Talent, Geography, and Offshore R&D

Jingting Fan
Penn State University

May 5, 2021

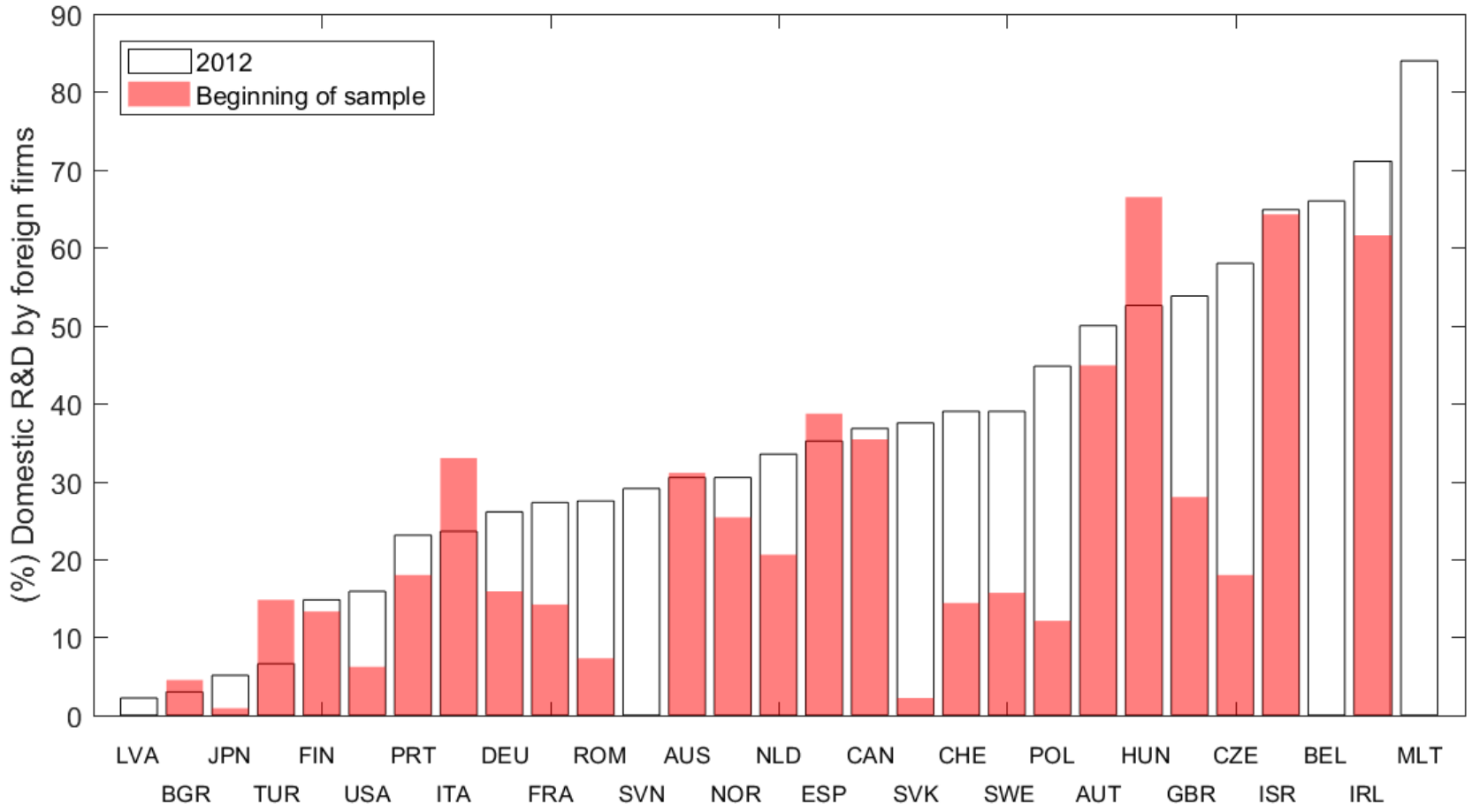
Motivation

- Global economic integration in the past decades through growing trade and activities of MNCs
  - Heated policy debates and growing academic research on the costs and benefits
  - The literature so far largely focuses on **trade** and **offshore production** of MNCs

Motivation

- Global economic integration in the past decades through growing trade and activities of MNCs
  - Heated policy debates and growing academic research on the costs and benefits
  - The literature so far largely focuses on **trade** and **offshore production** of MNCs
  - **Offshore R&D** of MNCs is overlooked
- An aspect of globalization with increasing importance
  - Offshore R&D: fraction of R&D in a **host country** by **affiliates** of **foreign corporations**

Large and Growing Offshore R&D in the Data



Notes: Offshore R&D in country i is measured as $\frac{\text{R\&D expenditures in country } i \text{ by foreign firms}}{\text{R\&D expenditures in country } i}$. Uncolored bars: value in 2012. Colored bars: value at the beginning of the sample, which differs by country and dates back to as early as 1985. Data source: OECD.

Motivation

- Goal: to model offshore R&D and quantify its global impacts
  - Direct: the spatial distribution and efficiency of R&D
  - Indirect: through trade and offshore production
- Challenge
  - R&D determined jointly with production, which in turn depends on market access
  - to discipline a model of R&D and production with realistic geographic features requires data on both activities of MNCs from different regions
  - firm-level R&D data scarce; most available sources focus on one host/home country at a time

This paper

- Assemble a new firm-level panel on R&D and production of MNCs
  - production + ownership network from Orbis, matched with patents in PATSTAT

This paper

- Assemble a new firm-level panel on R&D and production of MNCs
  - production + ownership network from Orbis, matched with patents in PATSTAT
- Document empirical regularity on MNC's R&D and production decisions
  - The role of human capital in affiliate R&D; colocation between affiliate R&D and production; headquarters effects for both affiliate R&D and production

This paper

- Assemble a new firm-level panel on R&D and production of MNCs
  - production + ownership network from Orbis, matched with patents in PATSTAT
- Document empirical regularity on MNC's R&D and production decisions
  - The role of human capital in affiliate R&D; colocation between affiliate R&D and production; headquarters effects for both affiliate R&D and production
- Interpret the empirical patterns and conduct counterfactuals through a model
  - Mechanisms: 'talent-acquisition' and 'market-access' motives
  - Measurement: around 70% of R&D in overseas affiliates for local production; offshore R&D as an important source of profit for developed country firms
  - Counterfactuals: offshore R&D generates on average 3.3% welfare gains and amplifies gains from globalization by one third
    - -significant advanced country biases
    - -important interactions with trade and offshore production

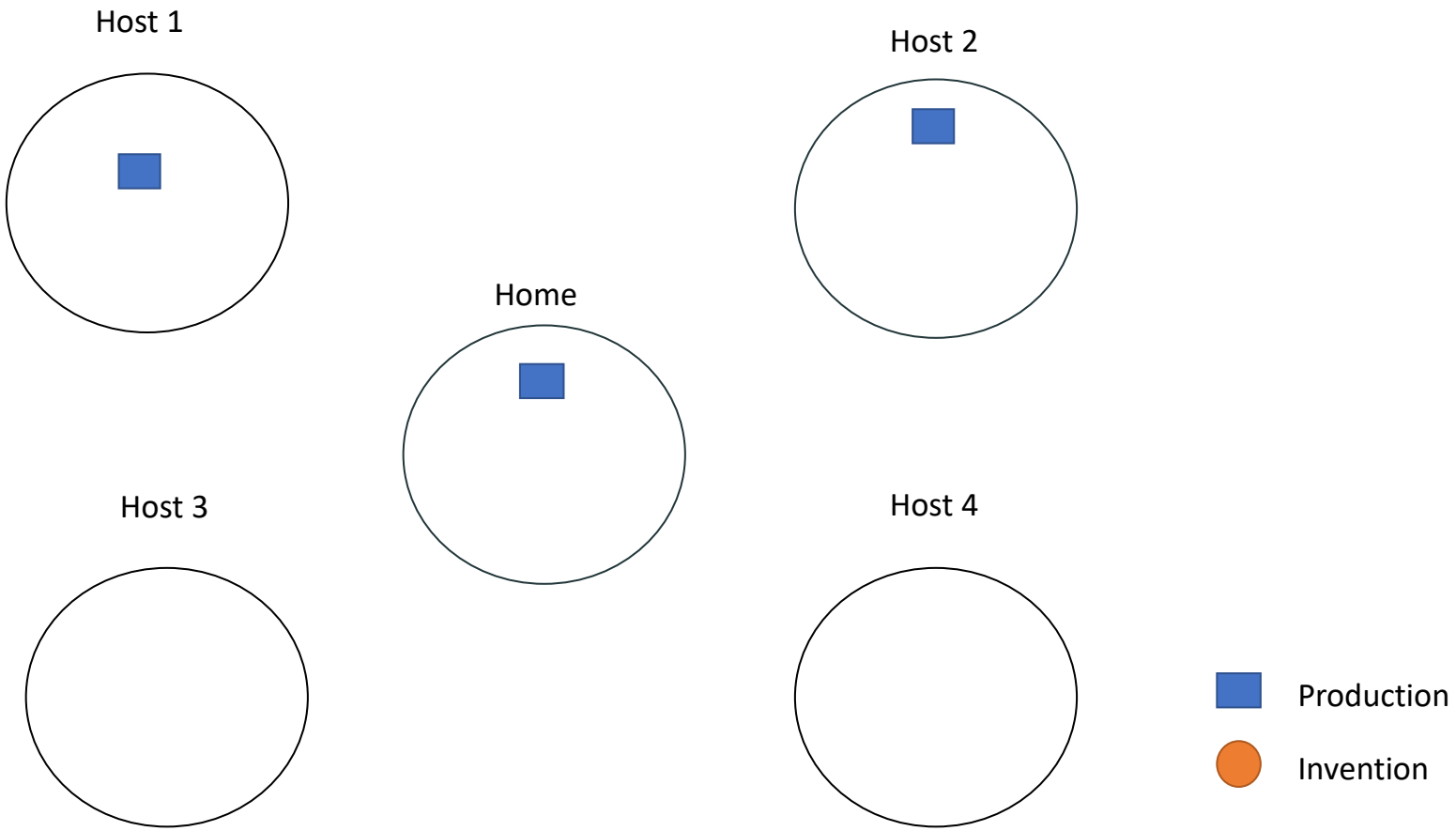
Literature

- The impacts of MNCs
  - Production: Alviarez (2019), Burstein and Monge-Naranjo (2009), Garetto (2013), McGrattan and Prescott (2009), Ramondo and Rodríguez-Clare (2013), Arkolakis et al. (2018), Tintelnot (2016)
  - R&D: Bilir and Morales (2020)
  - New- the focus on offshore R&D
- Patterns of FDI and multinational activities
  - Helpman (1984), Markusen (1984), Helpman et al. (2004), Nocke and Yeaple (2008), Head and Ries (2008), Keller and Yeaple (2013), Irarrazabal et al. (2013), Head and Mayer (2019), Wang (2019),
  - New- evidence on both R&D and production, a model that separates the roles of various factors
- Measurement of the GVC
  - Antràs and De Gortari (2020), Johnson and Noguera (2012), Koopman et al. (2014)
  - New- a four-stage GVC within MNCs, disciplined by firm-level data to shed light on the role of offshore R&D in the GVC

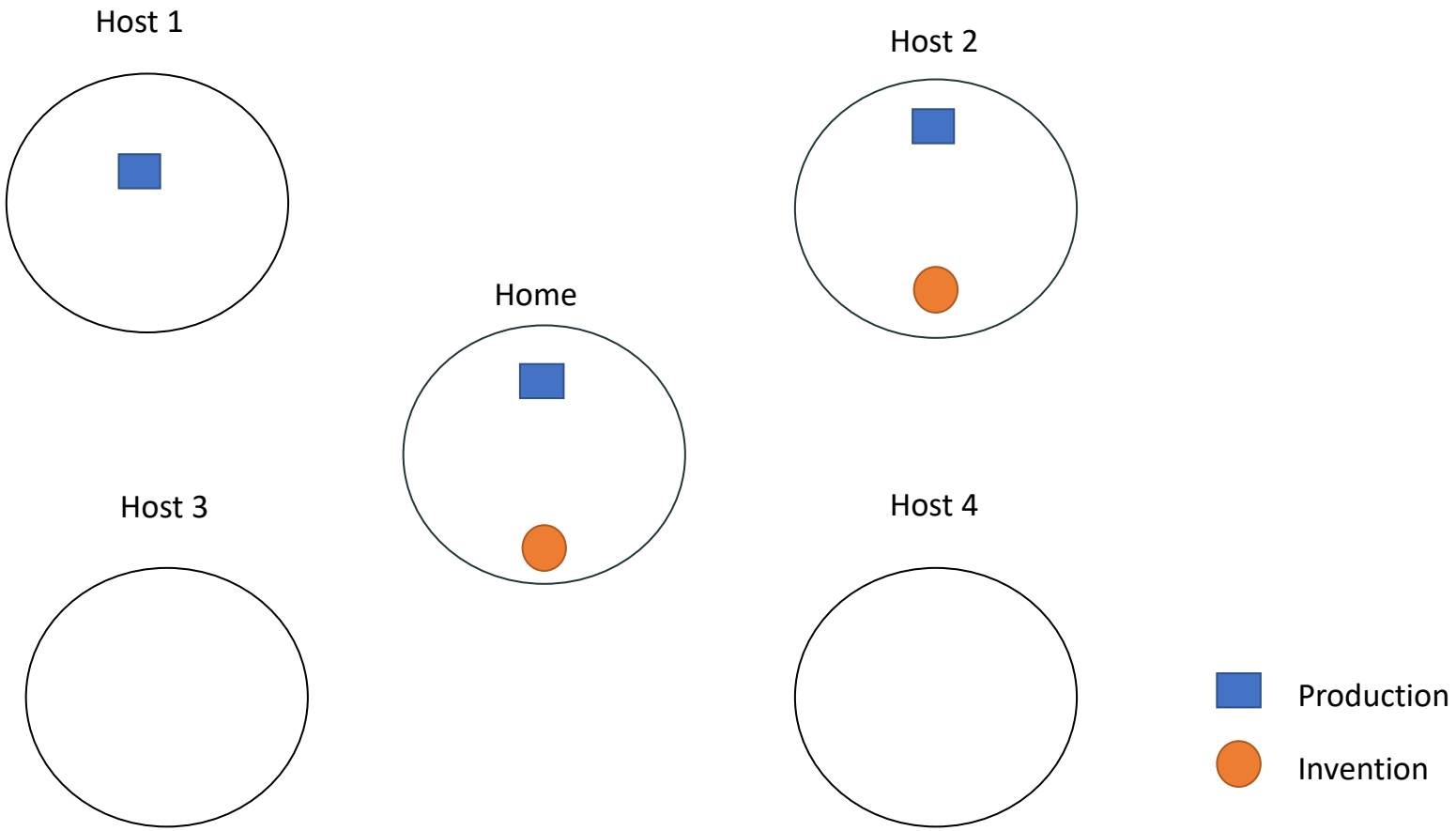
Data

- 37 countries, four periods over 1996-2016
- Production and firm ownership network
  - Historic disk of Orbis, coverage expanded over the years coverage
  - Parent firms defined as the entity with $\geq 50\%$ control of an entity ; aggregate all entities in a country with the same parent and call it an affiliate
- Patent invention by affiliate
  - All PATSTAT patents that can be matched to firms, de-duplicated by family
  - Aggregate by parent firm—inventor country—period
  - Selection into patenting concern $\rightarrow$ absorb systematic forces through firm, industry, host FEs and their combinations; control for other factors
  - Validation: comparison to offshore R&D calculated from expenditures detail

