High-Skill Immigration Restriction and Multinational Talent Offshoring

Simeng Zeng*

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Abstract

This paper examines the impact of restrictions on high-skill immigration by introducing a novel dimension: multinational (MNE) talent offshore. In response to restrictions on hiring foreign high-skilled workers at their U.S. headquarters, MNEs can engage foreign researchers in their overseas affiliates. I construct a dynamic model incorporating trade, MNE activities, innovation, and immigration. A critical assumption is that MNEs can segment their innovation process and deploy researchers to foreign affiliates. Calibrating to U.S. aggregate data on trade and MNE activities, the results show the existing immigration restrictions can explain 47.8 percent of observed MNEs talent offshore. By eliminating the restriction, the overall economy benefits from more efficient process innovation and higher product innovation, which leads to a gain in total productivity and aggregate welfare.

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1 Introduction

High-skilled workers are crucial for the firm to develop and manage new technologies. While the best-run firms and R&D centers are in advanced countries, emerging countries like China and India have some of the biggest pools of engineers and researchers. The uneven distribution of these two factors increases the firm's demand for foreign skilled workers. In the United States, an increasingly high proportion of these innovation researchers, particularly STEM workers, were born abroad and immigrated to the United States (Bound et al. (2017)). On the other hand, government policy has been strict against immigration in the United States. For example, the H-1B visa has an annual cap of 65,000 for workers with specialized skills and an additional 20,000 visas for applicants with a graduate degree. The demand from the firm's side, however, exceeded 200,000 in recent years[1]. Business leaders argue the cap is constraining, and the shortage of high-skilled workers has negatively affected firms' innovation and growth. Policymakers, however, express concerns that immigrants would take away employment opportunities from native talents.

However, the debate overlooks the fact that most immigration visas are sponsored by multinational enterprises (MNEs). With affiliates operating abroad, MNEs have offshore options when facing decreasing access to visas for skilled workers: they can directly hire foreign researchers at affiliates abroad. Big companies like Microsoft and Amazon have explicitly stated that they have built or are considering opening new foreign R&D centers in response to U.S. immigration problems. Glennon (2020) provides more concrete empirical evidence, combining MNEs' firm-level data with H-1B visa microdata, confirming that restrictions on high-skilled immigration indeed cause MNEs to offshore skilled jobs.

Motivated by these facts, this paper presents a model to quantify the extent to which MNEs' R&D offshore behavior could be explained by immigration restrictions and, further, to examine the consequences on the aggregate economy. A structural model is necessary since R&D offshore brings additional benefits to MNEs beyond simply relaxing immigration constraints. As the literature suggests, firms could use affiliate R&D to better serve the local market or gain access to

[1]The H-1B visa is the most commonly used high-skilled working visa in the U.S. It is the first step for most high-skilled workers to immigrate to the U.S. H-1B visas are tied to the firms; firms need to file applications for each of the talents they want to hire, subject to a filing cost. The H-1B visa program operates on a first-come, first-serve basis, and if the total applications in some years exceed the annual cap within a short period, the visa will be distributed by a random lottery.

cheaper researchers. A carefully calibrated model can help decompose these mixed factors[2]. Additionally, with some of the innovation jobs moving abroad, the level of economic activity could decrease. With this model, I examine the impact of immigration restrictions on U.S. aggregate productivity, production labor, and welfare by comparing the real world with an experiment where all immigration restrictions are eliminated.

The model features a two-country dynamic general equilibrium, following the literature on heterogeneous firms and international trade (Melitz (2003); Helpman, Melitz, and Yeaple (2004)). Monopolistic firms hire low-skill workers to produce differentiated products and can sell internationally through exports or foreign affiliates. Both activities are subject to fixed costs and variable costs, providing firms with incentives to improve productivity. Firms hire high-skill workers to innovate and have a probability of becoming more productive (*process innovation*). MNEs have an additional advantage of allocating talent to foreign affiliates. It's crucial to note that the assumption that both affiliate and headquarters' innovation can contribute to firm productivity is fundamental to explaining MNEs' R&D offshore. High-skill workers are also used to create more firms (*product innovation*). This aligns with evidence indicating that highly skilled immigrants are integral to entrepreneurial ecosystems, with over 50% of startups valued at $1 billion or more having at least one immigrant founder. Workers, on the other side of the story, cannot choose their types but can decide on the best location to live. If they migrate, there is a migration cost, reflecting the immigration restrictions of the country.

In the model, the immigration restriction on high-skill workers reduces the total supply of researchers, thereby increasing the domestic high-skill wage. This forces firms to choose less process innovation, reduces the probability of becoming more productive and larger, and diminishes firm profits. While MNEs utilize affiliate researchers to compensate, affiliate innovation is not as efficient and important as the parent one (Bilir and Morales (2020)), causing them to also be adversely affected by the policy. Furthermore, the economy can support fewer new firms since expected profits decrease, and entry becomes more expensive. As a result, the total productivity of the economy decreases. For the workers, demand for production workers decreases. High-skill labor indeed benefits from the policy, but the total gain is not as large as the loss of low-skill

[2]Based on U.S. Bureau of Economics, MNEs, on average, spend 20% of the total R&D expenditure in foreign affiliates.

production workers.

The model is calibrated to match four main features: trade and MNEs activity between the U.S. and the rest of the world (RoW), R&D allocation between parent and affiliate within MNEs, R&D spending of the U.S. and RoW, and firm size distribution in the U.S. economy. Using the calibrated model, I conduct a counterfactual experiment where I allow talents from the rest of the world to freely move into the United States. The results show that immigration restrictions could explain roughly 50% of MNEs' talent offshoring behavior, depending on how substitutable parent and affiliate innovation is. By eliminating immigration restrictions, the economy benefits from more efficient process innovation and an increase in product innovation. As total productivity improves, low-skill labor income increases, leading to an 8.4% gain in welfare. While high-skill workers experience losses, their relatively smaller group size results in an overall improvement in total welfare.

