac{\phi}{\phi-1}}$$ (Foreign Trad)

Model 4. Price Indices and Real Exchange Rates

- Aggregate Price Index

$$P_t = (\gamma_R P_{R,t}^{1-v} + (1-\gamma_R)((\gamma_{NT} P_{NT,t}^{1-\theta} + (1-\gamma_{NT}) P_{T,t}^{1-\theta})^{\frac{1}{1-\theta}})^{1-v})^{\frac{1}{1-v}}$$

- Tradable Price Index

$$P_{T,t} = (\omega_H \tilde{P}_{H,t}^{1-\lambda} + (1-\omega_H)\tilde{P}_{F,t}^{1-\lambda})^{\frac{1}{1-\lambda}}$$

$$\tilde{P}_{H,t} = ((1-\chi_{NT})P_{H,t}^{1-\phi} + \chi_{NT} P_{NT,t}^{1-\phi})^{\frac{1}{1-\phi}}$$

$$\tilde{P}_{F,t} = ((1-\chi_{NT})P_{F,t}^{1-\phi} + \chi_{NT} P_{NT,t}^{1-\phi})^{\frac{1}{1-\phi}}$$

- Nontradable Price Index

$$P_{NT,t}$$

- Housing Rent Index

$$P_{R,t}$$

- Agg *RER*

$$q = ln(P_t^* / P_t)$$

- Tradable *RER*

$$q_{T,t} = ln(P_{T,t}^* / P_{T,t})$$

- Nontradable *RER*

$$q_{NT,t} = ln(P_{NT,t}^* / P_{NT,t})$$

- Rent *RER*

$$q_{R,t} = ln(P_{R,t}^* / P_{R,t})$$

Model 5. Relative Quantities, International Risk Sharing, and the Equilibrium

- **Relative Consumption and Relative GDP per capita**

  $c_t = ln(C_t/C_t^*), y_t = ln(Y_t/Y_t^*)$

- **Backus-Smith Correlation**

  $Corr(q, c)$ and $Corr(\Delta q, \Delta c)$

- **Incomplete Market**

  $R_t = E_t[\frac{1}{\beta}(\frac{C_t^{-\sigma}}{C_{t+1}^{-\sigma}})(\frac{P_{t+1}}{P_t})] = E_t^*[\frac{1}{\beta^*}(\frac{(C_t^*)^{-\sigma}}{(C_{t+1}^*)^{-\sigma}})(\frac{P_{t+1}^*}{P_t^*})]$ when $\phi^C = 0$

cf) **If we assume a complete market?**

  $\frac{C_t^{-\sigma}}{P_t} = \frac{C_t^{*\,-\sigma}}{P_t^*} \rightarrow ln(C_t/C_t^*) = \frac{1}{\sigma}ln(P_t^*/P_t)$

- **Market Clearing and Equilibrium Definitions** ▸▸ Market Clearing and Eq

Simulation

Model Simulation

- **Why Simulation**

  RER is a general equilibrium object (Itskhoki 2021)

  Assessment on the **quantitative & qualitative importance of the housing market in** *RER* **dynamics** requires a *general equilibrium perspective.*

$\rightarrow$ Comparative statics w/ model simulations

- **Nature of Simulation**

  Model Calibration $\rightarrow$ Target Housing-related Moments

  Shock Process Calibration $\rightarrow$ Directly from the EUKLEMS Database

$\rightarrow$ *RER* has not been targeted at all

Model Calibration

Parameters	Variable	Value	Reference
1. Non-Housing Parameters			
Household			
Discount factor, yearly	β	0.99	
Relative risk aversion	σ	2	
Macro Frisch elasticity	ψ	1	
Non-Residential Consumption Aggregator			
Non-Tradable weight	γ^{NT}	0.4	Berka, Devereux and Engel (2018)
ES between traded and non-traded	θ	0.7	Berka, Devereux and Engel (2018)
Tradable Consumption Aggregator			
Home-bias	ω^H	0.5	No Homebias
ES between retail H and F	λ	8	Corsetti, Dedola and Leduc (2010)
Distribution Margin			
Distribution Margin Weight	χ^{NT}	0.32	Goldberg and Campa (2010)
ES betwen retail and distribution service	ϕ	0.25	Berka, Devereux and Engel (2018)
Production			
Elasticity of Labor	α	1	Berka, Devereux and Engel (2018)
International Financial Market			
Portfolio Adjustment Cost	ϕ^C	0.001	Benigno and Thoenissen (2008)
2. Housing Parameters			
Residential Consumption			
Housing Service Weight	γ^R	0.25	
ES between housing and non-housing	v	0.85	Davidoff and Yoshida (2013)
Residential Building Production			
Land Input Share	τ	0.35	Combes, Duranton and Gobillon (2021)
Depreciation Rate of Residential Structure	δ^S	0.0037	

Table 4. Model Calibration

Steady State of the Model

	Data	Model
Supply-side		
Residential Capital over GDP (*RCOY*)	1.457	1.403
Residential Investment over GDP (*RIOY*)	0.029	0.021
Labor Share of Construction Sector (*NConRatio*)	0.017	0.025
Housing Flow over Housing Stock (*HFoHS*)	0.009	0.009
Demand-side		
Housing Rent Expenditure Share (*REW*)	0.161 (0.212)	0.170
Tradable Expenditure Share	0.516	0.497
Nontradable Expenditure Share	0.328	0.331

Data period for 8 Eurozone countries is (2000-2019). Note that the construction sector in our model is effectively the residential construction sector, not the total construction sector. According to the European Construction Industry Federation, 50.4% of the total construction is estimated to be about the residential construction in 2022. So, I use the half of the value of corresponding construction sector for construction sector related variables when I match the empirical moments of the construction sector in our model.

Table 5. Housing Sector: Data vs Steady State

Shock Calibrations

- **Calibration of the Relative Sectoral Productivity Processes**

  1997 GGDC and 2023 EUKLEMS ⏩ Graph

  Observe $A^H_{jt}, A^N_{jt}, A^{CR}_{jt}$ for eight countries. [2]

  Calculate the EU average. $A^H_{EUt}, A^N_{EUt}, A^{CR}_{EUt}$

  Estimate following processes for eight countries.

  $$ln(A^X_{jt}/A^X_{EUt}) = ln(\bar{A}^X_j/\bar{A}^X_{EU}) + \rho_X(ln(A^X_{jt-1}/A^X_{EUt-1}) - ln(\bar{A}^X_j/\bar{A}^X_{EU})) + \epsilon_{X,t} \qquad X \in (H, N, CR)$$

  $$(\bar{\alpha}^X_j = ln(\bar{A}^X_j/\bar{A}^X_{EU}))$$

  Source of Country Heterogeneity ⏩ Table

  $(\bar{\alpha}^H_j, \bar{\alpha}^N_j, \bar{\alpha}^{CR}_j, \rho^H_j, \rho^N_j, \rho^{CR}_j, \sigma^H_j, \sigma^N_j, \sigma^{CR}_j)$

[2] Only Austria, Belgium, Spain, Finland, France, Germany, Italy, Netherlands, Denmark, Sweden, and UK provide industry level productivity data (Trad/Nontrad/Construction).

Simulation Procedure

1. **Simulate the model (2000-2019) for 8 Eurozone countries.**
   Countries: Austria, Belgium, Spain, Finland, France, Germany, Italy, Netherlands
   Periods: 2000-2019

   Home Country vs Foreign country (=EU Average)

   Only home country receives the shocks. (cf) Productivity shocks relative to EU average)

   Collect the Simulated Home Country Variables.

$\rightarrow$ Simulated Panel Data of RER (q, q^T, q^{NT}, q^R), Relative GDP per capita and Consumption (y, c)

2. **Replicate the empirical analysis with the model-simulated data.**

   Cross-sectional & Time-series Variations

   Regressions for the Balassa Samuelson Effect and the Backus-Smith Correlation.

3. **Repeat 500 times and compare with the data.**

Simulation

Simulation Result

- **Variation of *RER* in Cross-section and Time-series**

  Cross-country Variation ($q \neq 0$) : Absolute PPP

  Time-series Variation ($\Delta q \neq 0$) : Relative PPP

- **Model Viewpoint on the Role of Housing in Variations of *RER***

  In data, q^R is most volatile in cross-section and time-series.

  In data, q^R accounts for large portion of these variations.

$\rightarrow$ Why?

$\rightarrow$ Is there anything special about housing service? (Role of Land, Stock vs Flow)

- Performance of the Baseline Model

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\tau = 0.01$)	(5) Arrow-Debreu ($\delta = 0.99$)	(6) Arrow-Debreu (τ=0.01, δ=0.99)	(7) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Cross-section							
$\sigma_j(q_{jt})$	0.121	0.085	0.053	0.059	0.057	0.067	0.053
$\sigma_j(q_{jt}^T)$	0.081	0.039	0.028	0.027	0.028	0.027	0.027
$\sigma_j(q_{jt}^{NT})$	0.149	0.121	0.087	0.084	0.085	0.084	0.083
$\sigma_j(q_{jt}^R)$	0.297	0.197	0.134	0.212	0.149	0.214	0.126
Time-series							
$\sigma_t(q_{jt})$	0.025	0.033	0.022	0.023	0.025	0.028	0.028
$\sigma_t(q_{jt}^T)$	0.022	0.018	0.013	0.013	0.013	0.012	0.012
$\sigma_t(q_{jt}^{NT})$	0.039	0.054	0.041	0.039	0.039	0.038	0.038
$\sigma_t(q_{jt}^R)$	0.072	0.038	0.009	0.053	0.050	0.075	0.076

Table 6. Model Generated *RER*

- **Role of Risk Sharing**: Incomplete Market vs Complete Market

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\tau = 0.01$)	(5) Arrow-Debreu ($\delta = 0.99$)	(6) Arrow-Debreu (τ=0.01, δ=0.99)	(7) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Cross-section							
$\sigma_j(q_{jt})$	0.121	0.085	0.053	0.059	0.057	0.067	0.053
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$\sigma_j(q_{jt}^{NT})$	0.149	0.121	0.087	0.084	0.085	0.084	0.083
$\sigma_j(q_{jt}^R)$	0.297	0.197	0.134	0.212	0.149	0.214	0.126
Time-series							
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$\sigma_t(q_{jt}^{NT})$	0.039	0.054	0.041	0.039	0.039	0.038	0.038
$\sigma_t(q_{jt}^R)$	0.072	0.038	0.009	0.053	0.050	0.075	0.076