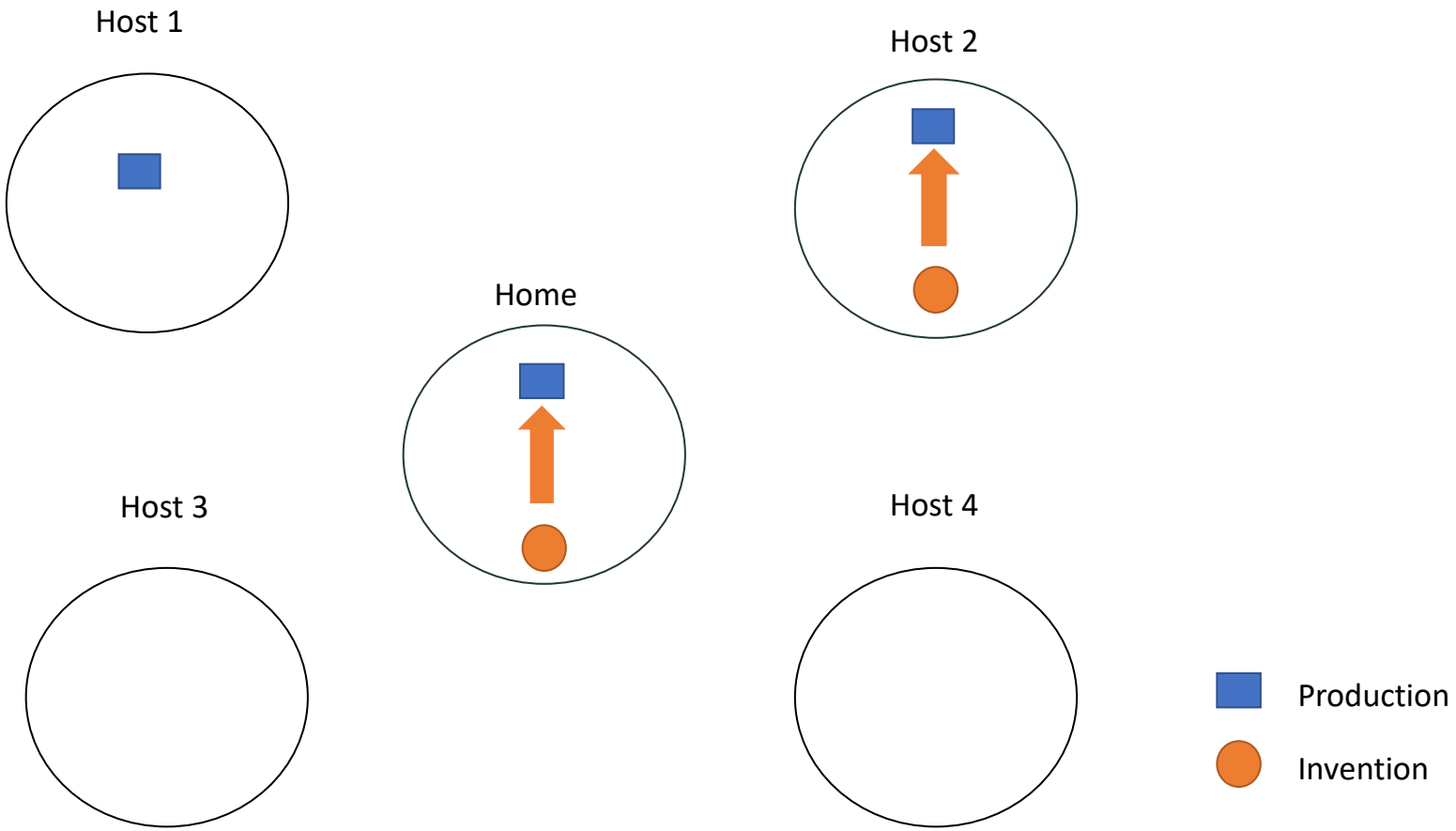
Data Structure



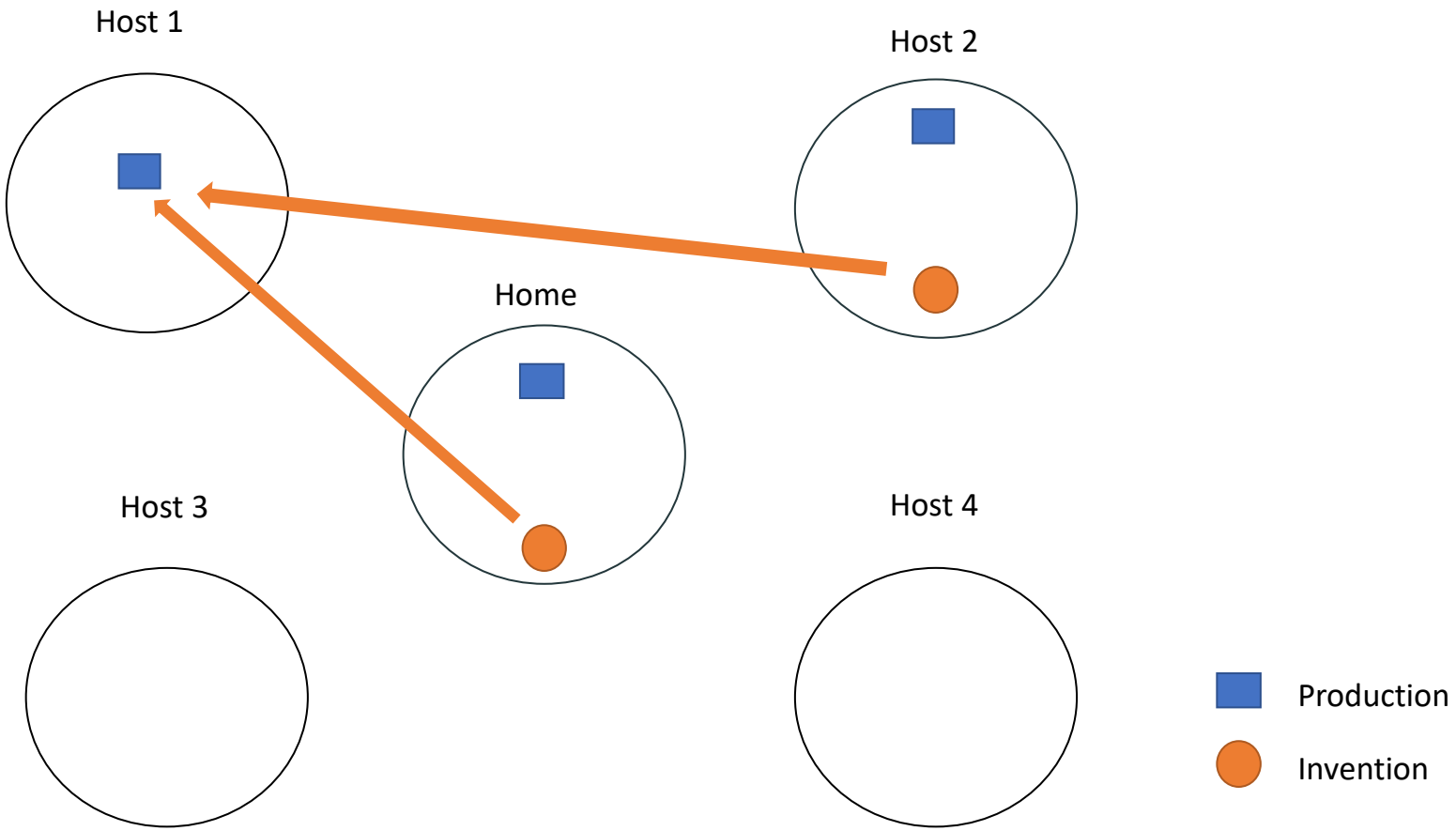
Data Structure



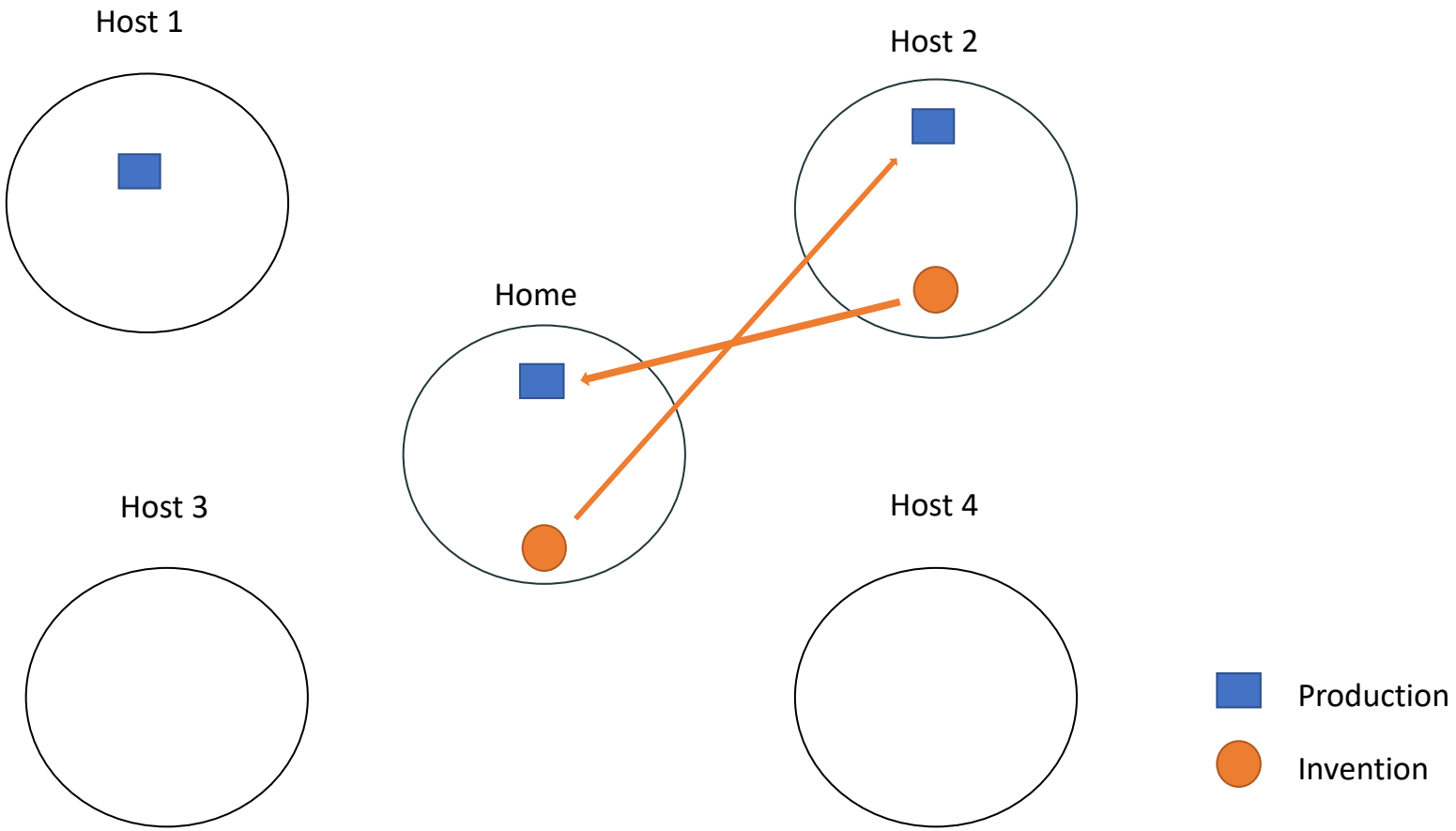
Data Structure



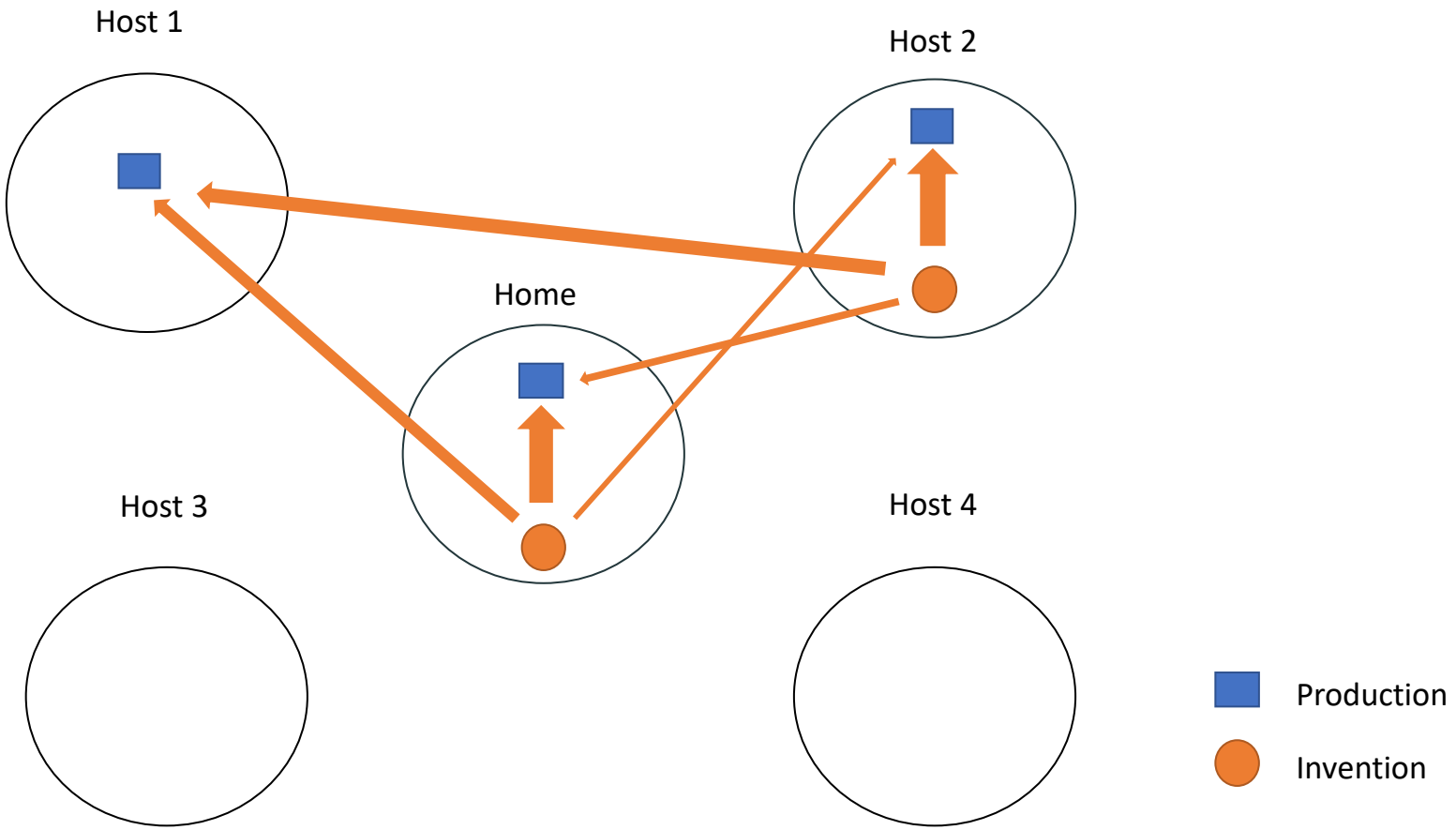
Data Structure



Data Structure



Data Structure



Stylized Facts

1. The role of firm heterogeneity Detail
   - $\uparrow$ headquarters invention $\Longrightarrow$ $\uparrow$ affiliate invention in ext. and int. margins, $\uparrow$ affiliate sales per invention

2. Human capital and affiliate invention intensity Detail
   - $\uparrow$ host human capital $\Longrightarrow$ $\uparrow$ affiliate $\frac{\text{patent}}{\text{sales}}$, in both cross section and over time