Related Literature. This paper relates to several strands in the literature. Various papers quantify the wage and employment impacts of immigrants, with many emphasizing the labor side, such as the different skills between native and immigrant workers (Burstein et al. (2020), Caliendo et al. (2017); Desmet et al. (2018); Ottaviano and Peri (2012), and many others). Previous studies often simplify firm structures to absorb and accommodate new immigrant populations. Morales (2020) is one of the few that incorporates MNEs' production, but the paper still omits details on the firm side. I contribute to this literature by including a more detailed firm structure of endogenous entry, exit and innovation, with a specific emphasis on the role that firms, especially MNEs, play.

This paper also closely relates to the extensive literature on the impacts of multinational enterprises (MNEs) and patterns of foreign direct investment (FDI) (McGrattan and Prescott (2009); Ramondo and Rodríguez-Clare (2013); Tintelnot (2017); Arkolakis, Ramondo, Rodríguez-Clare, and Yeaple (2018); Keller and Yeaple (2013), and many others). Most of these studies lack an innovation setting or assume that affiliates are merely recipients of knowledge. Few studies explore the fragmentation of innovation. Notably, Fan (2019) and Bilir and Morales (2020) are among the few, but they assume immobile factors. My contribution to this literature is emphasizing the crucial role that MNEs play in both immigration and innovation, given that MNEs are leading employers of high-skill foreigners.

This paper also builds on the literature of innovation and growth, dating back to Grossman and Helpman (1991) and Rivera-Batiz and Romer (1991). Within this literature, one of the most closely related papers is Atkeson and Burstein (2010). In their setting, process innovation is achieved by purchasing research goods, which are produced competitively by another sector. My model deviates from this by attaching high-skill workers to each firm. This setting distinguishes MNEs from other firms, as MNEs have the freedom to segment innovation. It also enables me to incorporate more foreign talent hiring restrictions for firms in the future, paralleling the H-1B visa application process.

The paper proceeds as follows. The model is presented in section 2. Section 3 shows the calibration results. Section 4 includes a counterfactual exercise where I allow talent to freely move to the United. Section 5 concludes.

2 Model

Time is discrete, and each period is labeled $t = 0, 1, 2, \ldots$. The world consists of two large open economies: U.S. and rest of the world (RoW), indexed by $1, 2$ respectively. The two economies can differ in the size of labor, distribution of firms and firm innovation efficiency. Each economy is endowed with L_i measure of low skilled workers and H_i measure of high skilled workers. Households inelastically supply labor, and they can move across countries with moving costs, but cannot change their skill type.

2.1 Households

Households are infinitely lived with lifetime utility $\sum_{t=0}^{\infty} \beta^t \log(C_t)$. In each period, they observe a moving cost that lower real income by a factor μ_{ij}^n, if the households would like to move from the birth place i to another country j, and are of skill type $n \in \{H, L\}$. Households own the firms, but workers moving out of the birth country have to forgo profits return from firms in their home (denoted as T_i), and cannot get shares from foreign firms. There is no saving in the economy, so households are facing a static problem each period, requiring them to choose the location that gives the highest real income. After settling down, they work to earn labor income and consume a non-tradable final good. I assume there is no difference between immigrant and native worker in their skill. The budget constraints and household problem are hence below, where P_j is the price index of the final good in country j.

$$P_j\, C_j = w_j^n \; + \; T_i \cdot 1_{\{i=j\}}, \quad n \in \{H, L\} \tag{1}$$

$$\max_j \, [\frac{w_j^n + T_i \cdot 1_{\{i=j\}}}{P_j} \frac{1}{\mu_{ij}^n}] \tag{2}$$

For simplicity, low skill labor from both of the countries and high skill labor from the U.S. are not allowed to move, this can be achieved by assuming

$$\mu_{ij}^n = \begin{cases} 1 & \text{if } i = j, \forall\, n \\ \infty & \text{if } i = 1,\ j = 2, \forall\, n \\ \infty & \text{if } i = 2,\ j = 1, n = L \end{cases}$$

High skilled labor from RoW gets a random draw of moving cost, which is independently and identically distributed across time. Denote the CDF as F. By the law of large number, the fraction of immigrants flow into the U.S. at each period is:

$$\frac{H_t^f}{H_2} = F\left[\frac{w_1^H(t)/P_1(t)}{(w_2^H(t) + T_2(t))/P_2(t)}\right] \tag{3}$$

2.2 Final Goods Production

The final good producers are competitive. They combine all the intermediate varieties ω selling in the local market j and use a a constant return to scale production technology of the form

$$Y_j = \left(\int_{\Omega_j} y_j(\omega)^{\frac{\rho-1}{\rho}} d\omega\right)^{\frac{\rho}{\rho-1}} \tag{4}$$

At each time t, the final good producers choose input $y_j(\omega)$ to maximize (4), while taking as given prices of the final good P_j and intermediate goods $p_j(\omega)$. This gives rise to the demand function for an individual variety,

$$y_j(\omega) = \left[\frac{p_j(\omega)}{P_j}\right]^{-\rho} P_j Y_j \tag{5}$$

The equilibrium price for the non-tradable final good in j must satisfies

$$P_j^{1-\rho} = \int_{\Omega_j} p_j(\omega)^{1-\rho} d\omega \tag{6}$$

2.3 Intermediate Goods

Intermediate goods are each produced by heterogeneous firms indexed by the productivity z. Firms are monopolistically competitive, use constant return to scale production technology in low skill labor. For convenience, the firm productivity is rescaled and equals to $\exp(z)^{1/(\rho-1)}$, where $\rho > 1$ and the production function is

$$y = \exp(z)^{1/(\rho-1)} l \tag{7}$$

As I show below, with the rescaling, each firm's equilibrium labor and variable profits are proportional to $\exp(z)$

Firms can also serve other countries by exporting or building affiliates. If a firm decides to export, it faces a fixed exporting cost F_x and an iceberg variable cost of D; if it builds affiliates, it is subject to a fixed multinational cost F_a and an efficiency variable cost E, which can be understood as the information lost when commuting between the headquarter and affiliate. Assume $D > E \geq 1,\ F_a > F_x > 0$, this ensures firms would never export without also selling in the domestic market, and a firm with higher productivity will always choose to become a multinational as long as the profit is enough to cover the F_a. Firms will never use affiliates to produce and export back products to serve the domestic market due to the variable costs. Fixed costs are all in units of local high skill labor.