Table 6. Model Generated *RER*

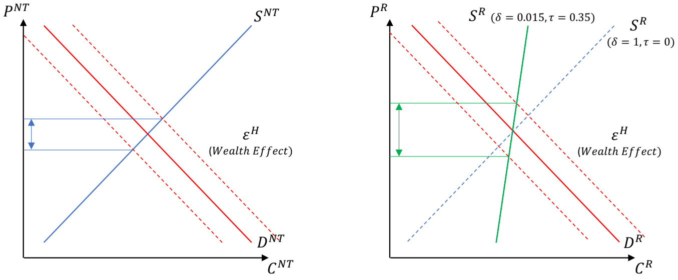

Figure 4. Nontradable Market and Housing Service Market

- **Housing VS Nontradable**

  $P^R \uparrow \nrightarrow S \uparrow$

  (Land & Stock vs Flow)

$\rightarrow$ Steeper Supply Curve

$\rightarrow$ Stronger Responses to **Demand Shock via Wealth Effect** under Incomplete Market

1. Variation of *RER* in Cross-section and Time-series

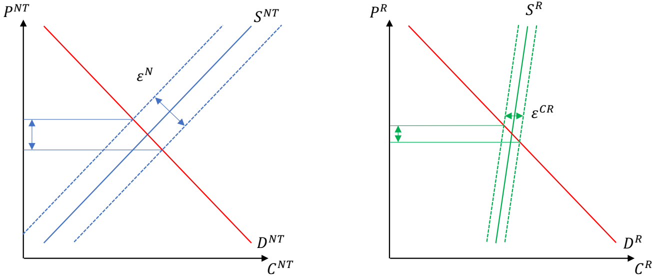

Figure 4. Nontradable Market and Housing Service Market

- **Housing VS Nontradable**

  $A^{CR} \uparrow \nrightarrow S^{R} \uparrow$ Effect of $\epsilon^{CR} \downarrow$ (Land & Stock vs Flow)

$\rightarrow$ Smaller Shift of S^{R}

$\rightarrow$ Smaller Responses to **Supply Effect** under Complete Market

- **Housing vs Nontradable**: Role of Land and Depreciation

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\tau = 0.01$)	(5) Arrow-Debreu ($\delta = 0.99$)	(6) Arrow-Debreu (τ=0.01, δ=0.99)	(7) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Cross-section							
$\sigma_j(q_{jt})$	0.121	0.085	0.053	0.059	0.057	0.067	0.053
$\sigma_j(q_{jt}^T)$	0.081	0.039	0.028	0.027	0.028	0.027	0.027
$\sigma_j(q_{jt}^{NT})$	0.149	0.121	0.087	0.084	0.085	0.084	0.083
$\sigma_j(q_{jt}^R)$	0.297	0.197	0.134	0.212	0.149	0.214	0.126
Time-series							
$\sigma_t(q_{jt})$	0.025	0.033	0.022	0.023	0.025	0.028	0.028
$\sigma_t(q_{jt}^T)$	0.022	0.018	0.013	0.013	0.013	0.012	0.012
$\sigma_t(q_{jt}^{NT})$	0.039	0.054	0.041	0.039	0.039	0.038	0.038
$\sigma_t(q_{jt}^R)$	0.072	0.038	0.009	0.053	0.050	0.075	0.076

Table 6. Model Generated *RER*

- **Distribution of Sectoral Productivities**: $Corr(\bar{A}_j^T, \bar{A}_j^N) = 0.76$ $Corr(\bar{A}^T, \bar{A}^{CR}) = -0.23$

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\tau = 0.01$)	(5) Arrow-Debreu ($\delta = 0.99$)	(6) Arrow-Debreu (τ=0.01, δ=0.99)	(7) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Cross-section							
$\sigma_j(q_{jt})$	0.121	0.085	0.053	0.059	0.057	0.067	0.053
$\sigma_j(q_{jt}^T)$	0.081	0.039	0.028	0.027	0.028	0.027	0.027
$\sigma_j(q_{jt}^{NT})$	0.149	0.121	0.087	0.084	0.085	0.084	0.083
$\sigma_j(q_{jt}^R)$	0.297	0.197	0.134	0.212	0.149	0.214	0.126
Time-series							
$\sigma_t(q_{jt})$	0.025	0.033	0.022	0.023	0.025	0.028	0.028
$\sigma_t(q_{jt}^T)$	0.022	0.018	0.013	0.013	0.013	0.012	0.012
$\sigma_t(q_{jt}^{NT})$	0.039	0.054	0.041	0.039	0.039	0.038	0.038
$\sigma_t(q_{jt}^R)$	0.072	0.038	0.009	0.053	0.050	0.075	0.076

Table 6. Model Generated *RER*

1. Variation of *RER* in Cross-section and Time-series

- Role of Housing Market

	(1) Data	(2) Bond ($\gamma^R = 0.01$)	(3) Bond ($\gamma^R = 0.25$)	(4) Bond ($\gamma^R = 0.45$)
Cross-section				
$\sigma_j(q_{it})$	0.121	0.073	0.085	0.106
$\sigma_j(q_{it}^T)$	0.081	0.039	0.039	0.039
$\sigma_j(q_{it}^{NT})$	0.149	0.122	0.121	0.123
$\sigma_j(q_{it}^R)$	0.297	0.198	0.197	0.200
Time-series				
$\sigma_t(q_{it})$	0.025	0.032	0.033	0.034
$\sigma_t(q_{it}^T)$	0.022	0.017	0.018	0.018
$\sigma_t(q_{it}^{NT})$	0.039	0.053	0.054	0.055
$\sigma_t(q_{it}^R)$	0.072	0.035	0.038	0.039

Table 7. Model Generated *RER* w/ Different Housing Weights

1. Variation of *RER* in Cross-section and Time-series

- **Summary of Findings**

1) Characteristics of housing service imply smaller variations of q^R in both dimension.
2) Incomplete market is necessary for large time-series variation of q^R.
3) Construction sector productivities account for large variations in cross-section.

$\rightarrow$ Importance of the Distribution of Cross-Country Relative Sectoral Productivity Levels.

4) Incorporating the housing sector into the model increases the cross-sectional/time-series variations of the aggregate real exchange rates.

2. Role of Housing in the Balassa-Samuelson Effect

- Balassa-Samuelson Effect

  $\bar{q} = \alpha + \beta \bar{y} + \epsilon$

- Model Viewpoint on the Role of Housing in the Balassa-Samuelson Effect

  In data, $\beta < 0$ for eurozone countries.

  Rent ($\gamma^R \beta^R$) accounts for more than half of it.

$\rightarrow$ Why?

$\rightarrow$ Is there anything special about housing service? (Role of Land, Stock vs Flow)

- Performance of the Baseline Model

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\gamma^R = 0.01$)	(5) Arrow-Debreu ($\tau = 0.01$)	(6) Arrow-Debreu ($\delta = 0.99$)	(7) Arrow-Debreu (τ=0.01, δ=0.99)	(8) Arrow-Debreu (7) $+ (\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1)$
Bal/Sam								
β	-0.26*	-0.57*	-0.17*	-0.06	-0.18*	-0.18*	-0.22*	-0.12
	(0.14)	(-0.76,-0.36)	(-0.27,-0.06)	(-0.17,0.04)	(-0.31,-0.05)	(-0.31,-0.03)	(-0.38,-0.06)	(-0.29,0.04)
β^T	-0.08	-0.21*	-0.04	-0.03	-0.04	-0.03	-0.02	-0.02
	(0.13)	(-0.32,-0.09)	(-0.11,0.03)	(-0.09,0.04)	(-0.11,0.04)	(-0.11,0.05)	(-0.09,0.07)	(-0.10,0.06)
β^{NT}	-0.33*	-0.65*	-0.13	-0.11	-0.12	-0.09	-0.05	-0.06
	(0.18)	(-0.96,-0.31)	(-0.34,0.09)	(-0.29,0.07)	(-0.34,0.12)	(-0.33,0.16)	(-0.28,0.22)	(-0.32,0.18)
β^R	-0.76**	-1.46*	-0.62*	-0.49*	-0.86*	-0.63*	-0.93*	-0.45
	(0.19)	(-1.64,-1.26)	(-0.82,-0.43)	(-0.67,-0.33)	(-1.19,-0.49)	(-0.95,-0.32)	(-1.38,-0.45)	(-0.89,0.01)

Table 8. Model Balassa-Samuelson

- **Role of Risk Sharing**: Incomplete Market vs Complete Market

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\gamma^R = 0.01$)	(5) Arrow-Debreu ($\tau = 0.01$)	(6) Arrow-Debreu ($\delta = 0.99$)	(7) Arrow-Debreu (τ=0.01, δ=0.99)	(8) Arrow-Debreu (7) $+ (\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1)$
Bal/Sam								
β	-0.26*	-0.57*	-0.17*	-0.06	-0.18*	-0.18*	-0.22*	-0.12
	(0.14)	(-0.76,-0.36)	(-0.27,-0.06)	(-0.17,0.04)	(-0.31,-0.05)	(-0.31,-0.03)	(-0.38,-0.06)	(-0.29,0.04)
β^T	-0.08	-0.21*	-0.04	-0.03	-0.04	-0.03	-0.02	-0.02
	(0.13)	(-0.32,-0.09)	(-0.11,0.03)	(-0.09,0.04)	(-0.11,0.04)	(-0.11,0.05)	(-0.09,0.07)	(-0.10,0.06)
β^{NT}	-0.33*	-0.65*	-0.13	-0.11	-0.12	-0.09	-0.05	-0.06
	(0.18)	(-0.96,-0.31)	(-0.34,0.09)	(-0.29,0.07)	(-0.34,0.12)	(-0.33,0.16)	(-0.28,0.22)	(-0.32,0.18)
β^R	-0.76**	-1.46*	-0.62*	-0.49*	-0.86*	-0.63*	-0.93*	-0.45
	(0.19)	(-1.64,-1.26)	(-0.82,-0.43)	(-0.67,-0.33)	(-1.19,-0.49)	(-0.95,-0.32)	(-1.38,-0.45)	(-0.89,0.01)

Table 8. Model Balassa-Samuelson

- **Role of Housing**: What If We Have No Housing?