3. The colocation of invention and production Detail
   - firms conducting invention in host *i* more likely to produce in *i*
   - true when focusing on the intensive margin & over-time changes

4. The headquarters effect for invention and production Detail
   - both affiliate invention and production decrease in distance to the headquarters

Model: Environment

- N countries
- Country i endowed with L_i workers, with ability drawn from $A_i(\alpha)$
  - A worker with ability α choose to work

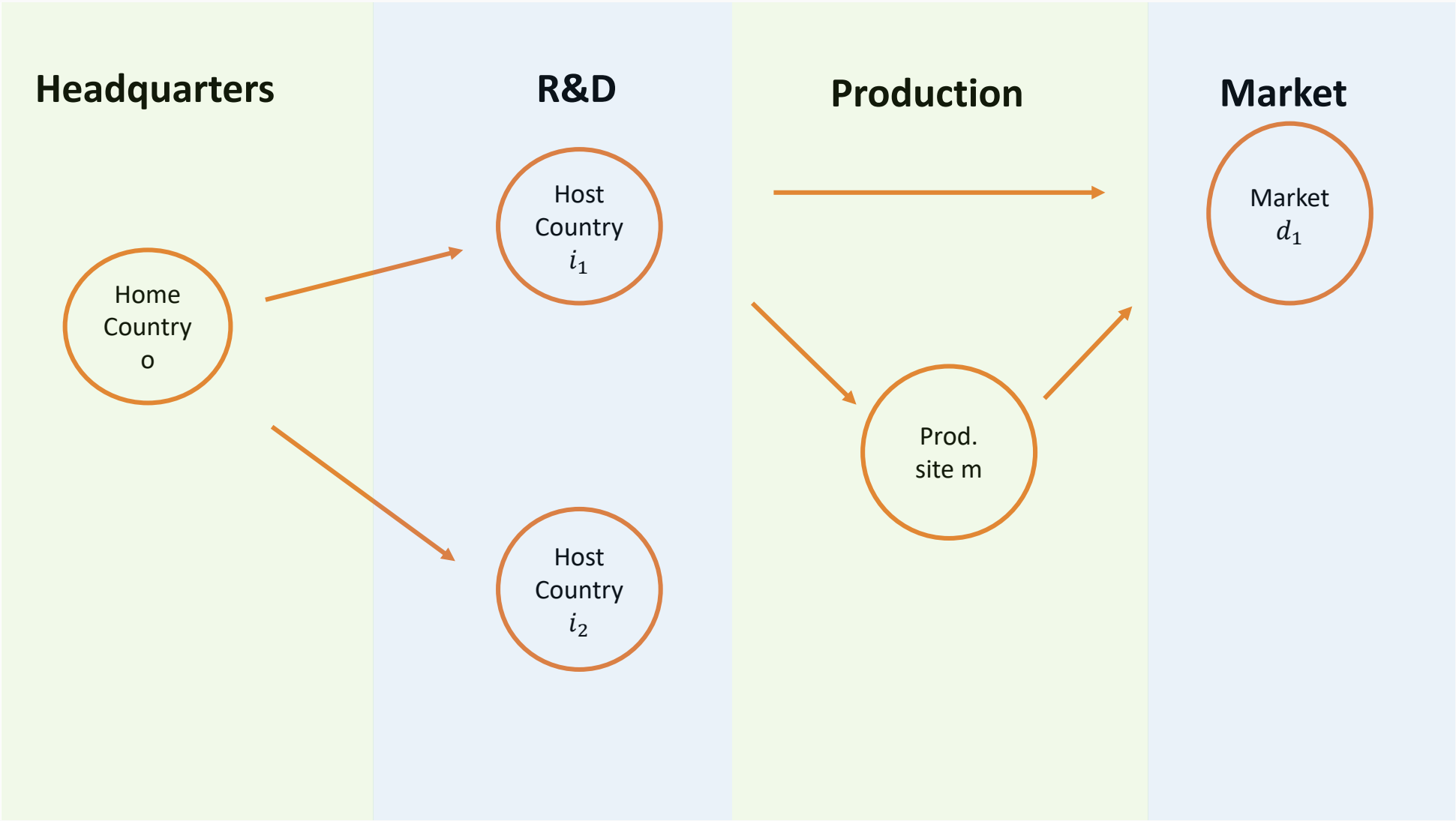
    either in mfg. prod. and earns a common wage W_i^l

    or in a high-skill job and earns $W_i^h \times \alpha$
- E_i measure heterogeneous firms (z^R, z^P): innovate, produce, export
  - z^R: efficiency in working with inventors in R&D
  - z^P: manufacturing productivity
- The representative consumer in i

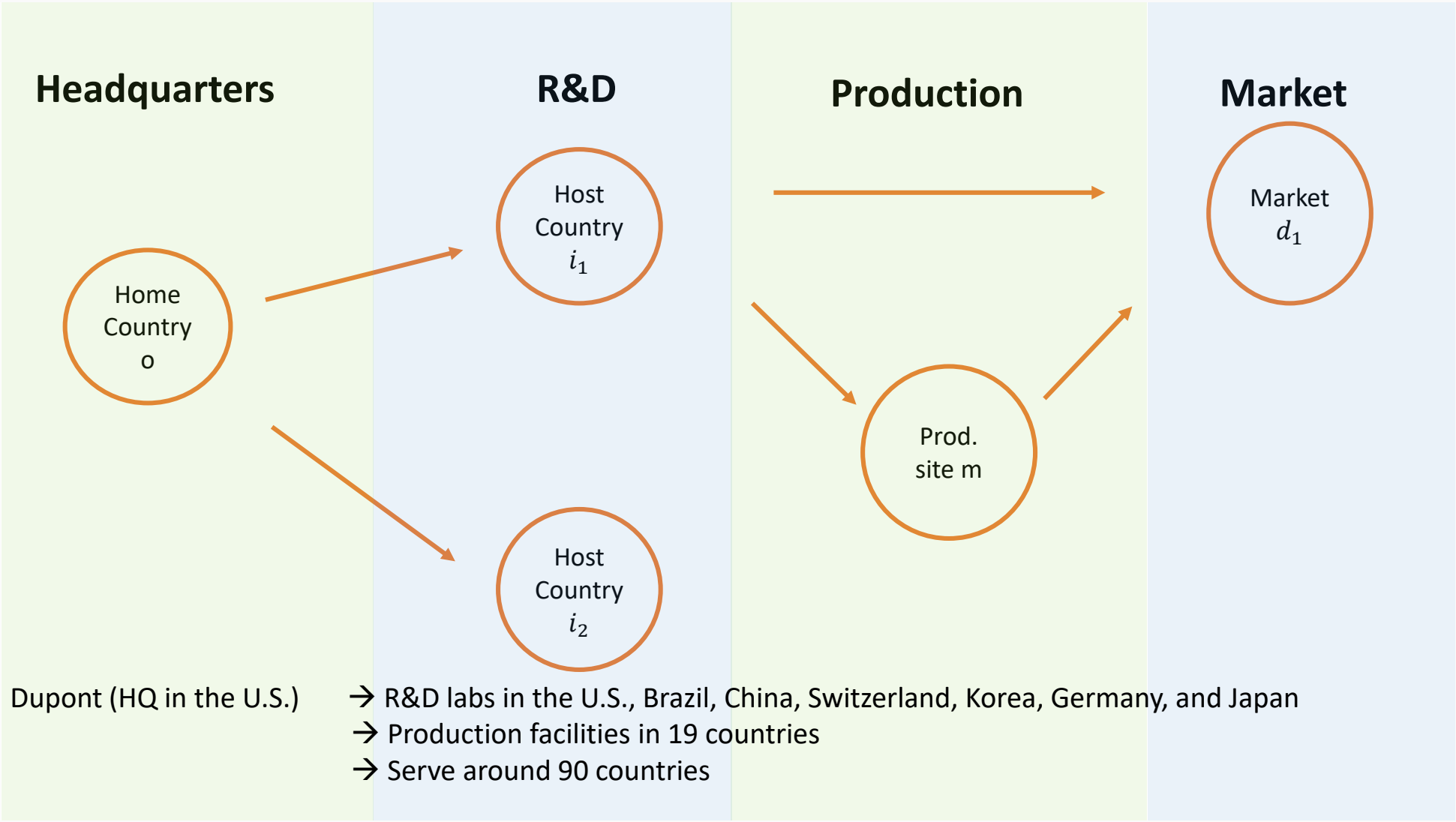
$$\max U_i = \left(\int_{\Omega_i} q(\omega)^{\frac{\sigma-1}{\sigma}} d\omega\right)^{\frac{\sigma}{\sigma-1}},$$

$$s.t. \int_{\Omega_i} p_i(w) q_i(w) d\omega \leq X_i$$

Firm Decision



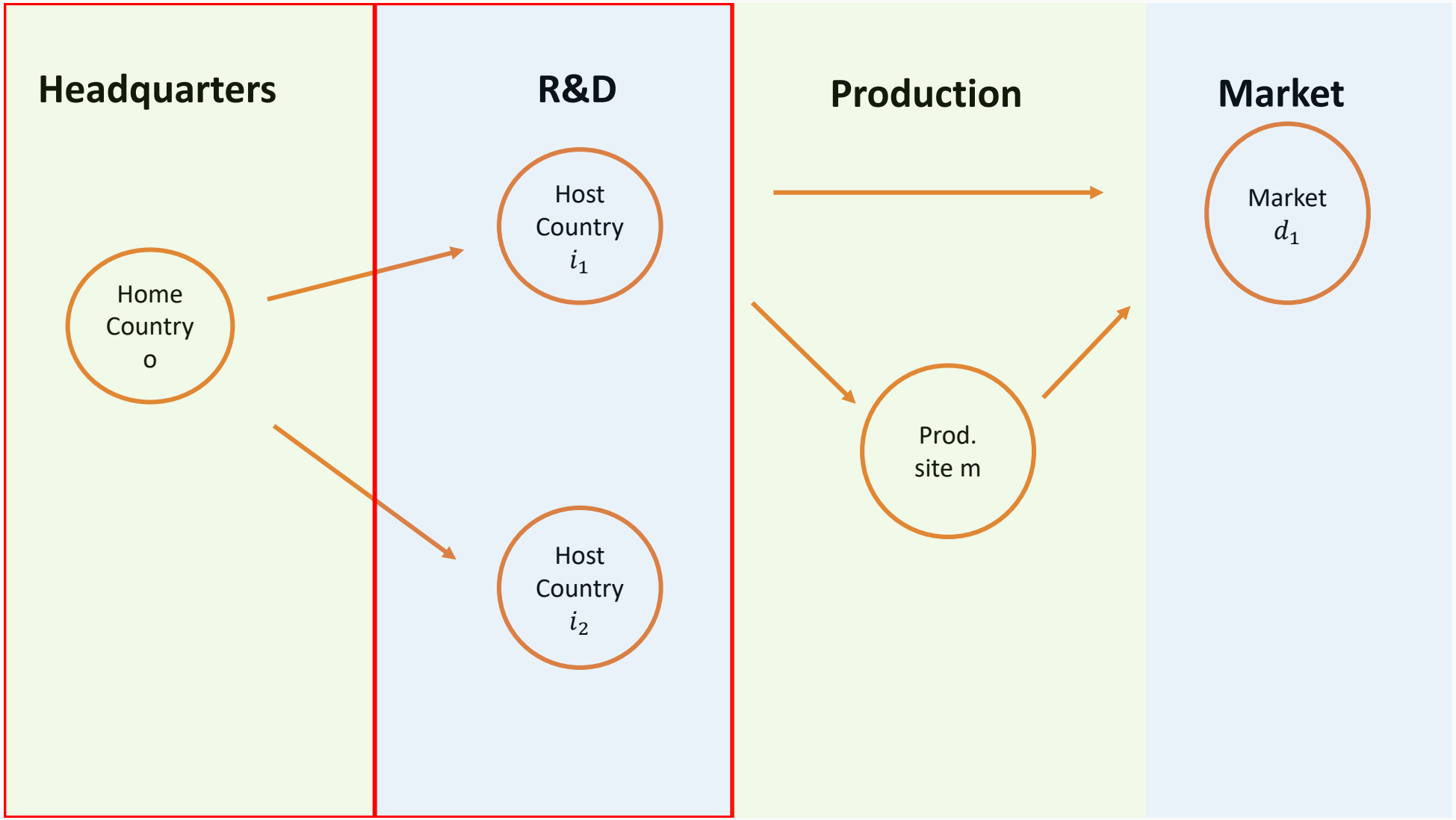
Firm Decision



Dupont (HQ in the U.S.)

→ R&D labs in the U.S., Brazil, China, Switzerland, Korea, Germany, and Japan
→ Production facilities in 19 countries
→ Serve around 90 countries