In each period, an intermediate firm in i with state z faces static profit maximization problems for each market it wants to serve. Take home market as an example, the firm chooses production labor $l_i(z)$ and price $p_i(z)$ to maximize

$$\Pi_i^d(z) = \max_{y_i(z), l_i(z), p_i(z)} p_i(z) y_i(z) - w_i^L l_i(z)$$

subject to (5) and (7). By an easy calculation, the above problem has the following form:

$$\Pi_i^d(z) = \underbrace{\frac{(w_i^L)^{1-\rho} P_i^\rho Y_i}{\rho^\rho\, (\rho-1)^{1-\rho}}}_{\Pi_i^d} \cdot \exp(z) \tag{8}$$

and the optimal price and production labor for domestic sales are

$$p_i^d(z) = \frac{\rho}{\rho-1} \frac{w_i^L}{\exp(z)^{1/(\rho-1)}}, \quad l_i^d(z) = \left(\frac{\rho-1}{\rho}\right)^\rho \left(w_i^L\right)^{-\rho} P_i^\rho Y_i \exp(z)$$

Similarly, the firm in i chooses production labor and product price to sell to j by exporting or through affiliates, and the related profits are of the similar expression, all as functions of current productivity and aggregate variables reflecting market price and size

$$\text{Export profit: } \Pi_{ij}^x(z) = \frac{(w_i^L)^{1-\rho} P_j^\rho Y_j}{\rho^\rho\, (\rho-1)^{1-\rho}} \exp(z) D^{1-\rho} - F_x^i \cdot w_i^H \tag{9}$$

$$\text{Affiliate profit: } \Pi_{ij}^a(z) = \Pi_d^j \cdot \exp(z) E^{1-\rho} - F_a^i \cdot w_i^H \tag{10}$$

Denote a firm's structure as $s \in \{d, x, a\}$, which stands for domestic only, exporting firm, or multinational. The associate static production profit of each firm type is

$$\pi_i^d(z) = \Pi_i^d(z), \quad \pi_i^x(z) = \Pi_i^d(z) + \Pi_{ij}^x(z), \quad \pi_i^a(z) = \Pi_i^d(z) + \Pi_{ij}^a(z) \tag{11}$$

For simplicity, set F_a^2 high enough for the RoW firm, so no firm could afford building affiliates in the U.S.

2.4 Firm Innovation

Productivity at the firm level evolves over time depending on the firm's investment in innovation and idiosyncratic productivity shocks. At the beginning of each period t, every existing firm has a probability δ of exiting exogenously, and $1-\delta$ of surviving to produce. Surviving firms can choose either to exit or to continue to operate and pay a fixed cost of operation F_d in terms of local high skill labor.

A continuing firm can improve its productivity by using efficient units of research, which is produced by high skill workers. A firm with productivity z that has h efficiency unit of research in the current period t has a probability $q(h,z)$ of having productivity $\exp(z+\Delta_z)^{1/(\rho-1)}$ and a probability $1-q(h,z)$ having $\exp(z-\Delta_z)^{1/(\rho-1)}$ in the next period $t+1$. I assume q is an increasing function of h and a decreasing function of z, meaning a high productivity firm needs to put extra effort to achieve the same probability q. I refer to q as a firm's *process innovation* decision[3].

The efficient research unit is produced by high skill workers, the researcher's number and location are the key elements of the production function. A firm at most can have two locations to choose from: headquarter and foreign affiliate. Let (h_n, h_a) be the researcher's number a firm from country i chooses in its headquarter and affiliate, the efficient unit of research is produced by a constant return to scale technology

$$h = \left(\underbrace{a_{i1}\left(h_n\right)^{\frac{\gamma-1}{\gamma}}}_{\text{parent talents' contribution}} + \underbrace{a_{i2}\left(h_a\right)^{\frac{\gamma-1}{\gamma}}}_{\text{Affiliate talents' contribution}} \right)^{\frac{\gamma}{\gamma-1}} \tag{12}$$

The first and second part inside the above function represents headquarter and affiliate contribution in innovation respectively[4]. The shifter a_{11}/a_{12} reflects how important or how efficient headquarter innovation is compared to affiliate's. Based on Bilir and Morales (2020), a_{11} is greater than a_{12} for the U.S. case. Mapping to the real world, it might be due to the headquarters having better

[3]Further in the calibration part, q is decreasing in $\exp(z)$. This will imply the growth rate of a sufficiently large firm is independent of size, consistent with Gibrat's law. When the time period is small, then this binomial process approximates a geometric Brownian motion in continuous time, as in the work of Luttmer (2007). Similar to Atkeson and Burstein (2010), the model differs from Luttmer's in that the firm controls the drift of the process through investment in researchers.

[4]The immigrant is treated the same as local researcher after she settles down. Right now the model deviates from the H-1B application system in the U.S. in the sense there is no friction of hiring researchers. Firm will always get the high skill labor it wants, and researchers then start to innovate, and help the firm get q successful probability.

lab equipment, better access to the world leading universities, or/and deepening understanding on the right direction of the research. γ is the elasticity of substitution between headquarter and affiliate innovation effort.

The above setting satisfies two properties. First, fixed high skill wages in both countries, a firm with higher parent R&D also hires more researchers in affiliate, corresponding to the fact Bilir and Morales (2020) states by analysing multinational firm-level data. Second, if we allow high skill workers to move across countries, firms will increase the number of high skill workers in affiliate under the equilibrium with higher U.S. researcher wage. This correspond to Glennon (2020) empirical evidence.