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\gamma^R = 0.01$)	(5) Arrow-Debreu ($\tau = 0.01$)	(6) Arrow-Debreu ($\delta = 0.99$)	(7) Arrow-Debreu (τ=0.01, δ=0.99)	(8) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Bal/Sam								
β	-0.26*	-0.57*	-0.17*	-0.06	-0.18*	-0.18*	-0.22*	-0.12
	(0.14)	(-0.76,-0.36)	(-0.27,-0.06)	(-0.17,0.04)	(-0.31,-0.05)	(-0.31,-0.03)	(-0.38,-0.06)	(-0.29,0.04)
β^T	-0.08	-0.21*	-0.04	-0.03	-0.04	-0.03	-0.02	-0.02
	(0.13)	(-0.32,-0.09)	(-0.11,0.03)	(-0.09,0.04)	(-0.11,0.04)	(-0.11,0.05)	(-0.09,0.07)	(-0.10,0.06)
β^{NT}	-0.33*	-0.65*	-0.13	-0.11	-0.12	-0.09	-0.05	-0.06
	(0.18)	(-0.96,-0.31)	(-0.34,0.09)	(-0.29,0.07)	(-0.34,0.12)	(-0.33,0.16)	(-0.28,0.22)	(-0.32,0.18)
β^R	-0.76**	-1.46*	-0.62*	-0.49*	-0.86*	-0.63*	-0.93*	-0.45
	(0.19)	(-1.64,-1.26)	(-0.82,-0.43)	(-0.67,-0.33)	(-1.19,-0.49)	(-0.95,-0.32)	(-1.38,-0.45)	(-0.89,0.01)

Table 8. Model Balassa-Samuelson

- **Housing vs Nontradable**: Role of Land and Depreciation

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\gamma^R = 0.01$)	(5) Arrow-Debreu ($\tau = 0.01$)	(6) Arrow-Debreu ($\delta = 0.99$)	(7) Arrow-Debreu (τ=0.01, δ=0.99)	(8) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Bal/Sam								
β	-0.26*	-0.57*	-0.17*	-0.06	-0.18*	-0.18*	-0.22*	-0.12
	(0.14)	(-0.76,-0.36)	(-0.27,-0.06)	(-0.17,0.04)	(-0.31,-0.05)	(-0.31,-0.03)	(-0.38,-0.06)	(-0.29,0.04)
β^T	-0.08	-0.21*	-0.04	-0.03	-0.04	-0.03	-0.02	-0.02
	(0.13)	(-0.32,-0.09)	(-0.11,0.03)	(-0.09,0.04)	(-0.11,0.04)	(-0.11,0.05)	(-0.09,0.07)	(-0.10,0.06)
β^{NT}	-0.33*	-0.65*	-0.13	-0.11	-0.12	-0.09	-0.05	-0.06
	(0.18)	(-0.96,-0.31)	(-0.34,0.09)	(-0.29,0.07)	(-0.34,0.12)	(-0.33,0.16)	(-0.28,0.22)	(-0.32,0.18)
β^R	-0.76**	-1.46*	-0.62*	-0.49*	-0.86*	-0.63*	-0.93*	-0.45
	(0.19)	(-1.64,-1.26)	(-0.82,-0.43)	(-0.67,-0.33)	(-1.19,-0.49)	(-0.95,-0.32)	(-1.38,-0.45)	(-0.89,0.01)

Table 8. Model Balassa-Samuelson

- **Distribution of Sectoral Productivities**: $Corr(\bar{A}_j^T, \bar{A}_j^N) = 0.76,\ Corr(\bar{A}_j^T, \bar{A}_j^{CR}) = -0.23$

	(1) Data	(2) Bond Baseline	(3) Arrow-Debreu Baseline	(4) Arrow-Debreu ($\gamma^R = 0.01$)	(5) Arrow-Debreu ($\tau = 0.01$)	(6) Arrow-Debreu ($\delta = 0.99$)	(7) Arrow-Debreu (τ=0.01, δ=0.99)	(8) Arrow-Debreu (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Bal/Sam								
β	-0.26*	-0.57*	-0.17*	-0.06	-0.18*	-0.18*	-0.22*	-0.12
	(0.14)	(-0.76,-0.36)	(-0.27,-0.06)	(-0.17,0.04)	(-0.31,-0.05)	(-0.31,-0.03)	(-0.38,-0.06)	(-0.29,0.04)
β^T	-0.08	-0.21*	-0.04	-0.03	-0.04	-0.03	-0.02	-0.02
	(0.13)	(-0.32,-0.09)	(-0.11,0.03)	(-0.09,0.04)	(-0.11,0.04)	(-0.11,0.05)	(-0.09,0.07)	(-0.10,0.06)
β^{NT}	-0.33*	-0.65*	-0.13	-0.11	-0.12	-0.09	-0.05	-0.06
	(0.18)	(-0.96,-0.31)	(-0.34,0.09)	(-0.29,0.07)	(-0.34,0.12)	(-0.33,0.16)	(-0.28,0.22)	(-0.32,0.18)
β^R	-0.76**	-1.46*	-0.62*	-0.49*	-0.86*	-0.63*	-0.93*	-0.45
	(0.19)	(-1.64,-1.26)	(-0.82,-0.43)	(-0.67,-0.33)	(-1.19,-0.49)	(-0.95,-0.32)	(-1.38,-0.45)	(-0.89,0.01)

Table 8. Model Balassa-Samuelson

2. Role of Housing in the Balassa-Samuelson Effect

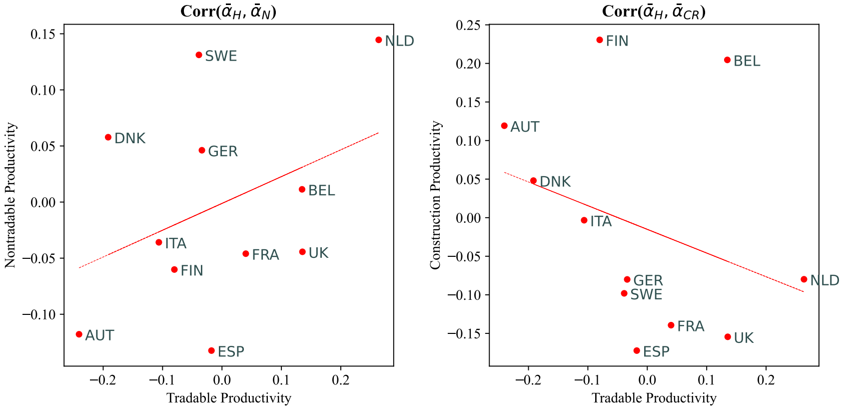

Figure 5. Cross-Country Distributions of the Sectoral Productivities

- Role of Housing Market

	(1) Data	(2) Bond ($\gamma^R = 0.01$)	(3) Bond ($\gamma^R = 0.25$)	(4) Bond ($\gamma^R = 0.45$)
Balassa/Samuleson				
β	-0.26*	-0.45*	-0.57*	-0.72*
	(0.14)	(-0.63,-0.26)	(-0.76,-0.36)	(-0.93,-0.52)
β^T	-0.08	-0.24*	-0.21*	-0.19*
	(0.13)	(-0.34,-0.14)	(-0.32,-0.09)	(-0.31,-0.08)
β^{NT}	-0.33*	-0.75*	-0.65*	-0.61*
	(0.18)	(-1.06,-0.44)	(-0.98,-0.31)	(-0.94,-0.26)
β^R	-0.76**	-1.51*	-1.46*	-1.43*
	(0.19)	(-1.69,-1.31)	(-1.65,-1.26)	(-1.65,-1.21)

Table 9. Model Balassa-Samuelson w/ Different Housing

- **Summary of Findings**

1) Characteristics of housing service imply weak textbook Balassa-Samuelson hypothesis mechanism for q^R
2) What generates $\beta < 0$ are

   Wealth Effect via Incomplete Market

   Cross-sectional Distributions of the Relative Sectoral Productivities.

   $Corr(\bar{A}_j^T, \bar{A}_j^N) = 0.76, \; Corr(\bar{A}_j^T, \bar{A}_j^{CR}) = -0.23$

   (Goolsbee and Syverson 2023)
3) Different land endowment may be potentially important Regressions

   Different Land-use Policies & Different Urban Planning

3. Housing and the Backus-Smith Puzzle

- **Backus-Smith Correlation**

  $\Delta q = \alpha + \beta \Delta q + \epsilon$

- **Model Viewpoint on the Housing and the Backus-Smith Puzzle**

  In data, $\beta < 0 \Leftrightarrow Corr(\Delta q, \Delta c) < 0$

  Rent ($\gamma^R \beta^R$) accounts for most of it.

$\rightarrow$ Why?