Firm Decision



Firm Decision

Headquarters

Innovation Efficiency $\tilde{z}^R$

Home Country o

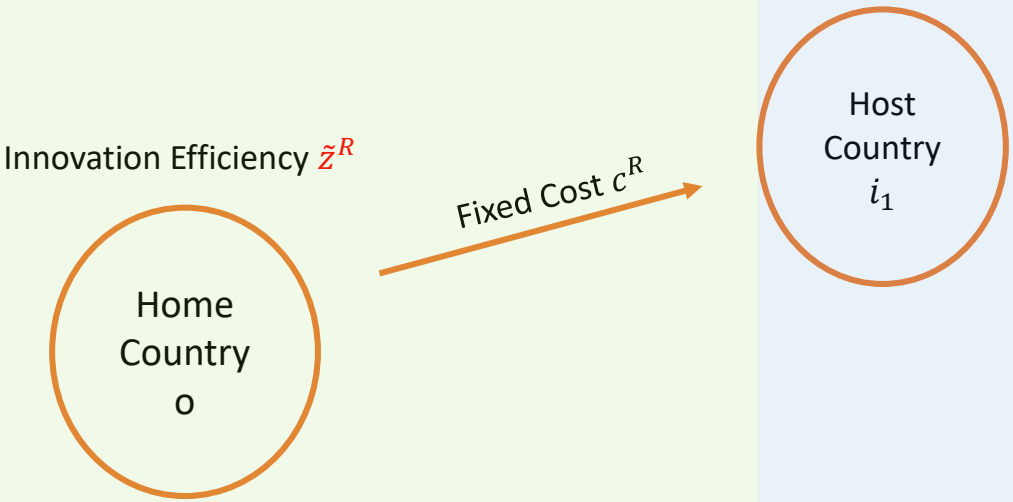
R&D

Host Country i_1

Firm Decision

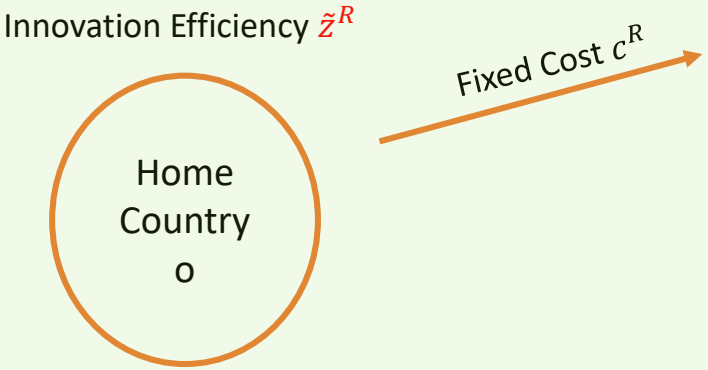
Headquarters

R&D



Firm Decision

Headquarters



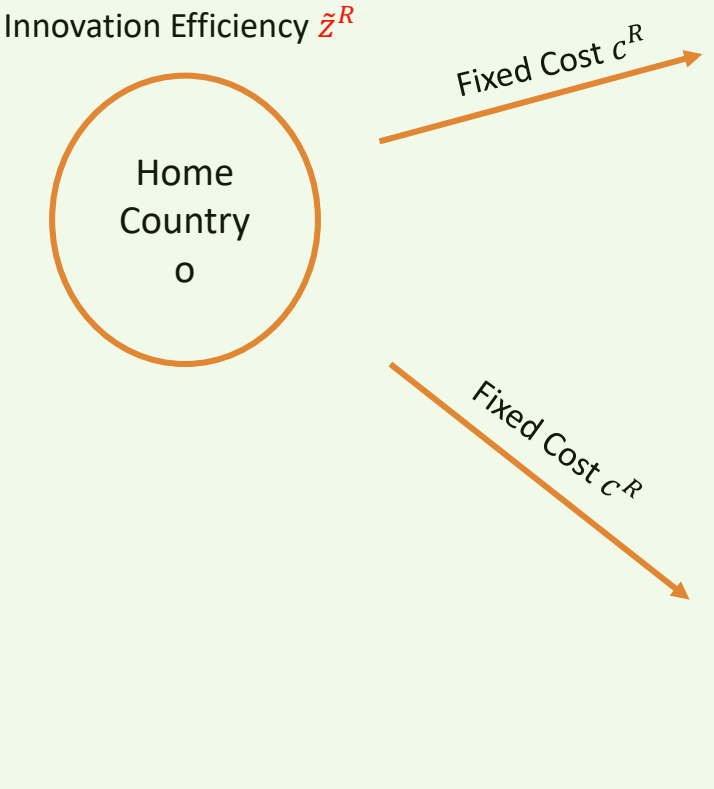
R&D

Retained innovation efficiency: $z^R = \tilde{z}^R \phi^R_{o\,i_1}$

Draw production efficiency z^P from $G^P(z^P|z^R)$

Firm Decision

Headquarters



R&D

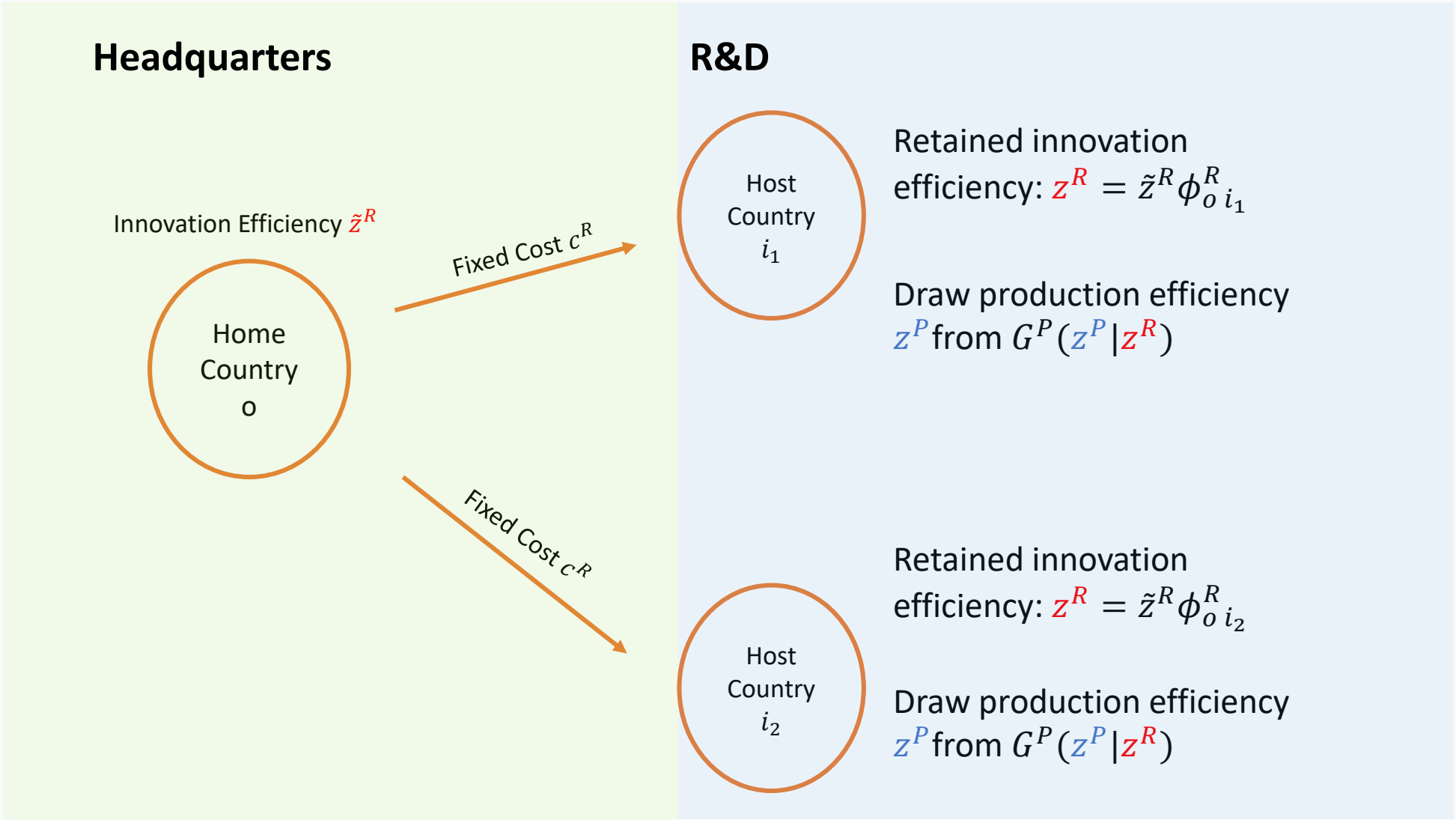
Host Country i_1

Host Country i_2

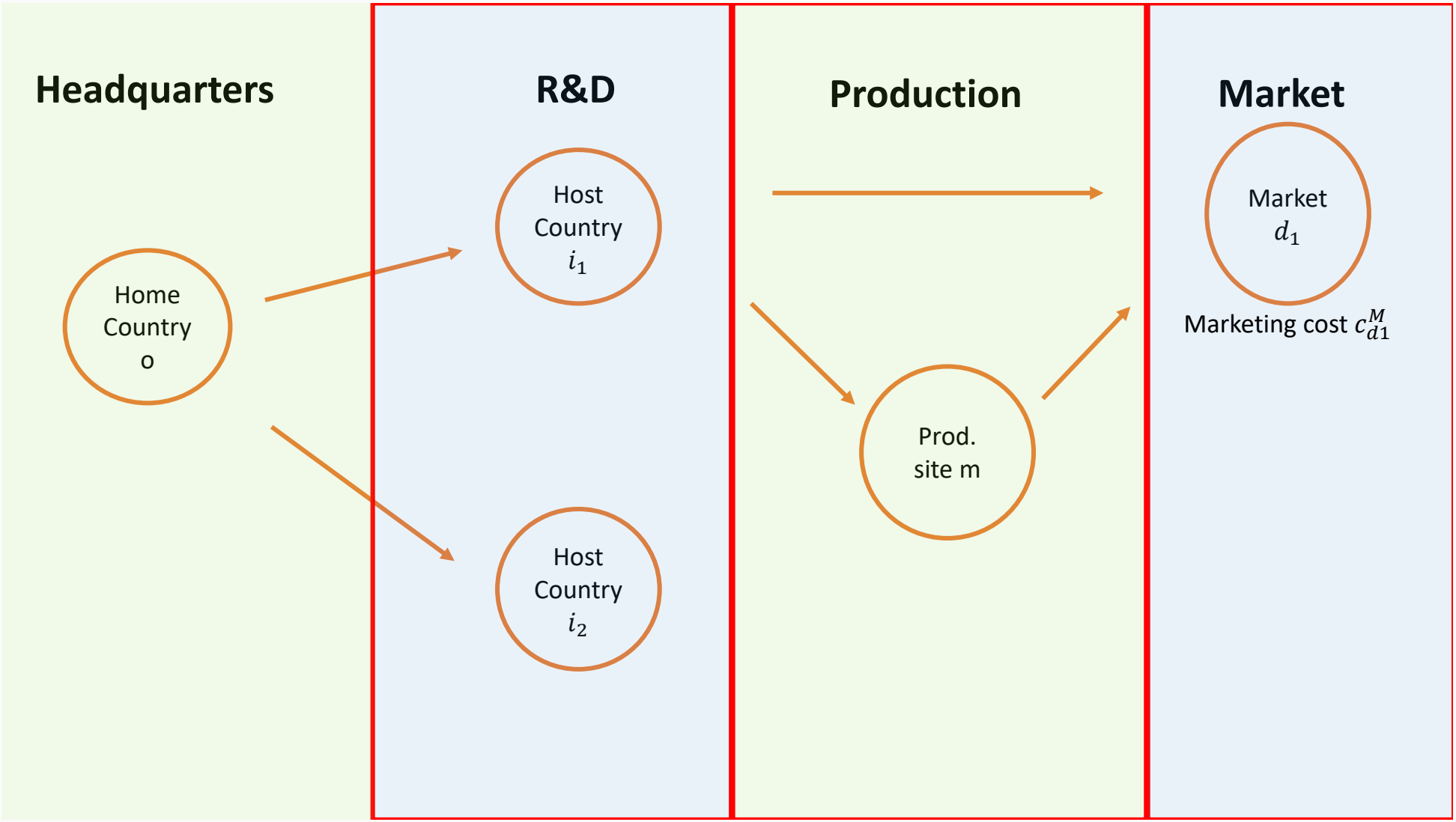
Retained innovation efficiency: $z^R = \tilde{z}^R \phi^R_{o\,i_1}$

Draw production efficiency z^P from $G^P(z^P|z^R)$

Firm Decision



Firm Decision



Firm Decision

R&D

(z^P, z^R)

Production

Market

Firm Decision

R&D

(z^P, z^R)