When the firm is domestic only or exporting firm, the CES function reduce to a linear one, with constant $a_{11}^{(\gamma-1)/\gamma}$ for U.S. and $a_{21}^{(\gamma-1)/\gamma}$ for RoW. a_{11}/a_{21} reflects comparative advantage of innovation across countries.

With this evolution of firm productivity, the expected, discounted present value of profits for a firm with z satisfies a Bellman equation:

$$V_t(z) \;=\; \max\,[\,0,\;\bar{V}_t(z)\,] \tag{13}$$

$$\begin{aligned}\bar{V}_t(z\,) = & \max_{h_n,h_a,s\in\{d,x,a\}} \{\, \pi_t^s(z) - F_d\cdot w_{1t}^H - w_{1t}^H h_n - w_{2t}^H h_a \\ & + \frac{1-\delta}{R_t}\,[\, q(h,z)V_{t+1}(z+\Delta) + (1-q(h,z))V_{t+1}(z-\Delta)\,] \\ & s.t. \quad h_a = 0 \quad \text{if } s \neq a \end{aligned} \tag{14}$$

Where $\pi^s(d)$ is given by (8)-(11), and h is given by (12). R_t is the world interest rate. Let $1_d^i(z,t) = 1$ if a firm in i with productivity z at t is domestic only firm, $1_x^i(z,t) = 1$ if it is exporting firm, $1_a^i(z) = 1$ if it chooses to become a multinational. The RoW firm's problem is a subset of above, since the firm could only choose between domestic only and exporting firm.

The value function of operating firms $\bar{V}_t(z)$ is strictly increasing in z. Clearly, in each period t, the decision of firms to operate follows a cutoff rule, with firms with productivity at or above a cutoff $\bar{z}_i^d(t)$ choosing to operate, and firms with productivity below this cutoff exiting. Similarly, there are also cutoffs for firms exporting $\bar{z}_i^x(t)$ or being MNE $\bar{z}_i^a(t)$. If the firm has productivity between $\bar{z}_i^x(t)$ and $\bar{z}_i^a(t)$, the firm can cover exporting fixed cost, but not MNE fixed cost. It can thus serve the foreign market by exporting and earn additional profits compares to domestic-only firms. If the firm is productive enough (z higher than $\bar{z}_i^a(t)$) to cover MNE fixed cost, the firm will become a multinational, and use affiliates to serve the foreign market. Note that MNEs have an additional advantage of hiring researchers aboard, there is a trade-off for the marginal firm which has productivity around $\bar{z}_i^a(t)$. That firm may want to forgo some profits in the current period to become MNE and enjoy access to the foreign talent market.

2.5 Firm Entry

New firms are created with an investment of innovation. It requires the firm hires F_e number of local researchers to get a blueprint of a new variety. The quality of the idea (or initial productivity) is drawn from a distribution G_i, and the firm is allowed to produce in the next period. The free entry condition requires that

$$F_e w_{it}^H = \frac{1}{R_t} \int V_{t+1}^i(z) G_i(z) dz \tag{15}$$

Let M_{et}^i denote the measure of new firms entering in the period t that start producing in period $t+1$. I refer M_{et}^i as the *product innovation*.

2.6 Closing the Model

The evolution of the distribution of operating firms M_t over time is given by the exogenous probability of exit δ, the optimal decisions of operating firms to invest in their productivity $q_t^*(z)$, and a measure of entering firms in the period t, M_{et}^i. The distribution of operating firm in country i in period $t+1$, denoted as $M_t^i(z)$, comes from three inflows of firms: new firms founded in period t, firms continuing from t that draws positive productive shocks (productivity equals $z - \Delta_z$ in t), and firms continuing from t that has negative productive shocks (productivity equals $z + \Delta_z$ in t).

Therefore, for $z \geq \bar{z}_i^d(t)$

$$\begin{aligned} M_{t+1}^i(z) \; = \; & M_{et}^i \, G_i(z) \\ & + \; (1-\delta) \, M_t^i(z-\Delta) \, q_t^*(z-\Delta) \\ & + (1-\delta) \, M_t^i(z+\Delta) \, [1 - q_t^*(z+\Delta)] \end{aligned} \tag{16}$$

Trade is assumed to be balanced each period, which requires the net export value plus net profit from MNEs activity equals zero.

$$\begin{aligned} & \rho \int \pi_1^x(z,t) 1_x^1(z,t) M_t^1(z) dz + \int \pi_1^a(z,t) 1_a^1(z,t) M_t^1(z) dz - w_2^H(t) \int_{\bar{z}_{at}^1} h_a^1(z,t) M_t^1(z) dz \\ = & \rho \int \pi_2^x(z,t) 1_x^2(z,t) M_t^2(z) dz \end{aligned} \tag{17}$$

An **equilibrium** in this economy is the immigration flow into U.S. H_t^f, a set of prices R_t, $\{w_i^H(t), \; w_i^L(t), \; P_i(t)\}_{i=1,2}$, prices for intermediate good $\{p_i^d(z,t), \; p_{ij}^x(z,t), \; p_{ij}^a(z,t)\}_{i=1,2}$, aggregate quantities $\{C_i(t), Y_i(t)\}_{i=1,2}$, quantities of the intermediate goods $\{y_i^d(z,t), \; y_{ij}^x(z,t), \; y_{ij}^a(z,t), \; l_i^d(z,t), \; l_{ij}^x(z,t), \; l_{ij}^a(z,t), \; h_n^i(z,t), \; h_a^i(z,t)\}_{i=1,2}$, and a collection of sequences of firm value functions $V_t^i(z)$, profits $\pi_i^s(z,t)$, exit $1_d^i(z,t)$, export $1_x^i(z,t)$, MNE decisions $1_a^i(z,t)$, together with distributions of operating firms and measures of entering firms $\{M_t^i, \; M_{et}^i\}_{i=1,2}$, such that (i) household and firms in each country optimize, (ii) all the labor market clears, trade balance in each period, and (iii) the distribution of operating firms evolve s described above. A **steady state** of the model is an equilibrium in which all aggregate variables are constant.