$\rightarrow$ Is there anything special about housing service? (Role of Land, Stock vs Flow)

3. Housing and the Backus-Smith Puzzle: Model-Simulated Regressions

- Incomplete Market + Housing = Negative Backus-Smith Correlation

	(1) Data	(2) Arrow-Deberu (γ^R = 0.25)	(3) Bond (γ^R = 0.01)	(4) Bond (γ^R = 0.25)	(5) Bond (γ^R = 0.45)
Backus/Smith					
β	-0.14**	1.99*	0.38*	-0.12	-0.51
	(0.07)	(1.98,2.02)	(0.09,0.68)	(-0.53,0.28)	(-1.14,0.07)
β^T	0.02	1.21*	0.19	0.05	0.04
	(0.05)	(1.20,1.23)	(0.04,0.37)	(-0.18,0.27)	(-0.31,0.36)
β^{NT}	-0.15**	3.75*	0.68*	0.22	0.18
	(0.06)	(3.72,3.79)	(0.18,0.90)	(-0.46,0.90)	(-0.87,1.15)
β^R	-0.53**	0.82*	-0.79*	-1.29*	-1.69*
	(0.23)	(0.81,0.83)	(-1.09,-0.51)	(-1.69,-0.89)	(-2.31,-1.11)

Table 10. Backus-Smith Correlation

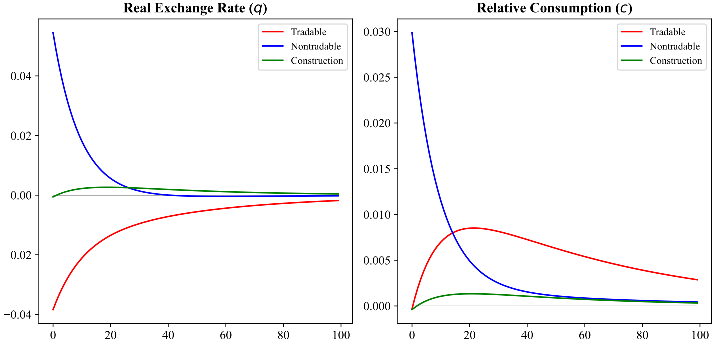

Figure 6. IRFs from $\epsilon_t^H = \bar{\sigma}^T,\ \epsilon_t^N = \bar{\sigma}^N,\ \epsilon_t^{CR} = \bar{\sigma}^{CR}$

- **Drivers of the Model**

  Tradable Shock (ϵ^T)

  $\rightarrow$ $Corr(q, cc^*) < 0$

  Nontradable Shock (ϵ^N)

  $\rightarrow$ $Corr(q, cc^*) > 0$

  Construction Shock (ϵ^{CR})

  $\rightarrow$ $Corr(q, cc^*) > 0$

3. Housing and the Backus-Smith Puzzle: Demand vs Supply

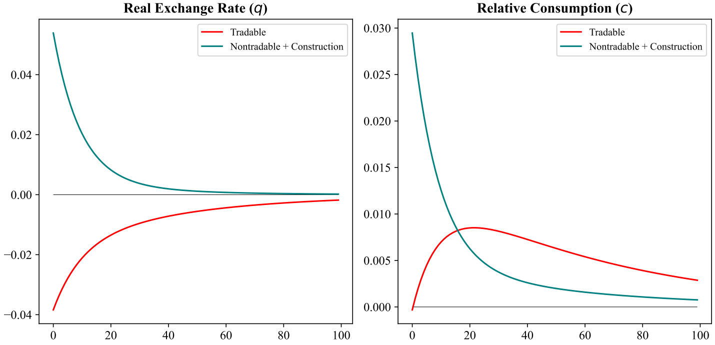

Figure 7. Demand Effect (ϵ^T) vs Supply Effect ($\epsilon^N + \epsilon^{CR}$)

- **Demand Effect** (A^T)

  $A^T \uparrow \to \text{WE} \uparrow \to D \uparrow \to C, P \uparrow$

  $A^T \uparrow \to W \uparrow \to P \uparrow$

  (Balassa-Samuelson Hypothesis)

$\to \; C \uparrow, P \uparrow \to Corr(q, cc^*) < 0$

- **Supply Effect** (A^{NT}, A^{CR})

  $A^{NT} + A^{CR} \uparrow \to Y^{NT}, Y^{CR} \uparrow \to P \downarrow$

$\to \; C \uparrow, P \downarrow \to Corr(q, cc^*) > 0$

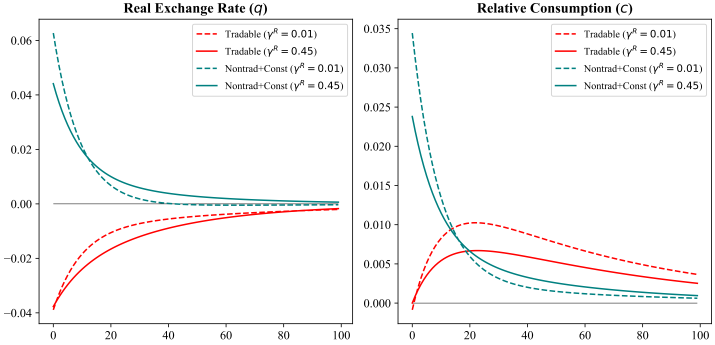

Figure 8. Role of Housings in Model Responses

- **Amplified Demand Effect**

  Housing is Big Part of C

  Housing Supply is Inelastic

$\rightarrow$ Steeper Aggregate Supply

$\rightarrow$ Effect of Demand Shock $\uparrow$ (Red IRFs)

- **Dampened Supply Effect**

  $A^{NT} + A^{CR} \uparrow \nrightarrow MC^{CR} \downarrow (\bar{L})$

$\rightarrow$ Dampens Supply Effect (Green IRFs)

▶▶ Model Corr

3. Housing and the Backus-Smith Puzzle: Sectoral q IRFs

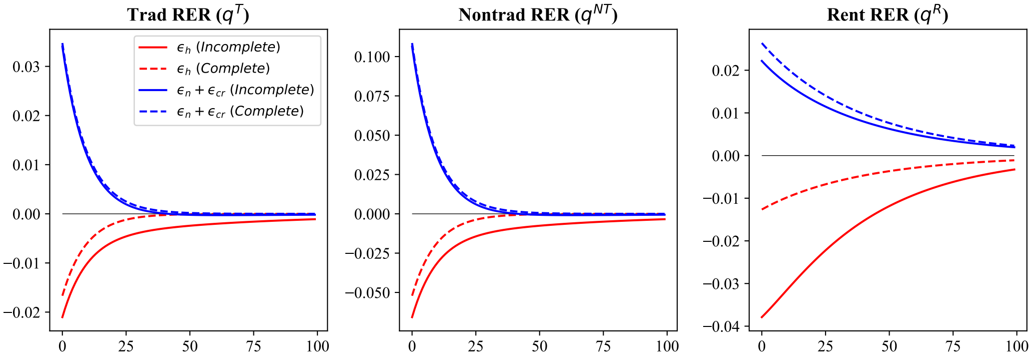

Figure 9. Incomplete Market and Importance of Wealth Effect

- Inelastic Supply is the Key

	(1) Data	(2) Bond Baseline	(3) Bond ($\tau = 0.01$)	(4) Bond ($\delta = 0.99$)	(5) Bond (τ=0.01, δ=0.99)	(6) Bond (7) + ($\bar{A}_j^{CR}/\bar{A}_{EU}^{CR} = 1$)
Backus/Smith						
β	-0.14**	-0.12	-0.32	0.62*	1.18*	1.21*
	(0.07)	(-0.53,0,28)	(-0.71,0.07)	(0.21,1.04)	(0.83,1.58)	(0.81,1.63)
β^T	0.02	0.05	-0.09	0.29*	0.30*	0.32*
	(0.05)	(-0.18,0.27)	(-0.29,0.12)	(0.09,0.49)	(0.15,0.47)	(0.13,0.50)
β^{NT}	-0.15**	0.22	-0.20	0.95*	0.95*	1.00*
	(0.06)	(-0.46,0.90)	(-0.84,0.44)	(0.36,1.57)	(0.47,1.48)	(0.43,1.56)
β^R	-0.53**	-1.29*	-1.44*	0.86*	3.48*	3.52*
	(0.23)	(-1.69,-0.89)	(-1.92,-0.95)	(0.17,1.57)	(2.72,4.27)	(2.73,4.38)

Table 11. Backus-Smith Correlation and Housing

3. Housing and the Backus-Smith Puzzle: What's New?

- **Previous Backus-Smith Puzzle Literature**

1) Early Papers (e.g. Chari, Kehoe and McGrattan 2002)
 : Supply effect dominates the Demand effect in sizes
$\rightarrow$ Incomplete market was not enough.

2) Corsetti, Dedola and Leduc (2008)
 : Make Demand works through the terms of trade by non-substitutable tradable.
 : Make Demand effect larger by assuming more persistent ϵ^T and very substitutable tradable.

3) Itskhoki and Mukhin (2021)
 : Use financial market shock and use nominal exchange rate to generate $Corr(\Delta c, \Delta q) < 0$.

- **What's New?**

- By using inelastic housing supply (land), I amplify and make the Demand effect persistent and dampen the Supply effect

$\rightarrow$ Change the response of the C and q in the model, rather than shock itself.

Conclusion

Housing and the International Business Cycles

- **Importance and Uniqueness of Housing Service**

  Large Expenditure Share

  Inelastic Supply (Land & Small Flow vs Large Stock)

- ***RER* and Housing in Data**

  q^R is the most volatile and accounts for large portion of q variation.

  More than half of the Balassa-Samuelson & Backus-Smith correlation is from q^R.

- ***RER* and Housing in Model**

  Incomplete Market is necessary for volatile q^R.

  Housing Sector improves model's predictions on the Balassa-Samuelson/Backus-Smith Corr.

  Negative cross-sectional correlation between A^T, A^N & Inelastic Housing Supply.

- **Future Plan**

  Non-homothetic Preference, Rent Control, and Housing driven Wealth Effect (e.g. Expectation.)

Thank You

Questions?