Host Country i_1

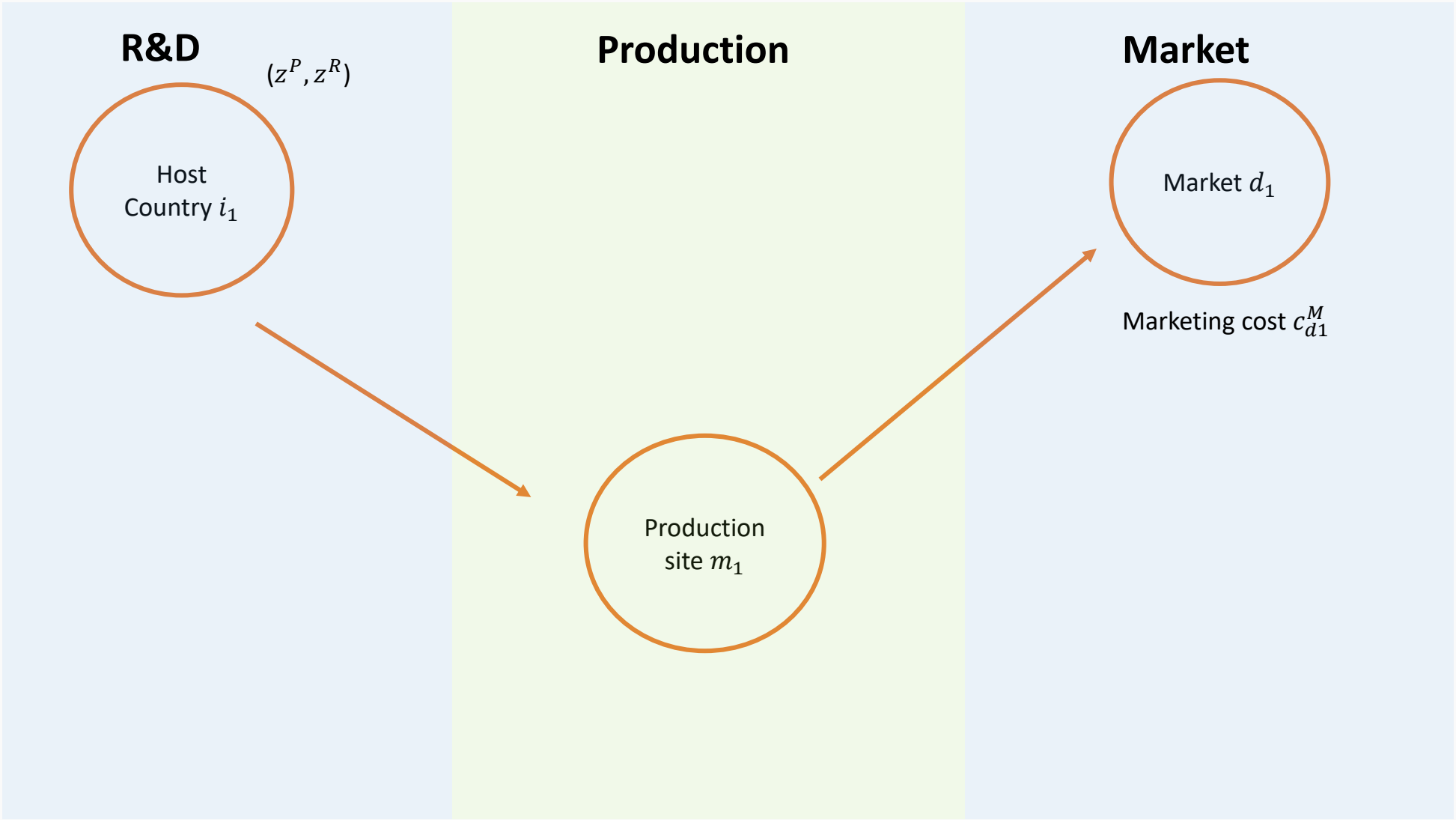
Production

Market

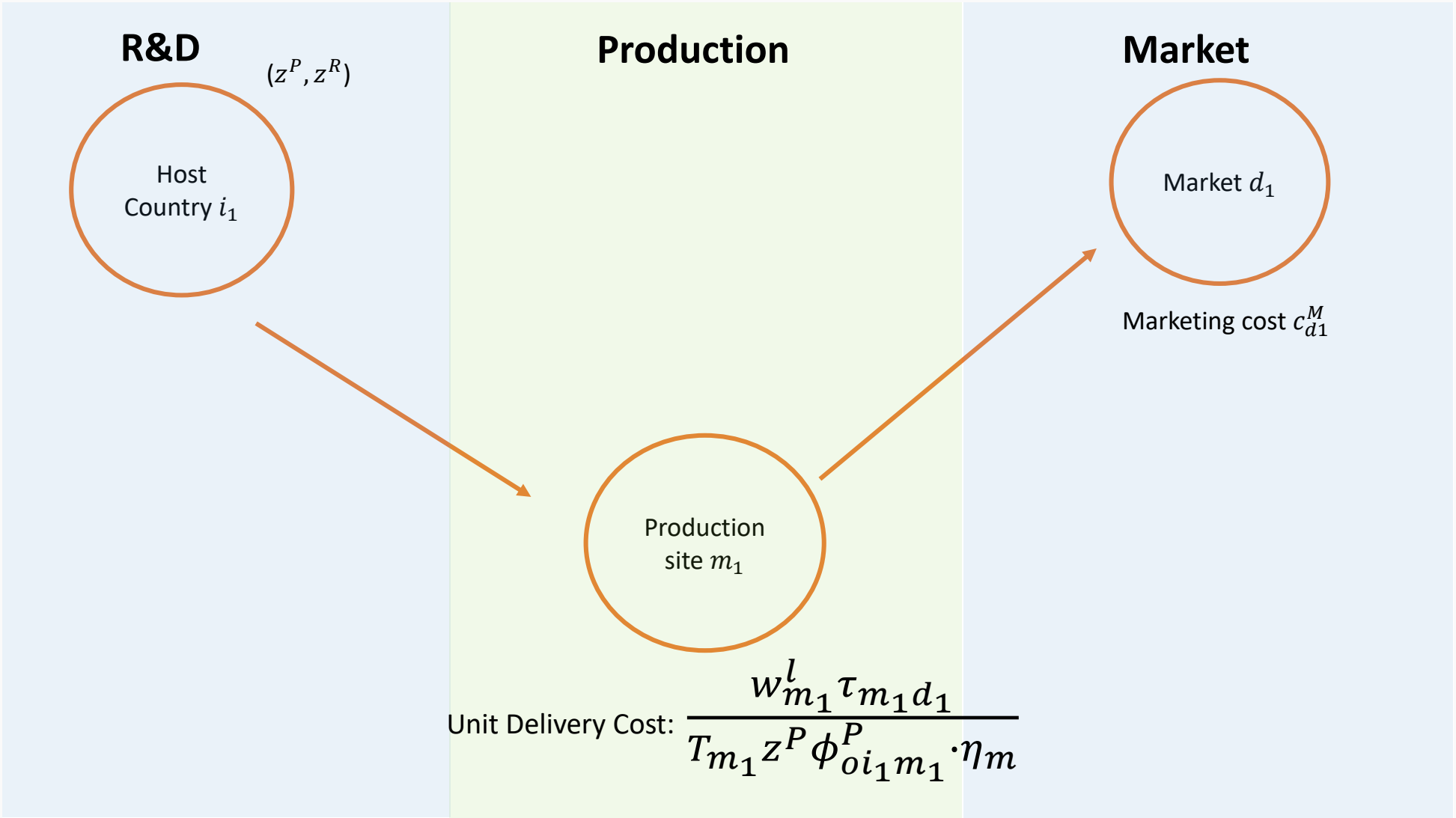
Market d_1

Marketing cost c_{d1}^M

Firm Decision

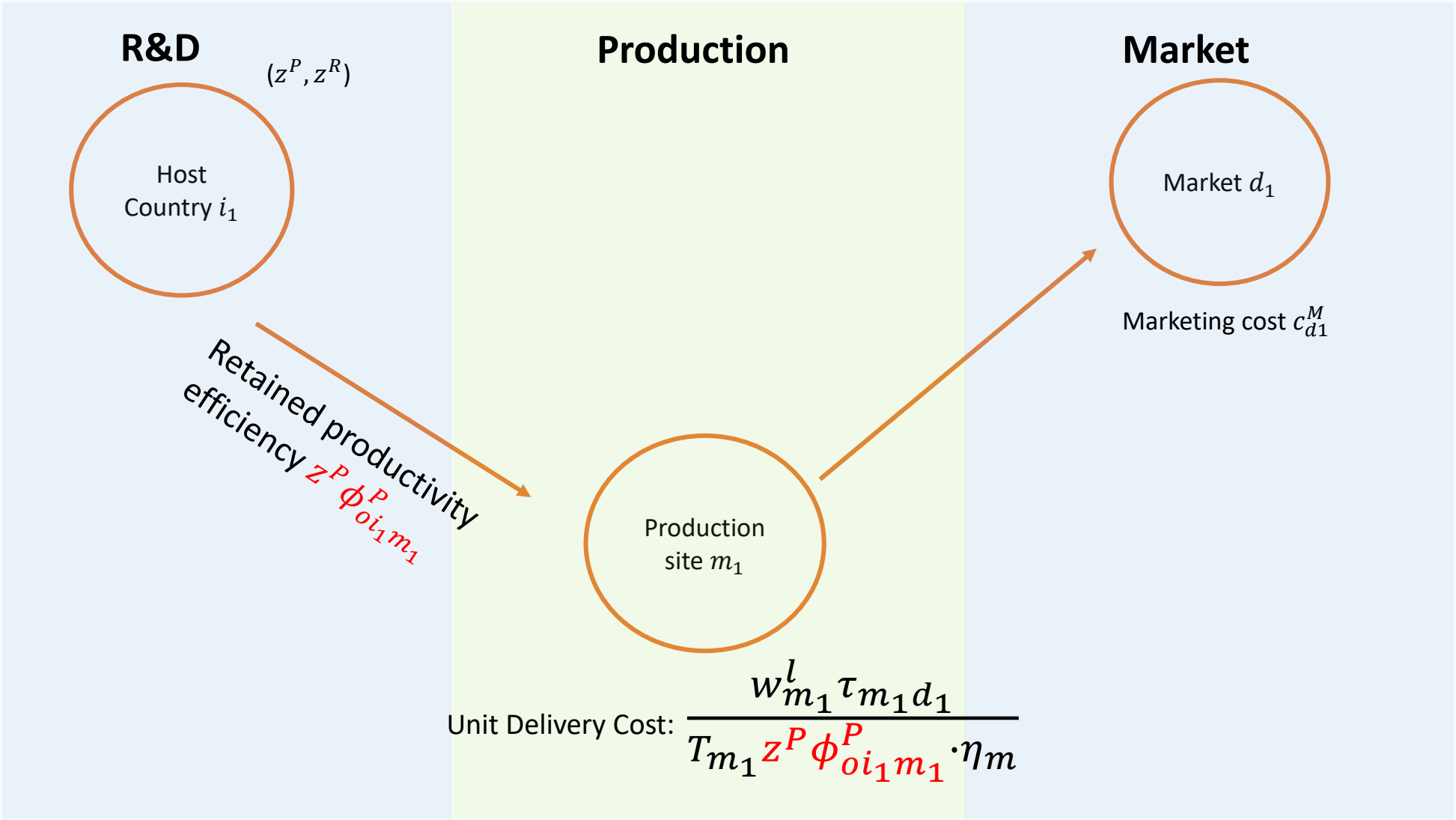


Firm Decision

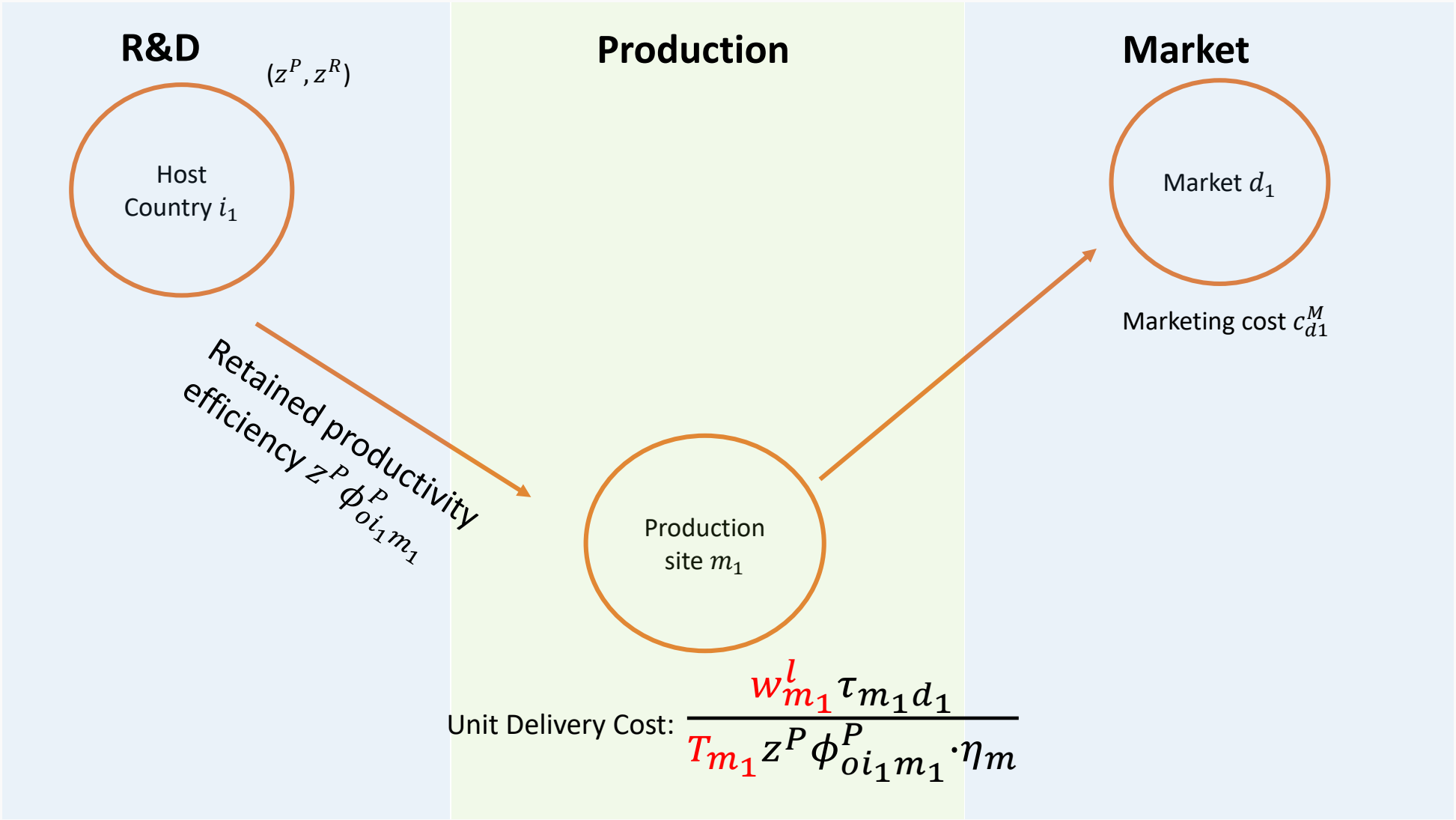


Unit Delivery Cost: $\dfrac{w_{m_1}^l \tau_{m_1 d_1}}{T_{m_1} z^P \phi_{oi_1 m_1}^P \cdot \eta_m}$