3 Parametrization

In this section, I parametrize the model for the United States and the rest of the world so that the model is consistent with features regarding firm size dynamic and firm size distribution, as well as exporting, MNEs activities pattern. The rest of the world consists of 36 regions that doing nonnegligible trade and FDI with the Unites States[5]. The wage of low-skill worker in the U.S. $w_1^H = 1$ is set to be the numeraire.

3.1 Additional Assumption

Several additional assumption have to be made before the calibration.

Process Innovation. The process innovation function $q(h, z)$ is assumed to have the following form, where b and H are parameters:

$$q(h, z) = \frac{1}{b} \log \left(\frac{h}{H \exp(z)} \right) \tag{18}$$

The benefit of using this form is that the system is now equivalent to Atkeson and Burstein (2010), wherein their setting, the firm is allowed to directly choose successful probability q, with the cost $H \exp(bq) \exp(z)$. As a result, process innovation cost is a fixed percentage scale with the size of the firm, which implies the growth rate of a sufficiently large firm is independent of size, consistent with Gibrat's law. This is especially true when b, the elasticity of process innovation, is large. This assumption also allows me to use the calibration strategy mentioned by Atkeson and Burstein (2010). Both b and H can be different across countries, and they will be calibrated within the model.

Utility Cost Distribution. The utility cost that the high skilled worker draws is assumed to be Type 1 Extreme distribution with shape parameter κ. ($F(\phi) = \phi_{21}^H \sim \exp(-(\phi - 1)^{-\kappa})$)

Firm Entry All firms enter at the same productivity.[6] The log productivity for the RoW firm is normalized to $z_0 = 0$. I assume the U.S firms are more productive than the RoW firms in general, so the entry firm productivity is a ratio over $z_0 = 0$. The ratio will be calibrated within the model.

[5]The list of 36 regions: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Republic of, Latvia, Lithuania, Mexico, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom.

[6]We could assume firm faces different exporting and MNEs fixed cost, so it could help to adjust the initial firm distribution as Atkeson and Burstein (2010).

Table 1: General Parameter: External Calibrated

Parameter	Value	Data/Source
Time Period Δt	2 month	
Annual Interest Rate r	5%	Atkeson and Burstein (2010)
Elasticity of Substitution ρ	5	
Exogenous Exit Rate	0.003	BDS (2011-2018 avg):$\geq$ 500 emp
Innovation:		
Step Size Δz	0.1021	Employment growth rate of large firm (SD) 0.25
Curvature $b_{U.S}$	1200	Atkeson and Burstein (2010)
Labor Endowment:	(Researcher Ratio)	
L1=0.935; H1=0.065	6.5%	OECD RDS: researcher ratio RoW/U.S=0.8
L2=4.763; H2=0.258	5.14%	*0.015 high skill immigrant (23% U.S researcher)

3.2 Calibration

I divide the parameters into three groups: general parameters that could be parametrized externally, innovation parameters and parameters related to trade.

General Parameters. Table 1 lists all the parameters that can be externally calibrated. I choose time periods equal to 2 months, so there are six time periods per year. Follow Atkeson and Burstein (2010), I keep the entry period of new firms at 1 year. The steady-state real interest rate (annualized) is 5 percent. The elasticity of substitution across intermediate goods in final output ρ is taken as 5. Exogenous exit rate δ equals 0.3 percent[7], which matches the U.S annual employment-weighted exit rate of large firms (defined as more than 500 employees). Note that in the model, large firms do not choose to exit endogenously because they have productivity far away from the threshold productivity of exit. Hence, δ determines the annual exit rate of these firms directly. The high skill labor wage in the U.S is set to be the numeraire.

The labor endowment in the U.S is normalized as 1, with 6.5 percent of high skill workers. This ratio roughly matches Atkeson and Burstein (2010) result on the fraction of workers that produce research goods. The RoW total population is 5.02, with a high skill ratio of 5.14 percent. The

[7] This is 2011-2018 average employment failure rate of U.S firms with more than 500 employees, computed using the Census Bureau Business Dynamics Statistics (BDS), available online at https://www.census.gov/programs-surveys/bds.html

researcher ratio between the U.S and RoW aims to match the Research and Development Statistics (RDS) in OECD database[8]. The full-time equivalent R&D personnel ratio of the 36 regions aggregation over the U.S is around 0.8. For robustness, I change the U.S researcher to 0.9 percent of the population, which is in line with the calculation of the OECD RDS database, and I keep the researcher share of the RoW to the U.S as 0.8. The result does not have significant changes. Note that researchers in the U.S includes 23 percent talent immigrant, based on the immigration data and previous literature (Kerr, Kerr, and Lincoln (2015)). This will help me to pin down the utility cost parameter κ.

The step size of innovation for both countries is taken so that the standard deviation of the growth rate of employment of large firms in the model is 25 percent on an annualized basis, suggested by Davis et al. (2006). The curvature parameter b inside the process innovation equation (18) for the U.S is assumed to be 1200, in which the process innovation decisions of firms are highly inelastic.