Appendix - Intro

Importance and Uniqueness of Housing in Eurozone Countries

Back

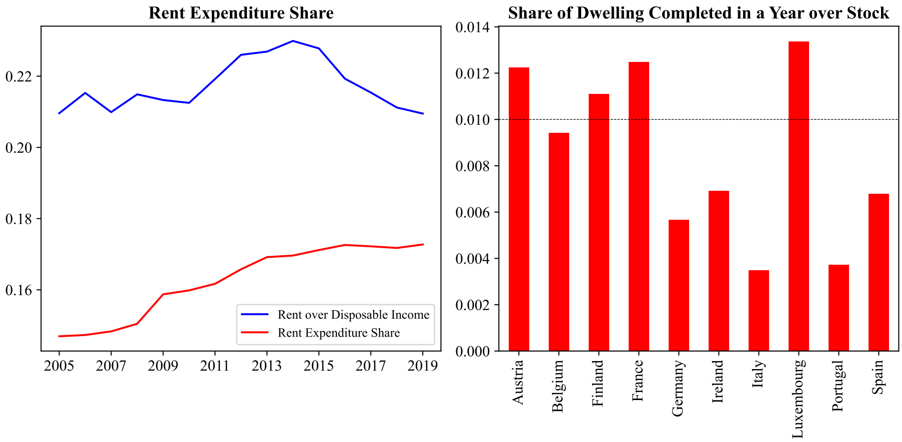

Figure A1. Share of Housing Rent and Housing Flow in Eurozone Countries

Balassa-Samuelson Effect and Hypothesis

Back

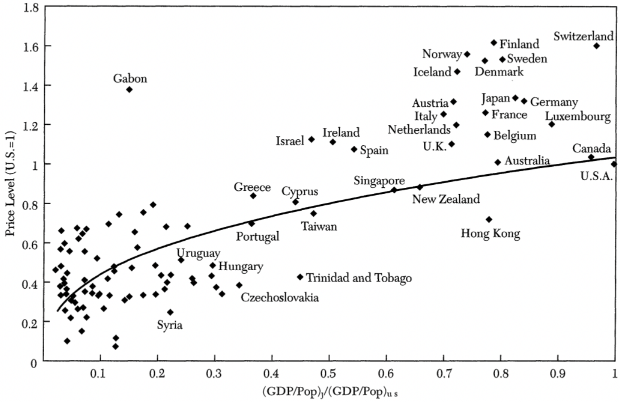

Figure A2. Figure 3 in Rogoff (1996)

- **Balassa-Samuelson Effect**

  Cross-sectional (Rogoff 1996)

  GDP per capita $\uparrow \rightarrow$ Price Level $\uparrow$

- **Balassa-Samuelson Hypothesis**

  $A^T \uparrow$ more than A^{NT}

  Production Input Price (e.g., W) $\uparrow$

  $P^{NT} \uparrow \rightarrow$ Price Level $\uparrow$

The Backus-Smith Puzzle ⏩ Back

- The Backus-Smith Correlation

$$Corr(\frac{C_t}{C_t^*}, \frac{P_t^*}{P_t}) < 0 \qquad \text{(Data)}$$

- International Risk Sharing under the Complete Market (*CRRA* preference)

$$\underbrace{\frac{C_t^{-\rho}}{P_t} = \frac{C_t^{*\,-\rho}}{P_t^*}}_{\text{Complete Market}} \Leftrightarrow \underbrace{\frac{P_t^*}{P_t}}_{\text{Real Exchange Rate}} = \underbrace{(\frac{C_t}{C_t^*})^{\rho}}_{\text{Relative Consumption}} \Leftrightarrow \underbrace{Corr(\frac{C_t}{C_t^*}, \frac{P_t^*}{P_t})}_{\text{Backus-Smith Correlation}} = 1 \qquad \text{(Model)}$$

- The Backus-Smith Puzzle[3]

  Data $\neq$ Model

$\rightarrow$ Data (Lack of Risk Sharing & Relative Demand Shock) vs Model (Strong Risk Sharing)

- **Resolutions:** Incomplete Market, Wealth Effect, Home Production, Financial Frictions

[3] Backus and Smith (1993), Cole and Obstfeld (1991), Stockman and Tesar (1995), Chari, Kehoe and McGrattan (2002), Benigno and Thoenissen (2008), Corsetti, Dedola and Leduc (2008), Karabarbounis (2014), Bai and Rios-Rull (2015), Jiang (2017), Lambrias (2020), Itskhoki and Mukhin (2021)

Appendix - Empricis Part

Data Quality of Eurostat PPP Database

Back

- **Superiority of Eurostat PPP data (OECD and Eurostat 2012)**
  - Standardized and centralized price comparison projects.
  - Homoegeneity across countries in Eurozone systems.
  - Internal Review Process for the Consistency and Comparability.

- **Rent Level Comparability**
  - Every year, survey is organized by Eurostat.
  - Only rent included, while not including any type of other services (e.g. utilities.)
  - Data based on the internal surveys used for national account construction.
  - Internal review process for the validity of the cross-country comparability.

Panel of Sectoral RER (q, q^T, q^{NT}, q^R) Back

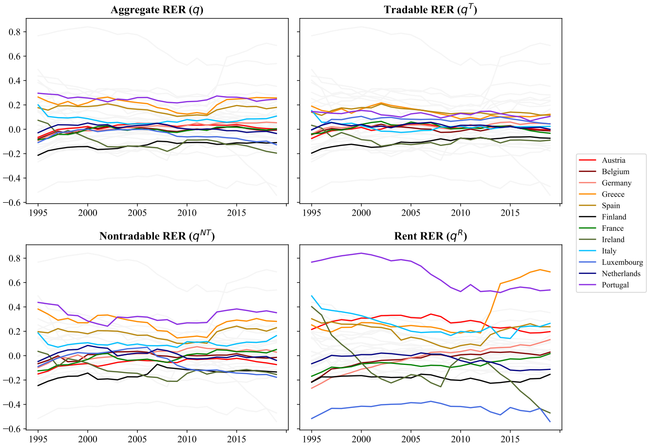

Figure A3. Properties of Real Exchange Rates

Panel of Expenditure Share $(\gamma, \gamma^T, \gamma^{NT}, \gamma^R)$ Back

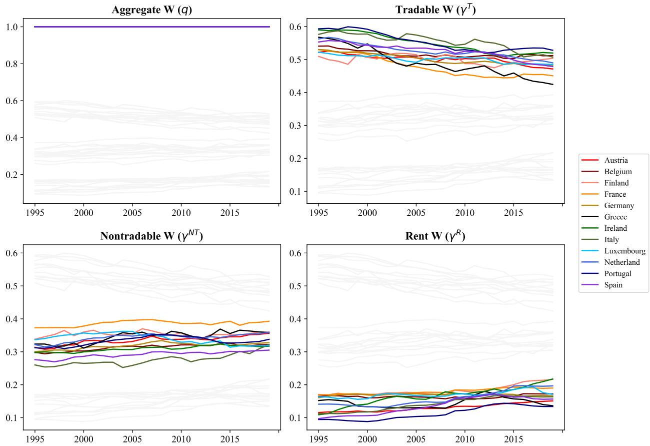

Figure A4. Properties of Expenditure Weights

Descriptive Statistics of *RER* (q) ⏩ Back

	Mean				Standard deviation				Autocorrelation(1)			
Country	$\bar{q}$	$\bar{q}^T$	$\bar{q}^{NT}$	$\bar{q}^R$	$std(q)$	$std(q^T)$	$std(q^{NT})$	$std(q^R)$	$\rho(q)$	$\rho(q^T)$	$\rho(q^{NT})$	$\rho(q^R)$
Ireland	-0.132	-0.102	-0.140	-0.187	0.034	0.021	0.035	0.128	0.737	0.500	0.731	0.866
Finland	-0.124	-0.093	-0.138	-0.187	0.021	0.028	0.034	0.022	0.823	0.919	0.725	0.681
Luxembourg	-0.047	0.080	-0.059	-0.425	0.040	0.015	0.087	0.039	0.954	0.692	0.965	0.564
France	0.002	0.023	0.002	-0.057	0.014	0.027	0.034	0.030	0.536	0.813	0.801	0.888
Belgium	0.005	0.006	0.006	-0.003	0.012	0.019	0.017	0.028	0.677	0.736	0.774	0.899
Netherland	0.010	0.027	0.010	-0.038	0.026	0.015	0.035	0.055	0.866	0.585	0.770	0.954
Austria	0.028	0.017	-0.047	0.273	0.015	0.014	0.018	0.053	0.715	0.690	0.732	0.920
Germany	0.030	0.033	0.029	0.020	0.023	0.015	0.028	0.068	0.912	0.644	0.885	0.979
Italy	0.068	0.008	0.100	0.222	0.018	0.018	0.021	0.049	0.693	0.723	0.416	0.682
Spain	0.162	0.147	0.176	0.172	0.032	0.025	0.047	0.070	0.858	0.877	0.814	0.869
Greece	0.211	0.134	0.254	0.364	0.050	0.041	0.062	0.200	0.863	0.916	0.839	0.944
Portugal	0.244	0.118	0.313	0.641	0.016	0.022	0.045	0.121	0.530	0.607	0.768	0.965

Aggregate	$std(mean_j)$	$mean(std_j)$	$mean(autocorr_j)$
q	0.119	0.025	0.764
q^T	0.079	0.022	0.725
q^{NT}	0.144	0.039	0.768
q^R	0.286	0.072	0.851

$q_j = ln(P_{EU15t}/P_{jt}),\ q_j^T = ln(P^T_{EU15t}/P^T_{jt}),\ q_j^{NT} = ln(P^{NT}_{EU15t}/P^{NT}_{jt}),\ q_j^R = ln(P^R_{EU15t}/P^R_{jt})$ where P_{EU15t} is a geometric mean of P over 15 Eurozone countries. Data period is from 2000 to 2019 and data is in annual frequency.