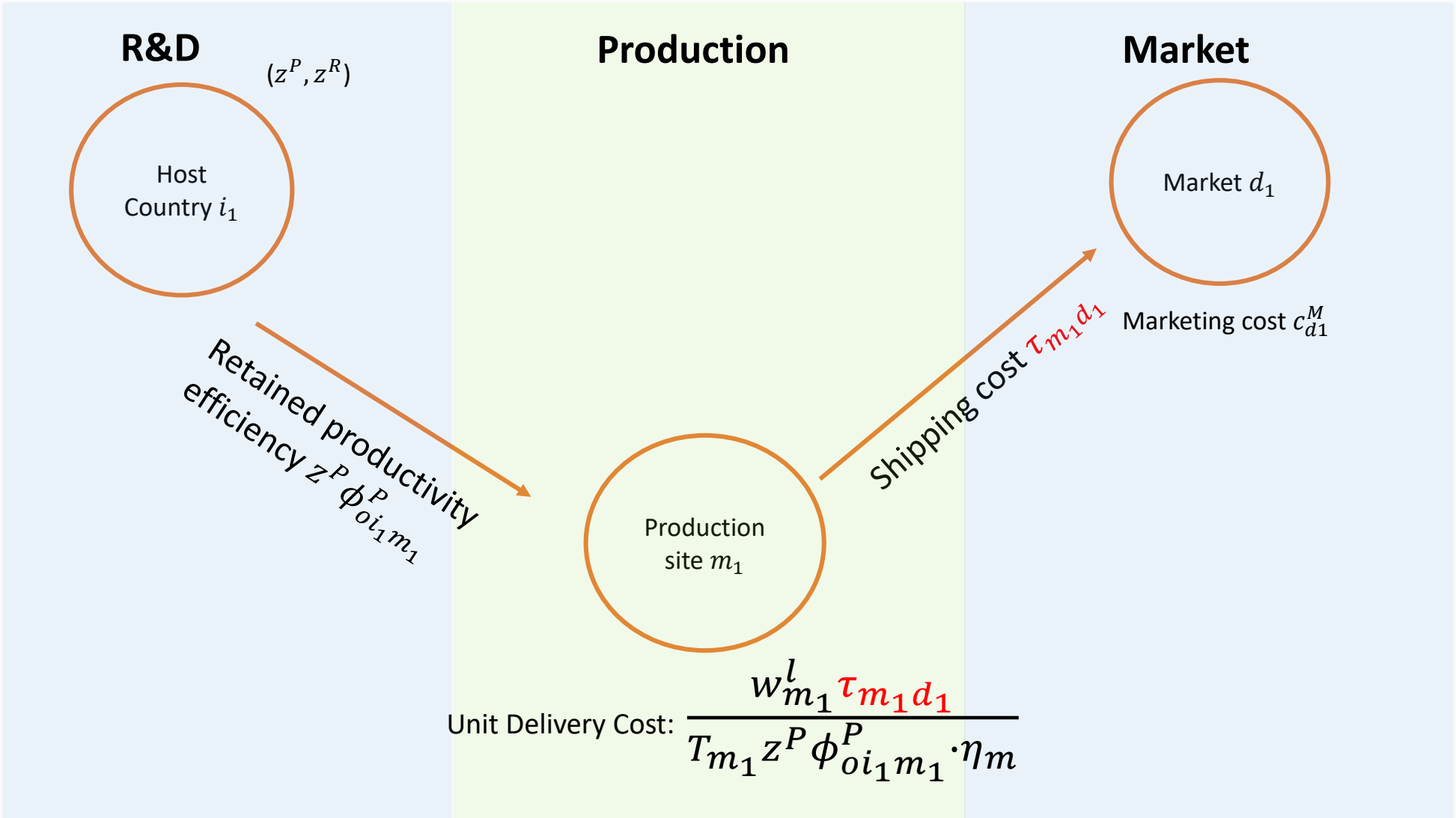
Firm Decision



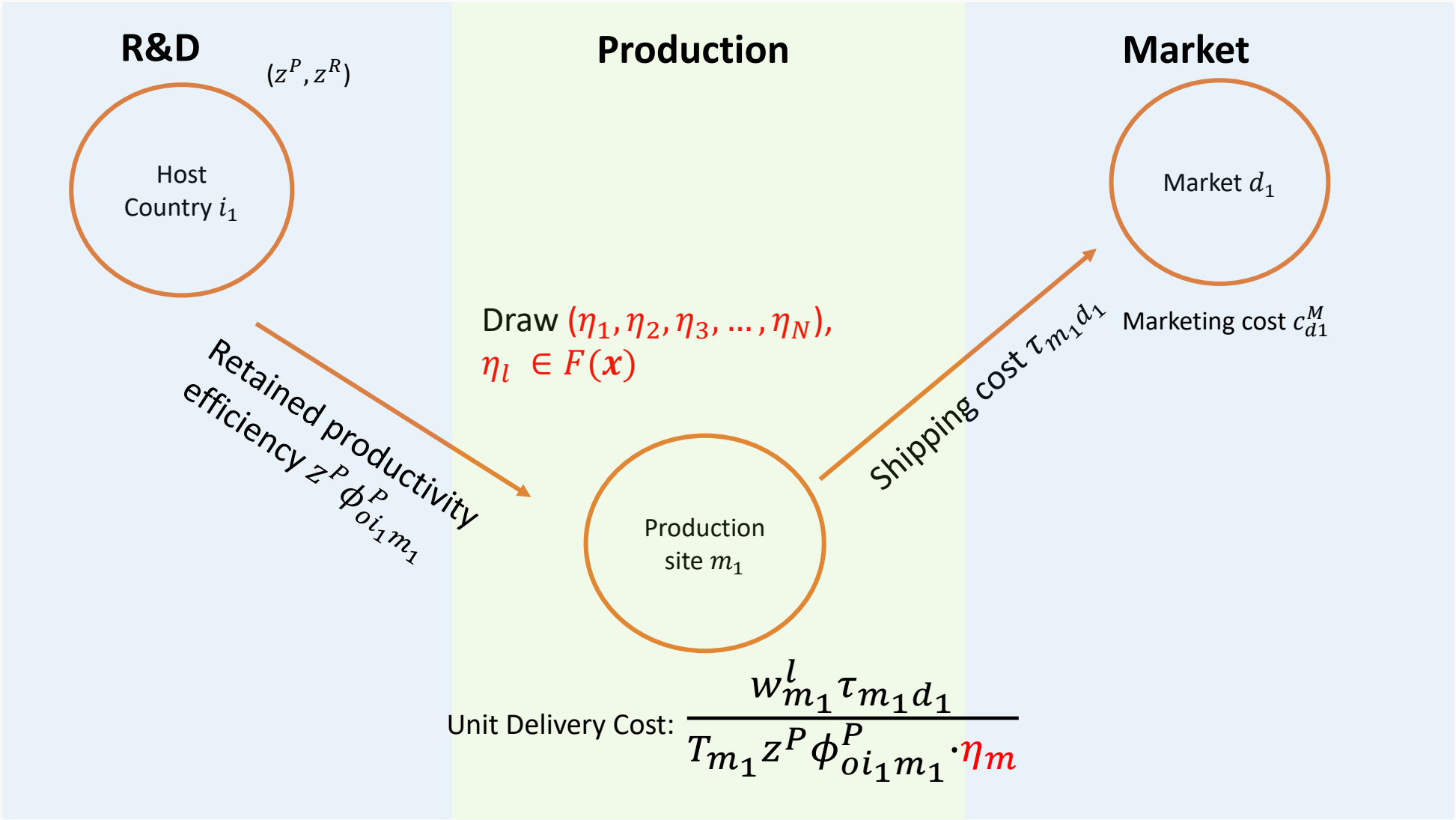
Firm Decision



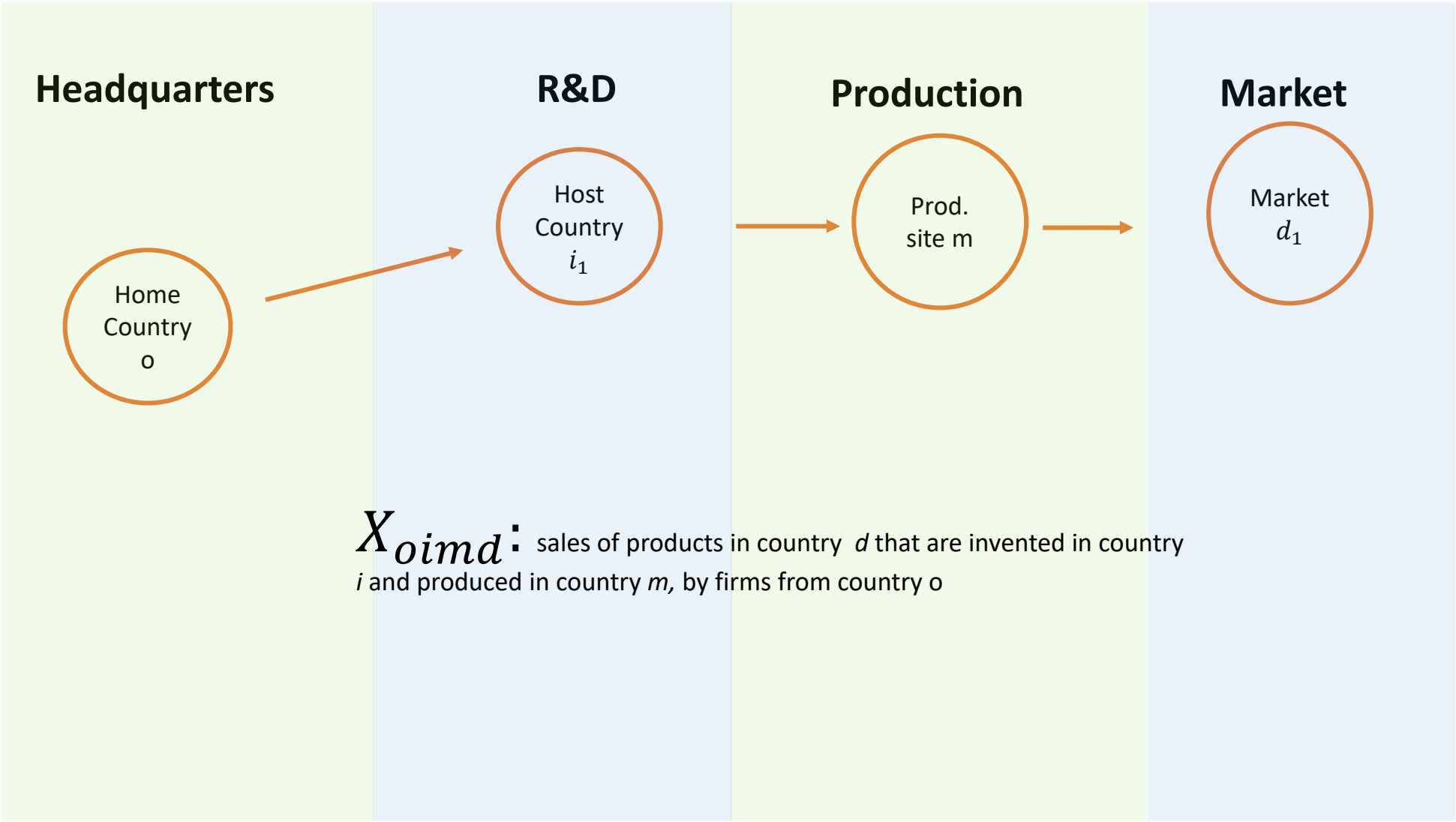
Firm Decision



Firm Decision

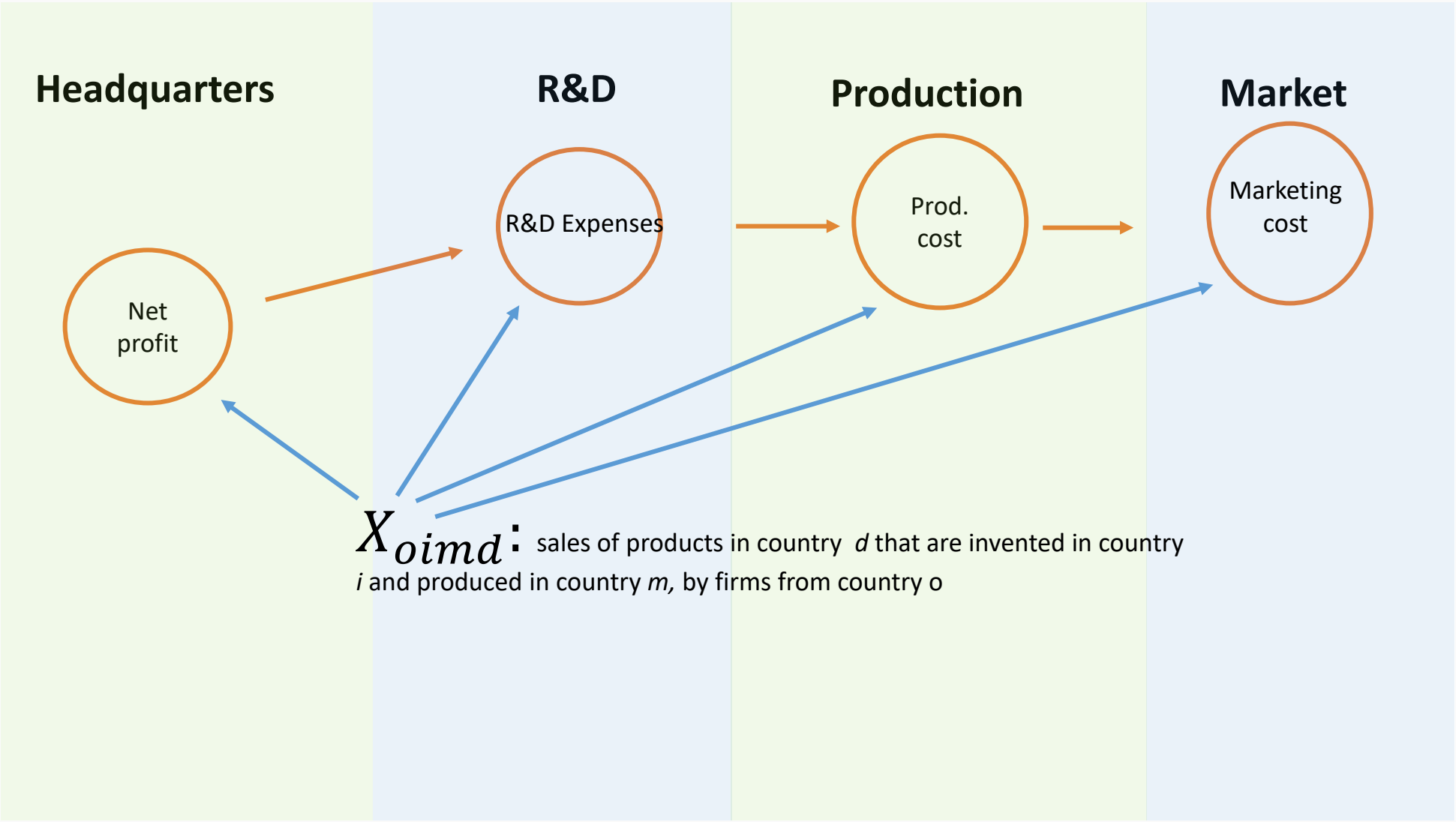


Firm Decision



X_{oimd}: sales of products in country *d* that are invented in country *i* and produced in country *m,* by firms from country o

Firm Decision



X_{oimd}: sales of products in country *d* that are invented in country *i* and produced in country *m,* by firms from country o

Firm Problem: R&D

- Horizontal innovation: output of R&D is new product blueprints/inventions, differentiated from one another
- The production function for inventions: $v = z^R \cdot h^\gamma,\ 0 < \gamma < 1.$
  1. γ: variable R&D expense share of variable profit

Endowment Distribution

- Country size: $L_i \rightarrow$ country i manufacturing employment
- Talent distribution - Hanushek and Woessmann (2012)
  - Based on the PISA score
  - Distribution of cognitive skill tests for each country
- Knowhow distribution - the World Management Survey (Bloom et al., 2012)
  - Production efficiency - averaged over **target**, **operations**, and **monitor** scores
  - Innovation efficiency - **talent** score

Detail

$$\text{Offshore Prod.} \begin{cases} \log(\phi^P_{oim}) = s \cdot \log(\phi^P_{im}) + (1-s) \cdot \log(\phi^P_{om}), \ s \in [0,1], \text{ where} \\ \log(\phi^P_{om}) = \mathbb{1}(o \neq m) \cdot [\phi^P_m + \overrightarrow{\beta^{P,om}} \cdot \overrightarrow{dist_{om}}] \\ \log(\phi^P_{im}) = \mathbb{1}(i \neq m) \cdot [\phi^P_m + \overrightarrow{\beta^{P,im}} \cdot \overrightarrow{dist_{im}}] \end{cases}$$

$$\text{Offshore R\&D} \begin{cases} \log(\phi^R_{oi}) = \mathbb{1}(o \neq i) \cdot [\phi^R_i + \overrightarrow{\beta^R} \cdot \overrightarrow{dist_{oi}}] \\ c^R_{oi} = \mathbb{1}(o \neq i) \cdot \exp\left(\phi^{cR}_i + \overrightarrow{\beta^{cR}} \cdot \overrightarrow{dist_{oi}}\right) \end{cases}$$

- ϕ^P_m ϕ^R_i ϕ^{cR}_i: overall openness measure of a host to foreign production, R&D (intensive and extensive margins)
- s $\overrightarrow{\beta^{P,om}}$ $\overrightarrow{\beta^{P,im}}$ $\overrightarrow{\beta^R}$ $\overrightarrow{\beta^{cR}}$: coefficients from regressions for the headquarters effects and colocation $\Longrightarrow$ s=0.8

$$\text{Offshore Prod.} \begin{cases} \log(\phi^P_{oim}) = s \cdot \log(\phi^P_{im}) + (1-s) \cdot \log(\phi^P_{om}), \ s \in [0,1], \text{ where} \\ \log(\phi^P_{om}) = \mathbb{1}(o \neq m) \cdot [\phi^P_m + \overrightarrow{\beta^{P,om}} \cdot \overrightarrow{dist_{om}}] \\ \log(\phi^P_{im}) = \mathbb{1}(i \neq m) \cdot [\phi^P_m + \overrightarrow{\beta^{P,im}} \cdot \overrightarrow{dist_{im}}] \end{cases}$$

$$\text{Offshore R\&D} \begin{cases} \log(\phi^R_{oi}) = \mathbb{1}(o \neq i) \cdot [\phi^R_i + \overrightarrow{\beta^R} \cdot \overrightarrow{dist_{oi}}] \\ c^R_{oi} = \mathbb{1}(o \neq i) \cdot \exp\left(\phi^{cR}_i + \overrightarrow{\beta^{cR}} \cdot \overrightarrow{dist_{oi}}\right) \end{cases}$$

- ϕ^P_m ϕ^R_i ϕ^{cR}_i: overall openness measure of a host to foreign production, R&D (intensive and extensive margins)
- s $\overrightarrow{\beta^{P,om}}$ $\overrightarrow{\beta^{P,im}}$ $\overrightarrow{\beta^R}$ $\overrightarrow{\beta^{cR}}$: coefficients from regressions for the headquarters effects and colocation $\Longrightarrow$ s=0.8

$$\text{Offshore Prod.} \begin{cases} \log(\phi^P_{oim}) = s \cdot \log(\phi^P_{im}) + (1-s) \cdot \log(\phi^P_{om}), \ s \in [0,1], \ \text{where} \\ \log(\phi^P_{om}) = \mathbb{1}(o \neq m) \cdot [\phi^P_m + \overrightarrow{\beta^{P,om}} \cdot \overrightarrow{dist_{om}}] \\ \log(\phi^P_{im}) = \mathbb{1}(i \neq m) \cdot [\phi^P_m + \overrightarrow{\beta^{P,im}} \cdot \overrightarrow{dist_{im}}] \end{cases}$$

$$\text{Offshore R\&D} \begin{cases} \log(\phi^R_{oi}) = \mathbb{1}(o \neq i) \cdot [\phi^R_i + \overrightarrow{\beta^R} \cdot \overrightarrow{dist_{oi}}] \\ c^R_{oi} = \mathbb{1}(o \neq i) \cdot \exp\left(\phi^{cR}_i + \overrightarrow{\beta^{cR}} \cdot \overrightarrow{dist_{oi}}\right) \end{cases}$$

- ϕ^P_m ϕ^R_i ϕ^{cR}_i: overall openness measure of a host to foreign production, R&D (intensive and extensive margins)
- s $\overrightarrow{\beta^{P,om}}$ $\overrightarrow{\beta^{P,im}}$ $\overrightarrow{\beta^R}$ $\overrightarrow{\beta^{cR}}$: coefficients from regressions for the headquarters effects and colocation $\Longrightarrow$ s=0.8

Model Validation

Table 1: Fit of Non-targeted Moments

Additional moments on firm size in U.S.	**Model**	**Data**
Fraction of firms with emp. < 10	0.91	0.90
Share of emp. in firms with emp. > 500	0.611	0.47
Share of R&D by parents of MNCs	0.84	0.79
The efficiency advantage of foreign affiliates		
Foreign affiliate advantage	0.21	0.15
coefficient of variation across countries	1.272	1.158
correlation with host log GDP per capita	-0.11	-0.25
Entry into Offshore R&D		
% of firms with R&D centers in 1 country	93.5	95.3
2 countries	1.9	2.7
3 countries	0.7	0.6
4 countries	0.6	0.3
5 countries	0.3	0.3
≥ 6 countries	3.0	0.7

- Also fits bilateral R&D and production shares, and occupation choice well Detail