Innovation Parameters Based on the production function of the efficient unit of research (12), MNEs choose the same way to allocate the talents in optimal as they take wage as given; in other words, the ratio of affiliate researchers over headquarter researchers is the same across heterogeneous firms.

$$\frac{h_a^*(z)}{h_n^*(z)} \equiv \frac{h_a^*}{h_n^*} = \left(\frac{w_1^H a_{12}}{w_2^H a_{11}}\right)^\gamma$$

Given b_{US} is high, process innovation is inelastic, most of the MNEs in the model choose the same amount q^* regardless of their productivity, hence the same number of h^*, h_n^* and h_a^*. So above researcher ratio could be matched directly by the multinational activity database conducted by the Bureau of Economic Analysis (BEA), which equals 0.28 in the year 2014[9]. The BEA data also includes R&D expenditure ratio, affiliate over the U.S headquarter, which equals 0.17. In the model, the R&D expenditure is the wage payment to the high skill workers. Therefore, by dividing these two ratios, I infer the high skill labor wage of the RoW as $w_2^H = 0.60$. Notice there

[8] The data is available online at oe.cd/rds

[9] The data is available online at https://www.bea.gov/international/di1usdop, information regarding researchers is provided only in the benchmark year, and the most relevant benchmark is 2014

Table 2: Innovation Parameters

Parameter	Value	Data/Source
MNE:		
a_{11}/a_{12}	0.46	R&D researcher ratio: 0.28
γ	5	R&D expenditure ratio: 0.17

Parameter	Value	Target	Data	Model
H		Employment-Based right tail: 1000-5000 emp	-0.20	-0.23
a_{11}	10^{-3}	Researcher: MNE headquarter/All firms	0.52	0.49
a_{21}	$0.4*10^{-3}$	R&D Expenditure used by domestic firms: ROW/US	2.14	2.14
Productivity ratio	5	High skilled wage in RoW w_2^H	0.60	0.60
Curvature b_{RoW}	1200	Production labor MNE headquarter/All firms	0.18	0.33

is a one to one relationship between shifter ratio a_{12}/a_{11} and the elasticity γ

$$\frac{a_{12}}{a_{11}} = (\frac{h_a}{h_n})^{1/\gamma} \cdot w_2^H$$

γ indicates to what extent parent innovation can be substituted by the affiliate. It is the key parameter when analyzing the impact of immigration restriction on MNEs R&D offshoring behavior. If γ is large, meaning affiliate innovation can easily substitute the parent one, then firm will find it beneficial to hire more talents aboard when the innovation cost is high due to the immigration restriction. In this case, high skill immigration restriction plays a huge role in explaining talent offshoring behavior. On the other hand, if affiliate and parent innovation are not very substitutable, then immigration restriction will play a minor role, and the talent offshoring must due to other reasons, for example, to quickly adjust products to satisfy local tastes. For now γ is taken as 5, hence a_{12}/a_{11} is 0.46.

The rest of the innovation parameters, as well as trade parameters are jointly calibrated within the model. The innovation parameters mainly control the aggregate firm size across countries, while the trade parameters control the margin of firm structure, hence the size across firm types. I start with the innovation ones and leave trade parameters in the next section.

Parameter within q function (18) : H, b_{RoW}; efficient unit parameters inside (12) a_{11} for the US, a_{21} for the RoW; and initial productivity advantage of the US over the RoW are chosen to mainly match five observations: (1) the shape of the right tail of the firm size distribution matches that in the U.S. [10]; (2) researchers used in MNEs headquarters over all the researchers used in U.S firm process innovation equals 52.3%; (3) domestic R&D expenditure[11] spending by the RoW over the U.S is 2.14; (4) production worker used by MNE headquarters is 18.3% of total production workers in the US; (5) the implied talent wage of RoW is 0.60. The result is summarized in Table 2.

The implied high skill wage ratio turns out to be a fairly important moment. $w_2^H = 0.60$ implies the innovation is relatively inefficient in the RoW, so firms in RoW find it hard to hire enough talent to achieve the U.S level of process innovation. As a result, the RoW firm size is in general smaller than the U.S.

Trade Parameters The entry costs F_e are normalized to 1 for both countries (in unit of local talent), and operating fixed cost F_d equals 0.1[12]. The rest of the parameters: the fixed cost of exporting for the U.S and the RoW $F_x^1,\ F_x^2$; the fixed cost of MNEs for the U.S F_a^1; iceberg cost of exporting D; communicating cost of MNEs E are chosen to mainly match following five moments: (1) export over total output value in both countries; (2) production workers employed by exports over total firms in the US [13]. (3) production workers hired by affiliates over total in MNEs; (4) sales value in affiliates over total. Results are listed in Table 3.

3.3 Model Fit and Discussion

As shown in previous tables, the model matches well with the targets. For innovation, the researcher used in MNE headquarters over total firms, as well as the R&D expenditure used by

[10]I adopt Atkeson and Burstein (2010) method. They represent the right tail of the distribution of employment across firms in the U.S data with a function that maps the logarithm of the number of employees $log(l)$ into the logarithm of the fraction of total employment in firms this size or larger. The function is known to be close to linear for large firms. The slope coefficient is targeted -0.2 for firms ranging between 1,000 and 5,000 employees.

[11]Domestic R&D excludes innovation expenditure spent by foreign affiliates from other countries.

[12]Same as Atkeson and Burstein (2010), the statistics are invariant to proportional changes in all fixed cost and H.

[13]Bernard et al. (2009) reports that the fraction of total U.S employment (excluding a few sectors such as agriculture, education, and public services) accounted for by non-exporters is 60 percent in 2000. Among them, some MNEs also engage in export and import, and they account for 18.3 percent employment. These imply the production employment accounted for by the pure exporting firm is 21.6 percent. For the exporting value, by Bernard et al. (2009), the average of exports and imports to gross output for the comparable set of sectors is roughly 7.5 percent in the U.S in 2000, where among them, 32.6 percent is due to intra-firm trade. Hence exporting value accounts for 5.06 percent gross output of intermediate goods.

Table 3: Trade Parameters

Parameter	Value	Target	Data	Model
Entry Cost F_e	1	Normalization	-	-
Operating Cost F_d	0.1	Atkeson & Burstein(2010)	-	-
Exporting:				
Iceberg Cost D	1.33	Export/Gross output (U.S)	0.05	0.05
Exporting Fixed Cost F_x	0.16	Employment share of Exporting firm	0.22	0.22
Exporting Fixed Cost F_x^2	5	Export/Gross output (RoW)	0.02	0.04
MNE:				
MNE Efficiency Cost E	1.20	within MNE: production worker affiliate/total	0.34	0.51
MNE Fixed Cost F_a	2	within MNE: output: affiliate/total	0.33	0.57

domestic firms RoW over US are close to the aggregate data. The high skilled wage in RoW calibrated through the model matches well with the data implication. For trade patterns, the model can produce similar results in export value share and exports employment share in the U.S.