Table A1. Descriptive Statistics of Real Exchange Rates

Panel of Relative GDP per capita (y) and Relative Consumption (Δc)

Back

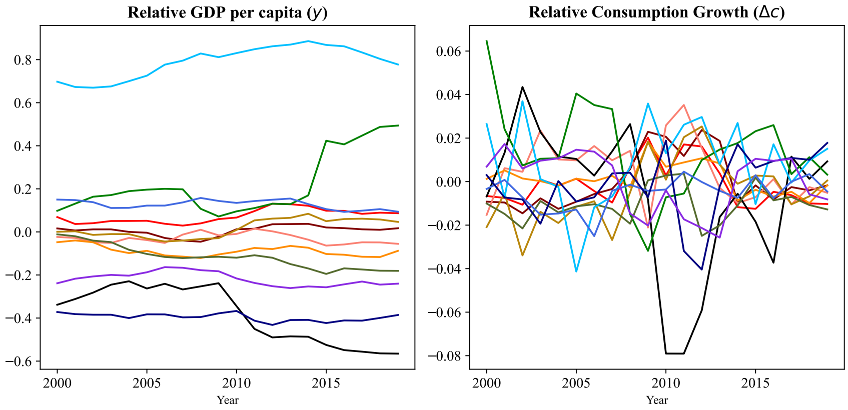

Figure A5. Relative GDP per capita and Relative Consumption Growth

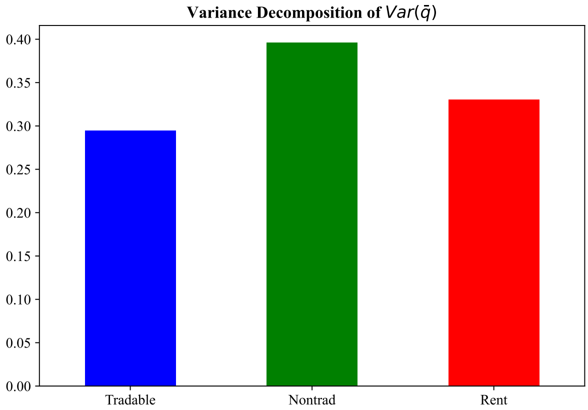

Figure A6. Variance Decomposition (Across-Country)

Variance Decomposition (Time-series) ⏩ Back

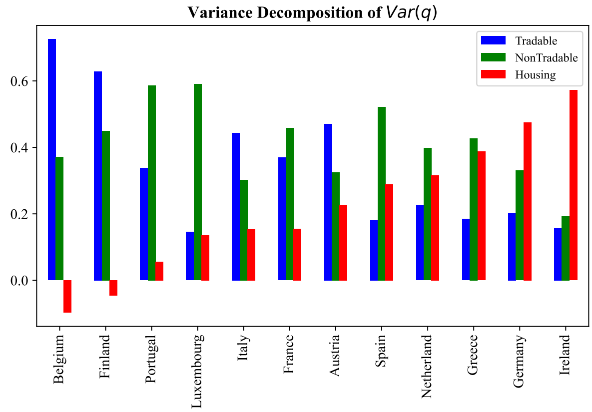

Figure A7. Variance Decomposition (Within-Country)

		Δq	Δq^T	Δq^{NT}	Δq^R
Growth Rate	Δy	0.07*	0.11***	0.13**	-0.17**
		(0.04)	(0.03)	(0.07)	(0.08)
	R^2	0.02	0.04	0.02	0.02
	N	240	240	240	240
		q	q^T	q^{NT}	q^R
Country-FE	y	-0.11***	0.08*	-0.08	-0.67***
		(0.04)	(0.05)	(0.10)	(0.22)
	R^2	0.07	0.07	0.02	0.25
	N	240	240	240	240

Table A2. Balassa-Samuelson Effect Regressions (Time-Series)

Backus-Smith Correlations in Eurozone Countries

Back

	$Corr(c,q)$	$Corr(c,q^T)$	$Corr(c,q^{NT})$	$Corr(c,q^R)$
Austria	0.026	-0.165	0.548	-0.458
Belgium	0.069	0.101	-0.424	0.494
Finland	0.793	0.938	0.623	-0.608
France	0.173	-0.503	0.745	0.305
Germany	-0.256	0.355	-0.509	-0.365
Greece	-0.421	0.505	-0.249	-0.833
Ireland	-0.556	0.236	-0.372	-0.611
Italy	-0.488	-0.486	-0.392	0.446
Luxembourg	-0.867	-0.407	-0.838	-0.814
Netherland	0.695	0.203	0.750	0.712
Portugal	-0.343	0.015	-0.508	0.730
Spain	-0.387	0.280	-0.525	-0.580
Average	-0.130	0.089	-0.096	-0.132

$q = ln(P_{EU15t}/P_{it})$, $q^T = ln(P^T_{EU15t}/P^T_{it})$, $q^{NT} = ln(P^{NT}_{EU15t}/P^{NT}_{it})$, $q^R = ln(P^R_{EU15t}/P^R_{it})$ where P_{EU15t} is a geometric mean of P over 15 Eurozone countries. $c = ln(C_{it}/C_{EU12t})$ where C_{EU12t} is a geometric means of C over 12 Eurozone countries. C is final consumption expenditure of households per capita. Data is from Eurostat national accounts. Data period is from 2000 to 2019 and data is in annual frequency.

Table A3. Backus-Smith Correlations in Eurozone Countries

Backus-Smith Correlations in Eurozone Countries

Back

	$Corr(\Delta c, \Delta q)$	$Corr(\Delta c, \Delta q^T)$	$Corr(\Delta c, \Delta q^{NT})$	$Corr(\Delta c, \Delta q^R)$
Austria	-0.066	-0.031	0.131	-0.489
Belgium	-0.029	0.047	-0.087	-0.118
Finland	0.246	0.481	-0.027	-0.020
France	0.307	0.219	0.467	-0.162
Germany	-0.205	-0.012	-0.122	-0.551
Greece	-0.075	0.090	-0.110	-0.080
Ireland	-0.418	-0.218	-0.242	-0.541
Italy	0.135	0.048	0.288	0.011
Luxembourg	-0.082	0.302	-0.159	-0.260
Netherland	-0.039	-0.149	0.176	-0.299
Portugal	-0.275	-0.183	-0.137	0.052
Spain	-0.203	0.114	-0.272	-0.235
Average	-0.059	0.059	-0.008	-0.224

$q = ln(P_{EU15t}/P_{it})$, $q^T = ln(P^T_{EU15t}/P^T_{it})$, $q^{NT} = ln(P^{NT}_{EU15t}/P^{NT}_{it})$, $q^R = ln(P^R_{EU15t}/P^R_{it})$ where P_{EU15t} is a geometric mean of P over 15 Eurozone countries. $c = ln(C_{it}/C_{EU12t})$ where C_{EU12t} is a geometric means of C over 12 Eurozone countries. C is final consumption expenditure of households per capita. Data is from Eurostat national accounts. Data period is from 2000 to 2019 and data is in annual frequency.

Table A4. Backus-Smith Correlations in Eurozone Countries

β Decomposition VS *Corr* Decomposition ⏩ Back

(1) $\beta = \gamma^T\beta^T + \gamma^{NT}\beta^{NT} + \gamma^R\beta^R \quad (\beta = \frac{Cov(c,\ q)}{Var(c)})$

$$\frac{Cov(c,q)}{Var(c)} = \gamma^T\frac{Cov(c,q^T)}{Var(c)} + \gamma^{NT}\frac{Cov(c,q^{NT})}{Var(c)} + \gamma^R\frac{Cov(c,q^R)}{Var(c)}$$

$$Cov(c,q) = \gamma^T Cov(c,q^T) + \gamma^{NT} Cov(c,q^{NT}) + \gamma^R Cov(c,q^R)$$

$$\begin{aligned} Corr(c,q)std(c)std(q) = \ & \gamma^T Corr(c,q^T)std(c)std(q^T) \\ & + \gamma^{NT} Corr(c,q^{NT})std(c)std(q^{NT}) \\ & + \gamma^R Corr(c,q^R)std(c)std(q^R) \end{aligned}$$

(2) $Corr(c,q) = \gamma^T Corr(c,q^T)\frac{std(q^T)}{std(q)} + \gamma^{NT} Corr(c,q^{NT})\frac{std(q^{NT})}{std(q)} + \gamma^R Corr(c,q^R)\frac{std(q^R)}{std(q)}$

$\rightarrow$ (1) $\times$ $\frac{std(c)}{std(q)}$ = (2)

3. Negative Backus-Smith Correlation Exists and Housing Rent is a Main Driver

		$\bar{q}$	$\bar{q}^T$	$\bar{q}^{NT}$	$\bar{q}^R$
Country Average	$\bar{c}$	0.03	0.00	0.03	0.07
		(0.02)	(0.02)	(0.02)	(0.05)
	R^2	0.07	0.01	0.07	0.09
	N	12	12	12	12
		q	q^T	q^{NT}	q^R
Time-FE	c	0.02	0.00	0.03	0.07
		(0.02)	(0.02)	(0.02)	(0.06)
	R^2	0.07	0.01	0.06	0.09
	N	240	240	240	240