The I-O of offshore R&D

	Source and use of R&D				Source of income (% of total income)				
	% by domestic firms		% by foreign firms		mfg.	profit		R&D	mkt.
Country		% of local prod.		% of local prod.		total	inventions abroad		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RUS	88.4	91.7	11.6	81.6	79.1	9.4	0.06	3.2	8.3
BRA	42.4	97.4	57.6	84.1	76.6	10.6	0.01	4.5	8.3
CHN	58.5	95.0	41.5	74.3	76.7	10.2	0.00	4.8	8.3
MEX	45.0	98.9	55.0	94.7	76.9	10.7	0.01	4.1	8.3
TUR	79.9	97.9	20.1	89.3	75.4	12.0	0.00	4.2	8.3
...									
DEU	71.8	70.5	28.2	59.4	76.9	11.2	1.69	3.6	8.3
FRA	73.4	71.0	26.6	55.8	76.4	11.6	1.39	3.7	8.3
GBR	37.0	46.8	63.0	39.0	83.9	5.4	1.99	2.4	8.3
BEL	41.1	63.6	58.9	45.9	85.0	4.6	0.72	2.0	8.3
USA	84.2	67.6	15.8	58.3	66.0	20.8	7.65	4.9	8.3
Mean	65.6	82.9	34.4	69.5	78.3	10.0	1.5	3.4	8.3

The I-O of offshore R&D

	Source and use of R&D				Source of income (% of total income)				
	% by domestic firms		% by foreign firms		mfg.	profit		R&D	mkt.
Country		% of local prod.		% of local prod.		total	inventions abroad		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RUS	88.4	91.7	11.6	81.6	79.1	9.4	0.06	3.2	8.3
BRA	42.4	97.4	57.6	84.1	76.6	10.6	0.01	4.5	8.3
CHN	58.5	95.0	41.5	74.3	76.7	10.2	0.00	4.8	8.3
MEX	45.0	98.9	55.0	94.7	76.9	10.7	0.01	4.1	8.3
TUR	79.9	97.9	20.1	89.3	75.4	12.0	0.00	4.2	8.3
...									
DEU	71.8	70.5	28.2	59.4	76.9	11.2	1.69	3.6	8.3
FRA	73.4	71.0	26.6	55.8	76.4	11.6	1.39	3.7	8.3
GBR	37.0	46.8	63.0	39.0	83.9	5.4	1.99	2.4	8.3
BEL	41.1	63.6	58.9	45.9	85.0	4.6	0.72	2.0	8.3
USA	84.2	67.6	15.8	58.3	66.0	20.8	7.65	4.9	8.3
Mean	65.6	82.9	34.4	69.5	78.3	10.0	1.5	3.4	8.3

- Column 2: % of local firm R&D devoted to local production; Column 4: % of R&D by foreign affiliates devoted to local production
- local production averages 70%, higher in countries with low manufacturing cost

The I-O of offshore R&D

	Source and use of R&D				Source of income (% of total income)				
	% by domestic firms		% by foreign firms		mfg.	profit		R&D	mkt.
Country		% of local prod.		% of local prod.		total	inventions abroad		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RUS	88.4	91.7	11.6	81.6	79.1	9.4	0.06	3.2	8.3
BRA	42.4	97.4	57.6	84.1	76.6	10.6	0.01	4.5	8.3
CHN	58.5	95.0	41.5	74.3	76.7	10.2	0.00	4.8	8.3
MEX	45.0	98.9	55.0	94.7	76.9	10.7	0.01	4.1	8.3
TUR	79.9	97.9	20.1	89.3	75.4	12.0	0.00	4.2	8.3
...									
DEU	71.8	70.5	28.2	59.4	76.9	11.2	1.69	3.6	8.3
FRA	73.4	71.0	26.6	55.8	76.4	11.6	1.39	3.7	8.3
GBR	37.0	46.8	63.0	39.0	83.9	5.4	1.99	2.4	8.3
BEL	41.1	63.6	58.9	45.9	85.0	4.6	0.72	2.0	8.3
USA	84.2	67.6	15.8	58.3	66.0	20.8	7.65	4.9	8.3
Mean	65.6	82.9	34.4	69.5	78.3	10.0	1.5	3.4	8.3

Implications: 'spillovers' of offshore R&D policies on offshore production and vice versa

The I-O of offshore R&D

Country	Source and use of R&D				Source of income (% of total income)				
	% by domestic firms		% by foreign firms		mfg.	profit		R&D	mkt.
		% of local prod.		% of local prod.		total	inventions abroad		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RUS	88.4	91.7	11.6	81.6	79.1	9.4	0.06	3.2	8.3
BRA	42.4	97.4	57.6	84.1	76.6	10.6	0.01	4.5	8.3
CHN	58.5	95.0	41.5	74.3	76.7	10.2	0.00	4.8	8.3
MEX	45.0	98.9	55.0	94.7	76.9	10.7	0.01	4.1	8.3
TUR	79.9	97.9	20.1	89.3	75.4	12.0	0.00	4.2	8.3
...									
DEU	71.8	70.5	28.2	59.4	76.9	11.2	1.69	3.6	8.3
FRA	73.4	71.0	26.6	55.8	76.4	11.6	1.39	3.7	8.3
GBR	37.0	46.8	63.0	39.0	83.9	5.4	1.99	2.4	8.3
BEL	41.1	63.6	58.9	45.9	85.0	4.6	0.72	2.0	8.3
USA	84.2	67.6	15.8	58.3	66.0	20.8	7.65	4.9	8.3
Mean	65.6	82.9	34.4	69.5	78.3	10.0	1.5	3.4	8.3

- Column 6: profit share of total income; Column 7: offshore R&D profit share of total income
- Average value of Column 7 is 1.5%, highly heterogeneous across countries

The I-O of offshore R&D

Country	Source and use of R&D				Source of income (% of total income)				
	% by domestic firms		% by foreign firms		mfg.	profit		R&D	mkt.
		% of local prod.		% of local prod.		total	inventions abroad		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
RUS	88.4	91.7	11.6	81.6	79.1	9.4	0.06	3.2	8.3
BRA	42.4	97.4	57.6	84.1	76.6	10.6	0.01	4.5	8.3
CHN	58.5	95.0	41.5	74.3	76.7	10.2	0.00	4.8	8.3
MEX	45.0	98.9	55.0	94.7	76.9	10.7	0.01	4.1	8.3
TUR	79.9	97.9	20.1	89.3	75.4	12.0	0.00	4.2	8.3
...									
DEU	71.8	70.5	28.2	59.4	76.9	11.2	1.69	3.6	8.3
FRA	73.4	71.0	26.6	55.8	76.4	11.6	1.39	3.7	8.3
GBR	37.0	46.8	63.0	39.0	83.9	5.4	1.99	2.4	8.3
BEL	41.1	63.6	58.9	45.9	85.0	4.6	0.72	2.0	8.3
USA	84.2	67.6	15.8	58.3	66.0	20.8	7.65	4.9	8.3
Mean	65.6	82.9	34.4	69.5	78.3	10.0	1.5	3.4	8.3

Implications: for measuring the intangible wealth of nations; for evaluating policies affecting return to R&D in foreign countries

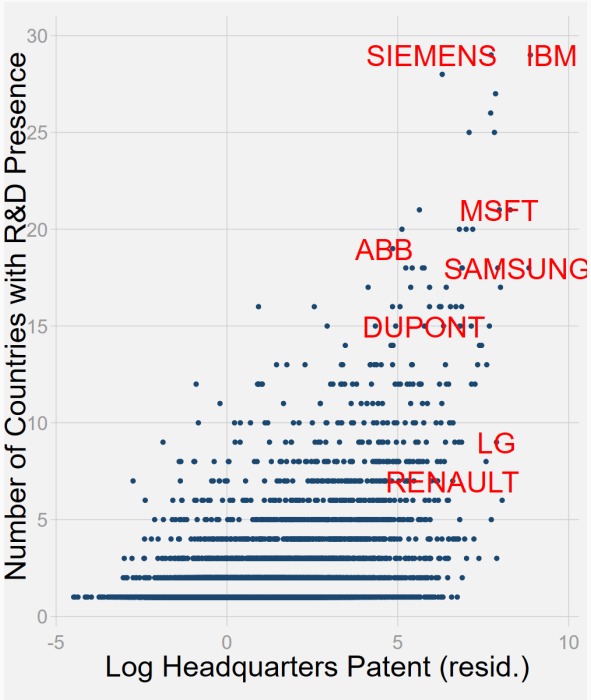
Summary of Counterfactual Experiments

- Offshore R&D generates around 3.3% gains on average, larger for developed countries (9% for the U.S.)
  - Amplifies the gains from openness by a factor of 1.3
  - It is substitutes to trade and offshore production for developing countries and complement for developed countries
  - Using micro-data to discipline the model is important
- GE effect+ firm linkages $\Longrightarrow$ incorporating offshore R&D is crucial when evaluating trade and offshore production policies

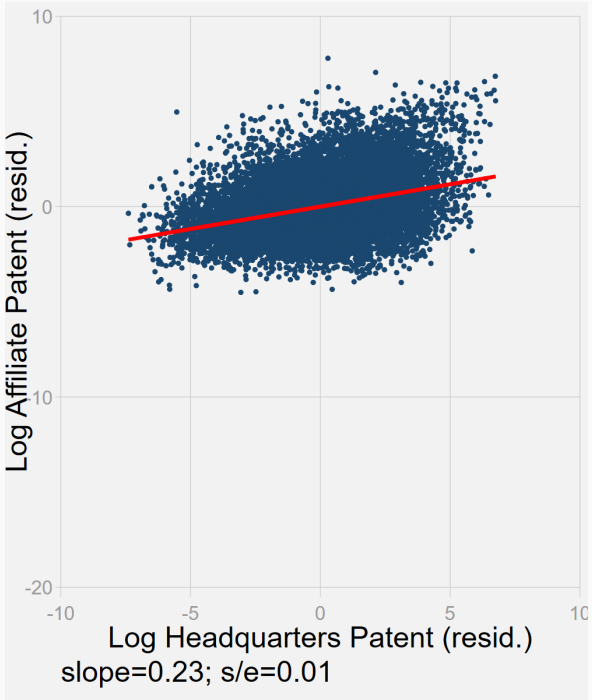
Conclusions

- Study determinants and welfare implications of offshore R&D
- New data and empirical patterns informative about underlying motives
  - talent; headquarters effect; colocation
- Theory based measurements show a lot can be leaned from these empirical patterns
- Counterfactual experiments highlight the importance of offshore R&D for welfare and income distribution
- Caveats: sectoral dimension and out-sourcing overlooked

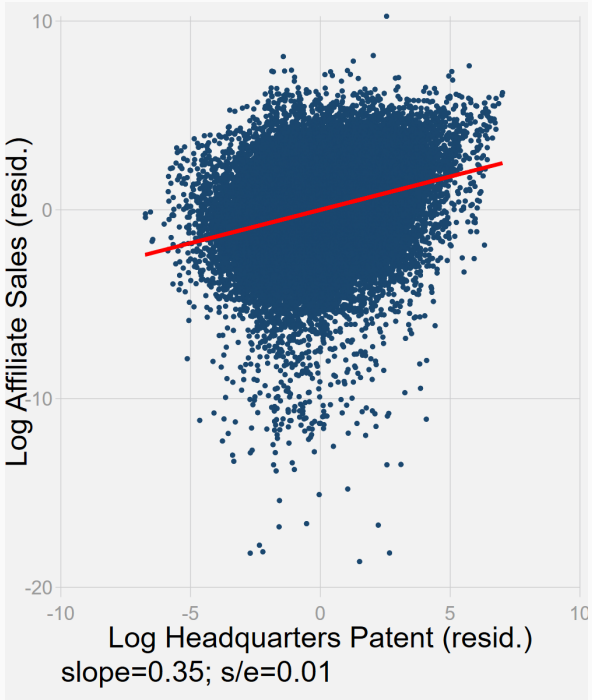
Headquarters invention and affiliate activities



(a) Offshore R&D Presence



(b) Affiliate Patent



(c) Affiliate Sales

- In (a): home country and industry (2 digit) FEs are netted out from the x-axis
- (b) and (c): residual plots controlling for host, home, and industry FEs

Back

Coverage of the financial data

	Full sample			Sample with patents	
ISO	(1) total sales / GDP	(2) total sales exc. finance / Eurostat total	(3) mfg. sales / Eurostat mfg.	(4) total sales exc. finance / Eurostat total	(5) mfg. sales / Eurostat mfg.
AUT	4.67	0.80	0.73	0.45	0.55
BEL	2.50	0.72	0.68	0.38	0.48
BGR	1.51	1.07	0.81	0.23	0.23
CHE	2.93	0.39	0.44	0.03	0.08
CZE	2.19	0.96	0.90	0.42	0.59
DEU	1.95	0.71	0.63	0.36	0.45
DNK	2.00	0.61	0.59	0.31	0.49
ESP	1.53	0.92	1.03	0.43	0.64
EST	2.27	0.96	0.88	0.20	0.33
FRA	1.88	0.81	0.80	0.42	0.56
GBR	0.83	0.26	0.31	0.11	0.21
GRC	0.96	0.64	0.78	0.08	0.08
HRV	1.13	0.93	1.13	0.14	0.20
HUN	2.20	1.10	0.99	0.40	0.51
IRL	4.33	0.83	0.56	0.61	0.34
ITA	2.02	0.87	0.97	0.31	0.46
LTU	1.34	0.68	0.48	0.08	0.14
LVA	1.82	0.99	1.04	0.10	0.18
NLD	0.92	0.26	0.15	0.11	0.12
NOR	2.68	0.99	0.82	0.40	0.47
POL	1.04	0.74	0.93	0.30	0.55
PRT	1.60	0.92	0.79	0.30	0.27
ROU	0.90	0.98	0.95	0.32	0.44
SVK	2.59	1.17	0.95	0.46	0.63
SVN	2.00	0.82	0.77	0.25	0.36
SWE	3.05	0.89	0.76	0.42	0.59
Average	1.83	0.81	0.75	0.29	0.37