Some future works may needed to further improve the results. Currently, three ratios related to MNEs are not matched well. Production labor used in MNE headquarters compares to all firms; the average ratio of production workers hired in affiliate over total MNEs; and the average ratio of output in affiliate over total MNEs are all higher in the model, compares to the data counterpart. These indicate the MNEs take too much resources, and the affiliates are also too more productive.

4 Counterfactual

Armed with the calibrated model, I perform a counterfactual experiment to understand the effect of talent immigration restriction on MNEs behavior and the overall economy. I keep all the parameters fixed but remove the utility cost when talents would like to move from RoW to the U.S, in other words, $\phi_{21}^H = 1$. In the new equilibrium, the real income talents get in the RoW equals the real wage talents earn in the U.S. The result shows the high skilled workers in the U.S increases from 0.065 to 0.084, hence the researcher ratio in the U.S rises from 6.5 percent to 8.2 percent. The foreign talent now accounts for 40 percent of the U.S high skill workers, compared to 23 percent with the immigration restriction. On the contrary, the RoW researcher ratio decreases from 5.14 percent to 4.78 percent, and the total population become smaller.

4.1 MNEs behavior

Since the headquarters are more efficient in innovation compared to the affiliates, MNEs are willing to move researchers into the United States. But with the immigration restriction, the cost exceeds the benefit, so 27.66 percent of researchers are kept in the affiliate. Now without the restriction, more talents flow into the United States, leading to a fall in high skill wage. MNEs can hire more talents in headquarters with less cost. This decreases the need for MNEs to hire talents in the affiliate. At the same time, the high skill wage in the RoW increases due to immigration, and this further decreases the need for R&D offshoring.

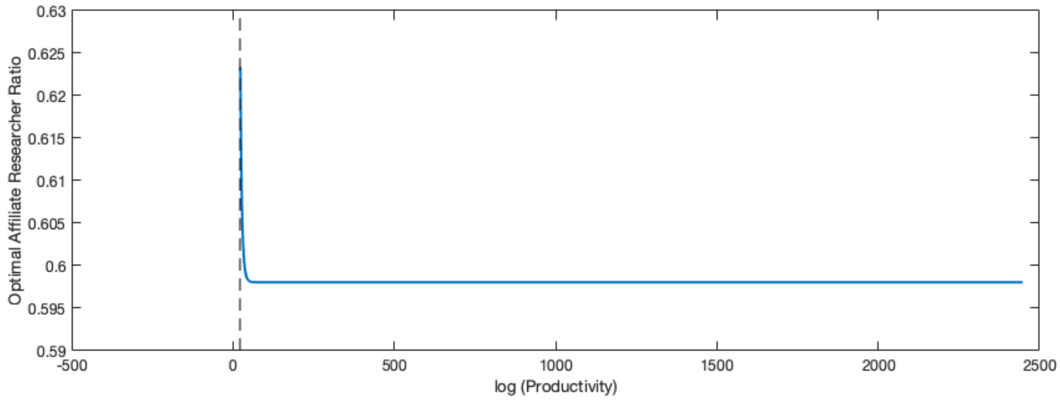
Figure 1 plots the ratio of the new steady-state over benchmark on the optimal affiliate researcher across MNEs' log productivities. All firms choose a much lower number of affiliate researchers. As a result, the average affiliate researcher ratio over headquarters is 14.43 percent, which indicates that with the current elasticity of substitution γ in the headquarters and affiliates innovation efficiency, immigration restriction could explain 47.8 percent talent offshoring of MNEs. If γ doubles, in which headquarters' innovation can be easily replaced by the affiliates', then the researcher ratio of affiliates over parents will further reduce to 7.52 percent, and the immigration restriction will account for 72.8 percent of the MNEs' talents offshoring.

By having a more efficient R&D investment, MNEs can choose a higher successful probability q, hence the productivity gets improved. Figure 2 shows that all MNEs optimally choose higher efficient units of research h^* compared to the benchmark. The aggregate productivity of MNEs (Z_a^1) increases. The inflow talents do not have any impact on the threshold firm, under the current parameter. Table 4 summarizes the results.

4.2 Aggregate Productivity

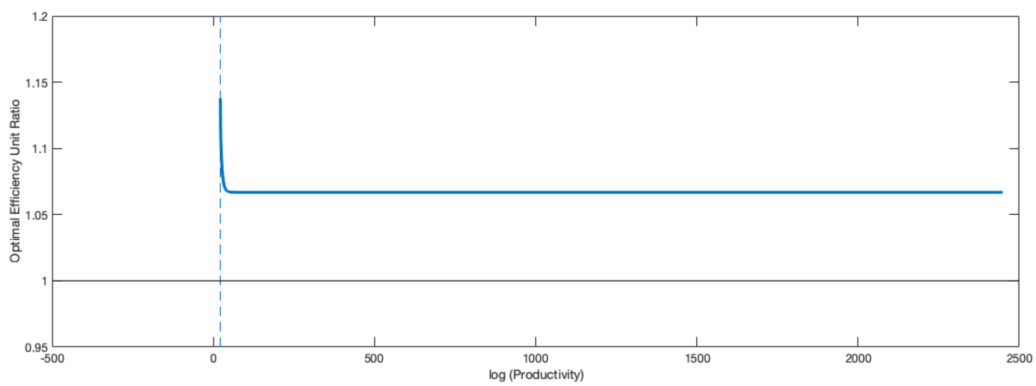
The impact of the extra researcher inflow to the domestic-only and exporting firms is through the general equilibrium effect, to be more specific, through the free entry condition. Recall the static

Figure 1: Optimal Affiliate Researcher: Counterfactual over Benchmark



Note: The dotted line represents the cutoff productivity of MNEs $\bar{z}_1^a$, as we can see from the figure, all MNEs choose much smaller number of affiliate researcher.