Table A5. Backus-Smith Regressions (Cross-section) ⏩ Back

Appendix - Model Part

Model Overview

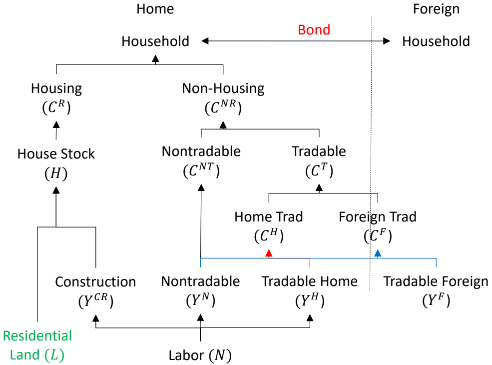

Figure A8. Model Structure

Model Overview

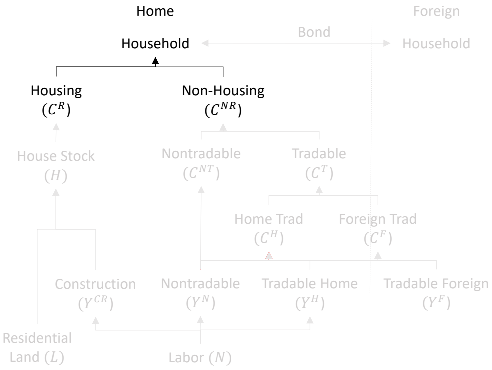

Figure A8. Model Structure

Model Overview

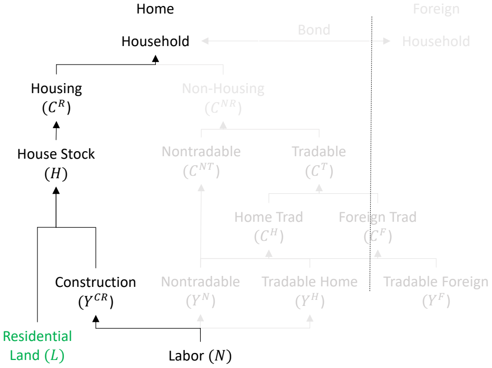

Figure A8. Model Structure

Model Overview

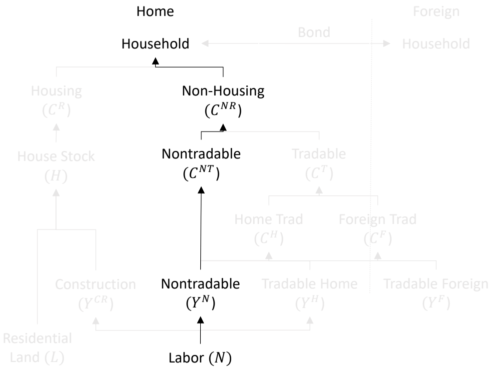

Figure A8. Model Structure

Model Overview

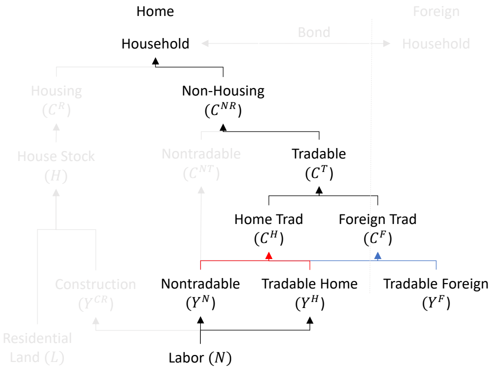

Figure A8. Model Structure

Model Overview

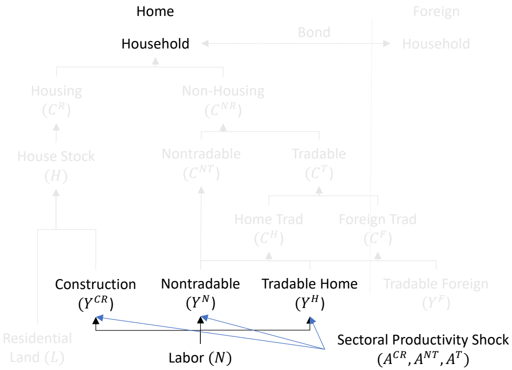

Figure A8. Model Structure

Model Overview ⏩ Return

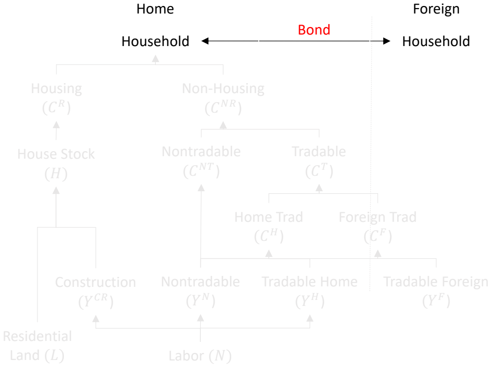

Figure A8. Model Structure

Model: 6. Market Clearing and Competitive Equilibrium ▸▸ Return

- Market Clearing

$$N_t = N_{H,t} + N_{N,t} + N_{CR,t}$$

$$l_t = \bar{l}$$

$$C_R = \kappa H_{t-1} \; (\kappa = 1)^4$$

$$Y_{H,t} = I_{H,t} + I^*_{H,t} \; (Y^*_{F,t} = I_{F,t} + I^*_{F,t})$$

$$Y_{N,t} = V_{H,t} + V_{F,t} + C_{NT,t}$$

$$\tilde{Y}_{CR,t} = Y_{CR,t}$$

- Equilibrium

Decision rules of HH/Producers and Prices

[4] Assuming housing service proportional to the housing stock is literature standard. See Iacoviello and Neri (2010)

Role of the Land

1. **Lower the housing supply elasticity**

   Assuming $P_t^{CR} = \bar{P}^{CR}$ and $l_t = \bar{l}$, optimal condition for housing production implies

   $Y_t^{CR} = (\frac{\bar{P}^{CR}}{\bar{l}^{\tau}(1-\tau)P_t^H})^{-\frac{1}{\tau}}$

   Substituting it into the production function, we have[5]

   $I_t^H = (P_t^H)^{\frac{1-\tau}{\tau}}(1-\tau)^{\frac{1-\tau}{\tau}}(\bar{P}^{CR})^{\frac{\tau-1}{\tau}}\bar{l} \quad \rightarrow \quad \frac{\partial ln(I^H)}{\partial ln(P^H)} = \frac{1-\tau}{\tau}$

   $\tau \uparrow \rightarrow$ inelastic supply

2. **Dampen the effect of supply-side shock**

   Even though the wage gets cheaper via productivity growth, land doesn't get cheaper.

[5] Note that this is the lower limit of supply elasticity because P^{CR} is a function of P^H increasing in P^H.

Estimated Housing Supply Elasticity Across Eurozone Countries

Country	Estimated Housing Supply Elasticity
Netherlands	0.40
Belgium	0.46
France	0.49
Austria	0.51
Italy	0.55
Germany	0.67
Finland	1.00
Spain	1.17
United States	2.82

Elasticities are from **?**. Data is from 1980 - 2017s for 25 economies. It uses multi-factor panel error correction model and instrument the price with demand shocks.

Table A6. Housing Supply Elasticity

Appendix - Simulation Part

Calibrated Relative Sectoral Productivity Shocks

Return

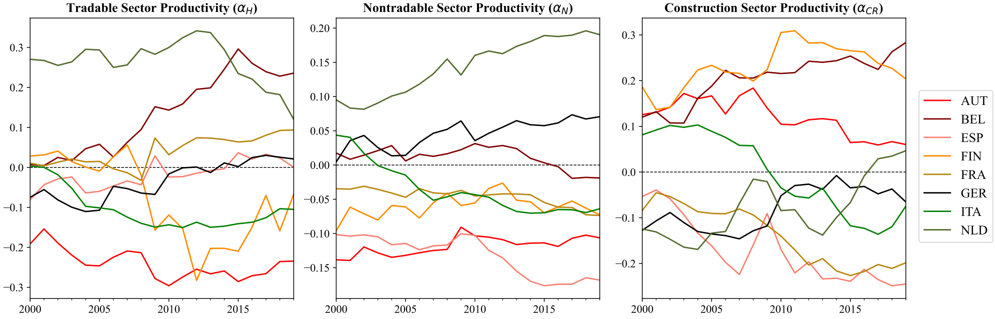

Figure A9. Relative Sectoral Productivities

Sectoral Productivity Shocks Calibration

Return

	A. Cross-section			B. Time-series					
	Mean values			AR(1) Coefficients			Standard Deviations		
	$\bar{a}_H$	$\bar{a}_N$	$\bar{a}_{CR}$	ρ_H	ρ_N	ρ_{CR}	σ_H	σ_N	σ_{CR}
AUT	-0.241	-0.118	0.119	0.918	0.894	0.966	2.367	0.936	2.344
BEL	0.135	0.011	0.205	0.983	0.976	0.971	2.700	0.907	2.017
ESP	-0.018	-0.132	-0.172	0.873	0.987	0.945	2.409	0.951	3.499
FIN	-0.080	-0.060	0.231	0.939	0.769	0.946	6.198	1.262	2.804
FRA	0.040	-0.046	-0.139	0.925	0.997	0.989	2.716	0.583	1.862
GER	-0.034	0.046	-0.080	0.973	0.905	0.962	2.198	1.206	2.228
ITA	-0.106	-0.036	-0.003	0.951	0.959	0.987	1.326	0.708	2.402
NLD	0.264	0.145	-0.080	0.990	0.986	0.986	2.919	1.153	3.359
AVG	-0.005	-0.024	0.010	0.944	0.934	0.969	2.854	0.963	2.564

Table A7. Properties of Sectoral TFP

cf) Relative Country Size

- Household Problem with Population $\neq 1$

$$U = E[\sum_{t=0}^{\infty} \beta^t (\frac{(C_t/POP)^{1-\sigma}}{1-\sigma} - \frac{(N_t/POP)^{1+\psi}}{1+\psi})], \quad \beta < 1$$

$$s.t. \quad P_t C_t + D_{t+1}/R_{t+1} + P_{RI,t} I_{RI,t} = D_t + W_t N_t + P_{R,t} H_{t-1} + P_{l,t} l_t - \frac{\phi}{2} D_{t+1}^2$$

$$H_t = (1-\delta) H_{t-1} + I_{RI,t}$$

- Land Supply with Population $\neq 1$

$\bar{l} \times POP$

cf) Relative Sizes of Countries Against EU12

Country	$\frac{Y}{Y_{EU12}}$	$\frac{C}{C_{EU12}}$
Austria	0.682	0.747
Belgium	0.824	0.854
Finland	0.392	0.440
France	4.466	5.076
Germany	6.251	6.643
Italy	3.964	4.662
Netherland	1.424	1.364
Spain	2.726	2.974

Table A8. Relative Sizes of Simulated Countries Against EU12 Average

RER and Urban Land per capita

Back

	q	q^T	q^{NT}	q^R
Urban Land per capita	0.091*	0.079*	0.104*	0.159*
	(0.048)	(0.043)	(0.059)	(0.091)
y	-0.238**	-0.089	-0.2945**	-0.6564**
	(0.074)	(0.067)	(0.097)	(0.091)
N	300	300	300	300
R^2	0.5814	0.2674	0.5638	0.7018

Table A9. Balassa-Samuelson and Land

Small Open Economy: Balassa-Samuelson Effect (Later)

- Analytical Solution for Nontradable w/ Fixed Factor
  (No distribution margin, only one nontradable, $v = 1$, Small Open Economy)

$$P^R = \underbrace{\frac{A^T}{A^R}}_{\text{Balassa-Samuelson}} \overbrace{(\frac{\bar{N}}{l})^{\tau}}^{\text{Inverse of Land per capita}} \underbrace{\frac{1}{(1-\tau)}(\frac{\gamma^R - \tau\gamma^R}{1-\tau\gamma^R})^{\tau}}_{\text{Relative Importance of } l \text{ and } C^R}$$

- Intuition

  $\frac{A^T}{A^{NT}} \uparrow \rightarrow W \uparrow$ Substitute to $l \rightarrow$ Fixed Supply $\rightarrow$ Larger Price Response.