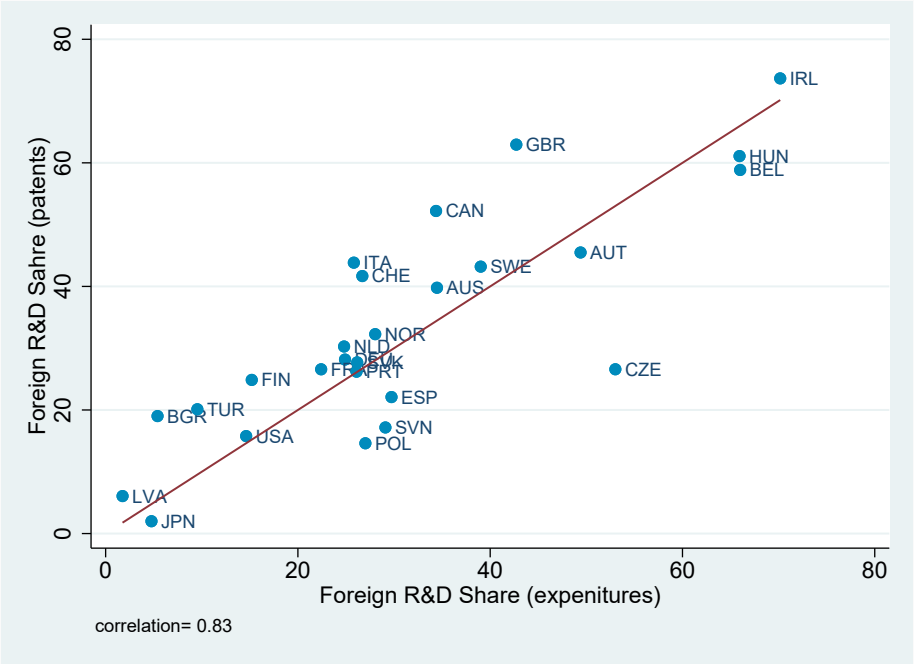
back

Composition of the patent data

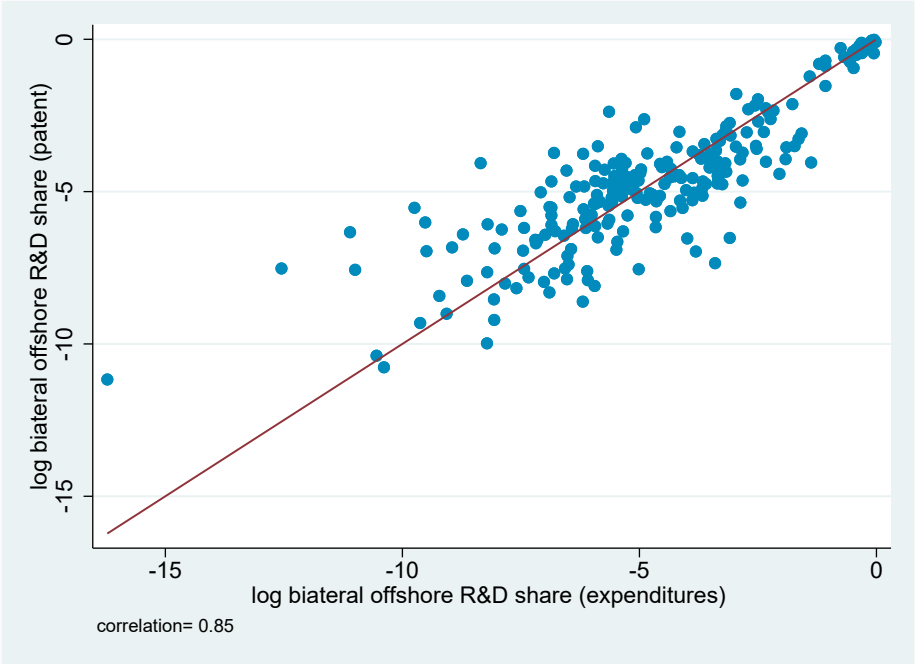
Patent office	All historic patents		Patents filed in 1996-2016	
	% of obs. (1)	% with location (2)	% of obs (3)	% with location (4)
USA	23.24	71.72	17.03	100.00
CHN	22.14	21.53	32.18	20.61
GER	8.52	59.61	4.22	99.97
KOR	8.33	93.67	10.12	93.39
EPO	6.48	99.72	8.38	99.75
CAN	6.01	29.28	5.37	21.80
PCT	5.18	94.19	7.46	94.64
AUS‘	4.06	1.01	3.13	0.74
AUT	2.95	70.34	1.81	98.42
TWN	2.89	99.99	4.19	99.99
All others	10.20	56.52	6.10	75.11
Total	100.00	58.19	100.00	64.50

back

Offshore R&D, measured in patents and R&D expenditures

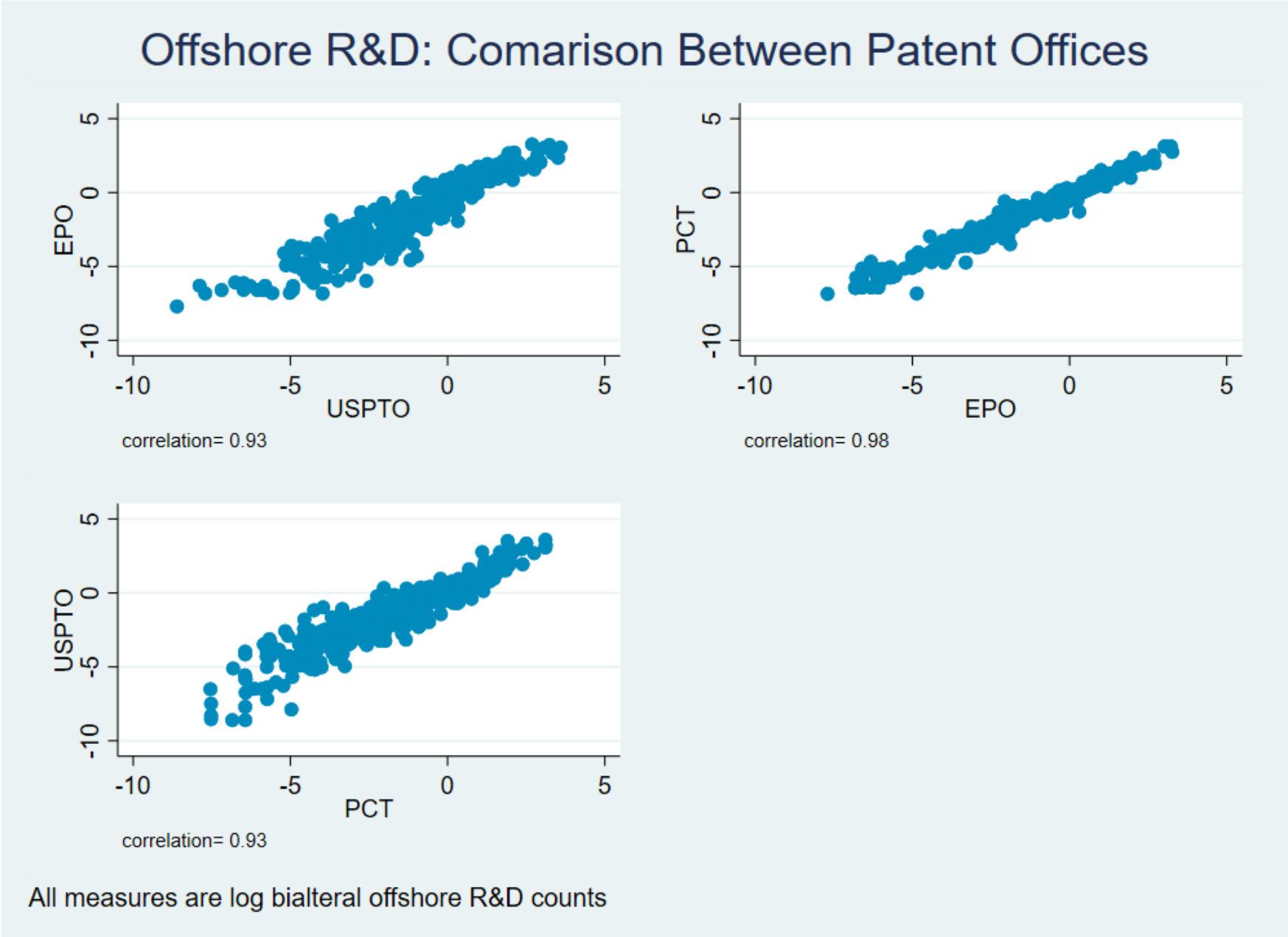


(d) Aggregate Inward Offshore R&D Share



(e) Log Bilateral Offshore R&D Share

Bilateral Offshore R&D measured using different patent offices



Human Capital and Affiliate Invention Intensity

	(1)	(2)	(3)	(4)
Dependent variable:	ln (patent/sales)			R&D Indicator
human capital index	0.979***	3.013**	3.431**	0.181**
	(0.260)	(1.365)	(1.334)	(0.076)
IPR protection		0.563***	0.404**	0.020
		(0.205)	(0.176)	(0.015)
R&D subsidies		0.508	0.572	0.011
		(0.384)	(0.403)	(0.029)
ln (researchers)			0.421**	0.067***
			(0.172)	(0.016)
log (sales)				0.004***
				(0.001)
Observations	21031	11803	11464	80253
R^2	0.252	0.677	0.675	0.637
Within R^2	0.029	0.010	0.015	0.005
Distance measures	Y	-	-	-
Firm-period FE	Y	Y	Y	Y
Affiliate FE	-	Y	Y	Y

Note: Additional controls include GDP and GDP per capita. Standard errors (in parenthesis) are clustered by host country and by firm. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Back

Colocation of Invention and Production

- Obs are at firm-affiliate-period level;
- blue: proximity to local offshore R&D centers; orange: proximity to other countries in which the firm has an R&D center Back

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent var.	prod. indicator			ln (sales)		
R&D Indicator$_{fh,t}$	0.281***	1.164***		1.042***		
	(0.003)	(0.024)		(0.026)		
ln(patent)$_{fh,t}$			0.331***		0.329***	0.181***
			(0.012)		(0.012)	(0.042)
ln (distance)$_{fh,t}$				-0.024	-0.328**	
				(0.025)	(0.144)	
common language$_{fh,t}$				0.220***	0.408	
				(0.051)	(0.267)	
contiguity$_{fh,t}$				0.143***	0.224	
				(0.049)	(0.235)	
colonial tie$_{fh,t}$				0.090**	-0.563*	
				(0.046)	(0.306)	
Observations	7494979	119659	19519	119503	19519	8839
Firm-period FE	Y	Y	Y	Y	Y	Y
Host-period FE	Y	Y	Y	Y	Y	-
Home-host FE	Y	Y	Y	Y	Y	-
Host-industry FE	Y	Y	Y	Y	Y	-
Affiliate FE	-	-	-	-	-	Y
Host-industry-period FE	-	-	-	-	-	Y

Note: Standard errors (in parenthesis) are clustered by firm. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Headquarters effects for invention and production

- Obs are at firm-affiliate-period level

Back

	(1)	(2)	(3)	(4)
	Affiliate Invention		Affiliate Production	
Dependent var.	indicator	ln(patent)	indicator	ln (sales)
$\ln(\text{distance})_{oh}$	-0.002**	-0.129***	-0.005***	-0.282***
	(0.001)	(0.034)	(0.002)	(0.028)
$\text{common language}_{oh}$	0.020***	0.258***	0.022***	0.162**
	(0.004)	(0.072)	(0.009)	(0.064)
contiguity_{oh}	0.002	0.106	0.004	0.185***
	(0.002)	(0.072)	(0.004)	(0.061)
colonial tie_{oh}	0.002	0.029	0.024***	0.153**
	(0.004)	(0.067)	(0.008)	(0.075)
Observations	7295102	45364	7295102	103131
Firm-period FE	Y	Y	Y	Y
Host-industry FE	Y	Y	Y	Y
Host-period FE	Y	Y	Y	Y

Note: Standard errors (in parenthesis) are clustered by country pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

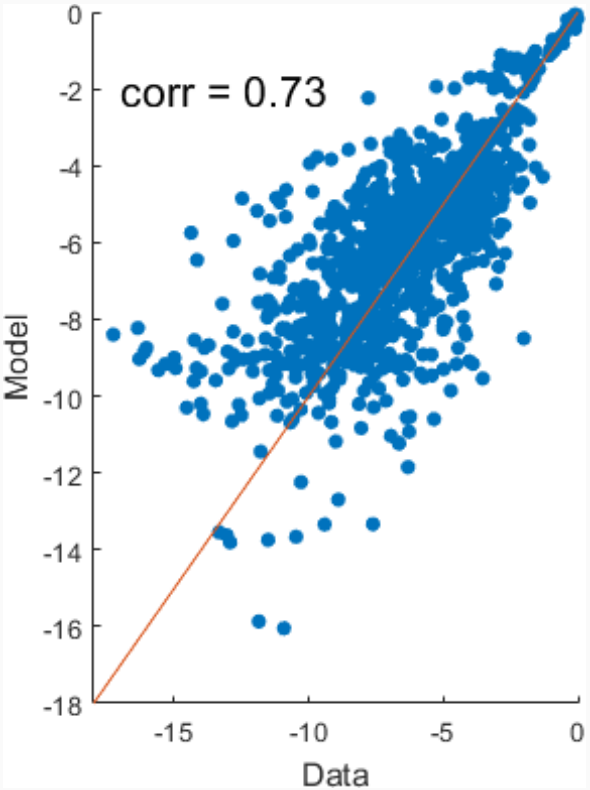
Calibration: Distributions

Model:

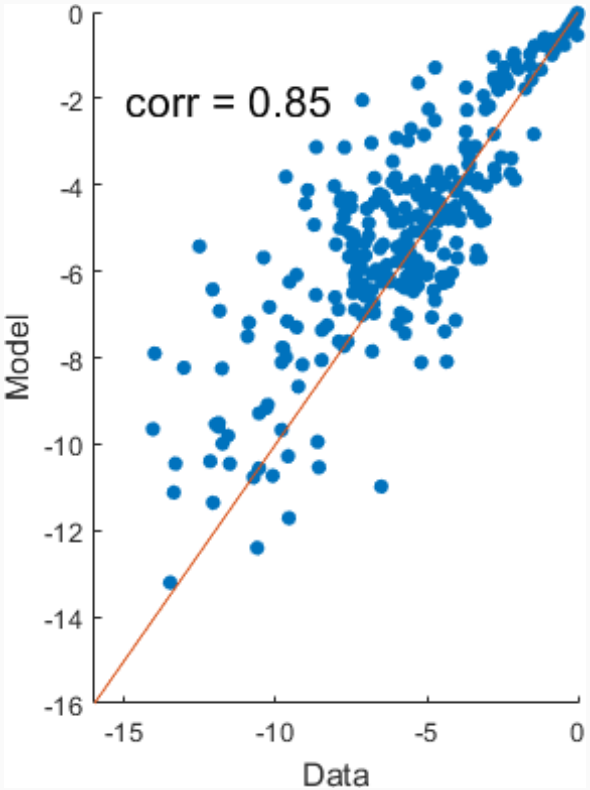
- Truncated Pareto distribution, calibrated to match distribution statistics in worker talent and firm innovation management efficiency
- Specification of $G^P(z^P|z^R)$:
  - Assume z^P is drawn from either a **H** or a **L** Pareto distribution, with **dispersion parameter** κ_P, and **lower bound** $\underline{Z}_L^P$ and $\underline{Z}_H^P$:
    $\text{Prob}(H|z^R) = \frac{1}{1+\exp(A+Bz^R)}$.
  - Classify top 1% production management score in the database to be **H** type, and estimate A and B using Logit model.
- f: CES with elasticity of substitution $\alpha < 1$.

▸ Back

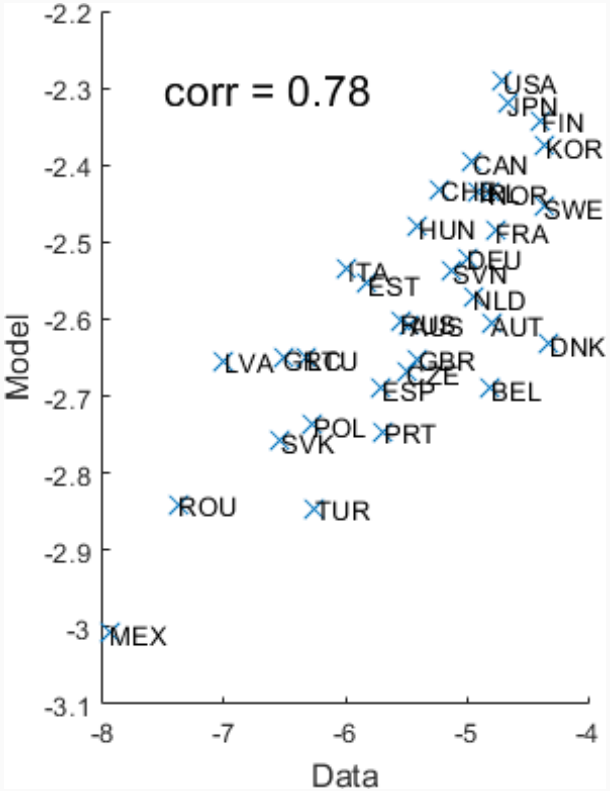
Model Fit



(f) Offshore Production



(g) Offshore R&D



(h) Share of High-Skill Workers

Back