  If $v \neq 1$, no analytical solution but $v \uparrow \implies P^R \downarrow$

  Need to dig into more about the analytical solutions

Log-linearized Law of Motion of Δq

- Role of Housing Sector

- As housing rent expenditure increases, q behaves more like q^R and less like q^T or q^{NT}.
- q becomes more responsive to a^H and less responsive to a^N

- Log-linearized Form of q

$$\Delta q_t = \gamma^{R*}(\frac{P_{ss}^{RL*}}{P_{ss}^*})^{1-v^*}\Delta ln(P_t^{RL*}) + (1-\gamma^{R*})(\frac{P_{ss}^{NR*}}{P_{ss}^*})^{1-v^*}\Delta ln(P_t^{NR*})$$
$$-\gamma^R(\frac{P_{ss}^{RL}}{P_{ss}})^{1-v}\Delta ln(P_t^{RL}) - (1-\gamma^R)(\frac{P_{ss}^{NR}}{P_{ss}})^{1-v}\Delta ln(P_t^{NR})$$

Log-linearized Law of Motion of Δq (Continued)

$$\Delta q_t = \frac{W^{RL*} + W^{RL}}{2} \underbrace{(\Delta ln(P_t^{RL*}) - \Delta ln(P_t^{RL}))}_{\Delta q_t^R} + \frac{\Delta ln(P_t^{RL*}) + \Delta ln(P_t^{RL})}{2} (W^{RL*} - W^{RL})$$

$$+ \frac{W^{NR*} + W^{NR}}{2} \underbrace{(\Delta ln(P_t^{NR*}) - \Delta ln(P_t^{NR}))}_{\Delta q_t^{NR}} + \frac{\Delta ln(P_t^{NR*}) + \Delta ln(P_t^{NR})}{2} (W^{NR*} - W^{NR})$$

where $\quad W^{RL*} = \gamma^{R*}(\frac{P_{ss}^{RL*}}{P_{ss}^*})^{1-v^*}, \quad W^{RL} = \gamma^{R}(\frac{P_{ss}^{RL}}{P_{ss}})^{1-v}, \quad W^{NR*} = (1-\gamma^{R*})(\frac{P_{ss}^{NR*}}{P_{ss}^*})^{1-v^*},$

$$W^{NR} = (1-\gamma^{R})(\frac{P_{ss}^{NR}}{P_{ss}})^{1-v}$$

3. Housing and the Backus-Smith Puzzle: Role of Housing (Country Average)

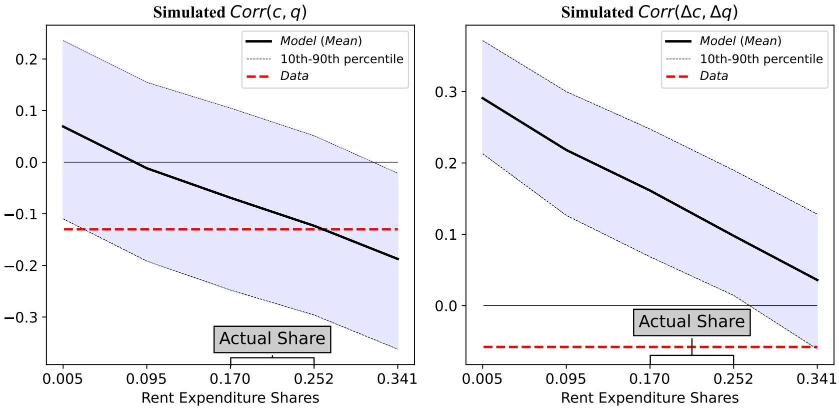

Figure A10. Model-Simulated Backus-Smith *Corr* under Different Rent Expenditure Shares

Return

Core Model Mechanism

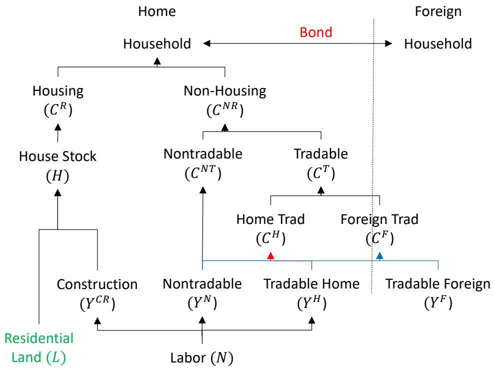

Figure A11. Model Mechanism

Core Model Mechanism 1. Assume a Complete Market

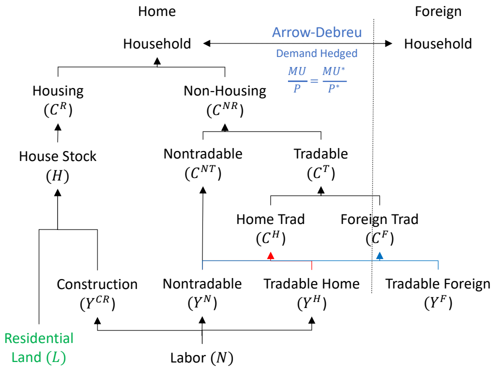

Figure A11. Model Structure

Core Model Mechanism 2. Shocks on A^T, A^{NT}, A^{CR}

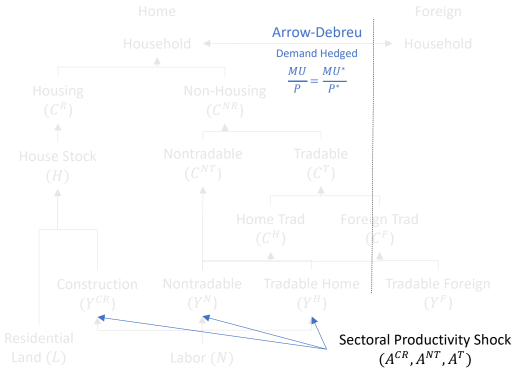

Figure A11. Model Mechanism

Core Model Mechanism 3. Substitution Effects w/o Demand (Wealth) Effect

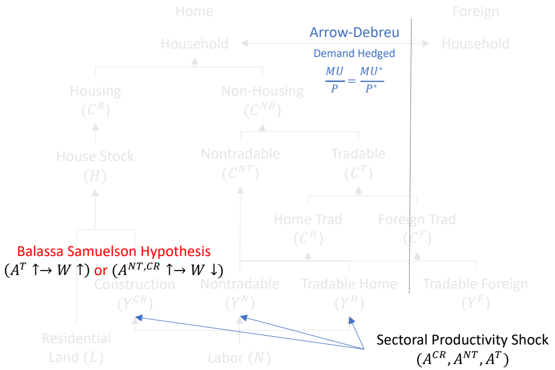

Figure A11. Model Mechanism

Core Model Mechanism 3. Substitution Effects w/o Demand (Wealth) Effect

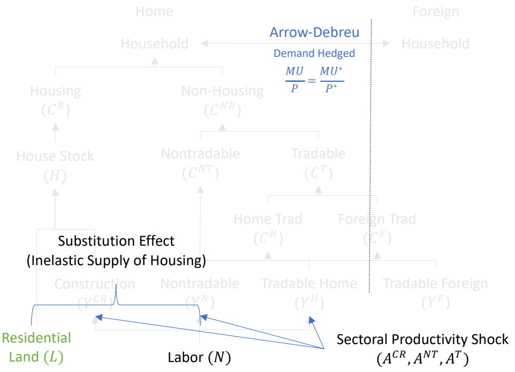

Figure A11. Model Mechanism

Core Model Mechanism 3. Substitution Effects w/o Demand (Wealth) Effect

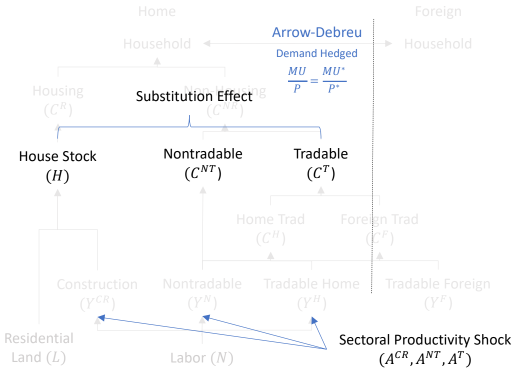

Figure A11. Model Mechanism

Core Model Mechanism 4. Incomplete Market and Demand (Wealth) Effect

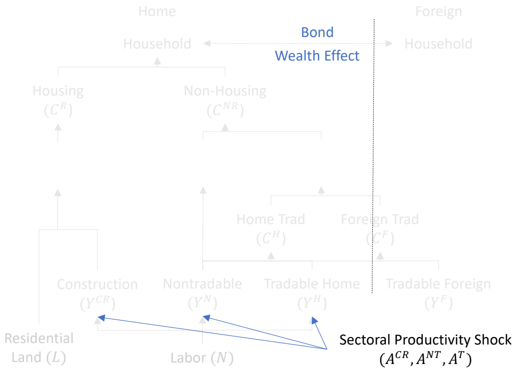

Figure A11. Model Mechanism

Core Model Mechanism 5. Role of Housing Rent

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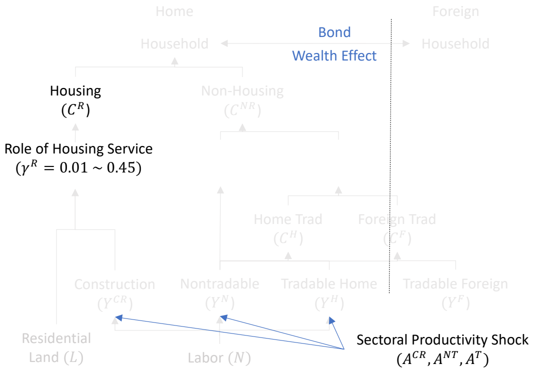

Figure A11. Model Mechanism

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