Figure 2: Optimal Efficiency Unit: Counterfactual over Benchmark



Note: The dotted line represents the cutoff productivity of MNEs, as we can see from the figure, all MNEs choose higher efficiency unit of research.

Table 4: Free Mobile Experiment: Impact to MNEs

	w_2^H to benchmark	h_a^*/h_n^*	Z_a^1 to benchmark	MNEs Researcher Share
Benchmark	1	27.7%	1	49.1%
Free Move ($\gamma = 5$)	1.14	14.4%	1.05	53.5%
Free Move ($\gamma = 10$)	1.14	7.5%	1.04	54.6%

$Z_a^1 = \int 1_a^1(z) \exp(z) \frac{M^1(z)}{M_e^1} dz$ is an index of productivity aggregated across all U.S MNEs. MNEs researcher share is the fraction of researchers MNEs use out of total researchers used in process innovation in the U.S The threshold firm is the firm that has the smallest productivity across MNEs. The number in the table represents the location of this firm on the grid. U.S talent wage is normalized to 1.

Table 5: Free Mobile Experiment: Impact to Aggregate Productivity

Ratio to benchmark	Z_d^1	Z_x^1	Z_a^1	M_e^1	Z^1
Free Move ($\gamma = 5$)	1.05	0.82	1.05	1.26	1.06

Note: The reduction of aggregate productivity of exporting firms is due to the free entry condition. To keep the condition hold, domestic profit decreases 1%. Although exporting profit increases, there are still fewer firms that could cover the exporting fixed cost.

profit is a firm's productivity times a market term Π_i^d, which can be seen as a unit profit. As more firms are getting productive, the unit profit of the domestic market drops to keep the free entry condition holds. Although this does not affect the operating productivity threshold $\bar{z}_1^d$, it increases the exporting threshold $\bar{z}_1^x$, in other words, fewer firms can afford the exporting fixed cost. Hence, the aggregate productivity index of exporting firm Z_x^1 decreases, and the aggregate productivity index of domestic-only firm Z_d^1 increases.

Having a larger talent stock does not only benefit the process innovation, but it also allows the economy to have more firms, or equivalently, higher product innovation. The total mass of firm M_e^1 in the United States increase 26.2 percent. Since labor is the only variable factor of production, the ideal measure of aggregate productivity from $Y_i = Z_i \cdot L_i$ is given by

$$Z^1 = \{M_e^1[Z_d^1 + Z_x^1 + Z_a^1 + Z_x^1 \cdot u \cdot D^{1-\rho}]\}^{1/(\rho-1)}$$

The overall productivity, as a result of the mixed effect of the process and product innovation, becomes higher. The results are listed in Table 5.

4.3 Welfare

As a result of higher aggregate productivity, total firm profits (in real terms) increase 16.4 percent, from 0.25 to 0.29. Firms also demand more production workers, leading to a 6.5 percent increase in production workers' real wage. Hence, the native low skill workers are the winners of the high skill immigration, as they get higher profits from firms and earn a higher real wage. The welfare

Table 6: Free Mobile Experiment: Impact to Welfare

Ratio to Benchmark	Firm profit	w_1^H/P_1	w_1^L/P_1	Low-skilled Welfare Gain	High-skilled Welfare Gain
Free Move ($\gamma = 5$)	1.16	0.86	1.06	8.4%	-10.9%

Note: the firm profit is evenly distributed across natives, which consists of 0.935 low skilled production workers and 0.05 high skilled innovation researchers.

gain[14] is 8.4 percent by using the measure of equivalent variation in consumption.

High skill workers, on the other hand, lose from the relaxation on immigration restriction, since inflow foreign talent lowers the real wage by 13.9 percent. Welfare loss is 10.9 percent. But since the low skill workers are the majority of the economy, when taking the aggregate, the whole economy gains from removing the immigration restriction. Results are listed in Table 6.

5 Conclusion

In this paper, I built a dynamic general equilibrium model to quantify the impact of high skill immigration restriction on MNEs research offshore and the aggregate economy. The model includes a detailed firm structure, where the firm can make endogenous decisions on exit, export, MNE activity and process innovation. A multinational can slice up its innovation process, and relocate researchers into affiliates to relax the immigration constraint. The results show the current immigration restriction could account for 47.8 percent of MNEs talent offshore behavior that we see in the data. By eliminating the restriction, the overall economy benefits from a more efficient process innovation from incumbent firms and a higher product innovation. The total productivity and aggregate welfare all get improved. The low skill production workers are the big winner of relaxing the high skill immigration restriction.

This paper abstracts from some aspects of the reality that might be important in explaining the R&D offshore. For example, the model has overlooked the role of sectors. As data has suggested,

[14] Welfare metric is equivalent variation in consumption, defined as the change in consumption at the old steady-state that leaves households indifferent between the old steady-state and the new steady-state.

firms in different sectors have different dependence on highly skilled immigrants. The sector that has been constrained the most is IT, which is an important intermediate input for other sectors. Incorporate sector input-output linkage may strengthen the impact of high skill immigration restriction. Another aspect that I have overlooked is the endogenous choice households could make to change their types. Low skill workers might want to invest in human capital and become high skilled researchers. It will then reduce the impact of high skill immigration restrictions.

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Appendix

A Evidence

This section presents some facts regarding the demand for H-1B visa and how MNEs react. As explained earlier, H-1B visa program operates on first-come first-serve basis. If the total applications in the year exceed the annual cap within a short period, the visa will be distributed by a random lottery. The below table records how many days it take to reach the cap limit across years, and within the filling days, how many petitions the system receives. The table therefore serves as the evidence that there is a increasing need for foreign born high-skilled workers, as the filling days shorted from more than three hundreds days to five days in the recent years.

Table 1: Final Receipt Dates of the Cap-Subject H-1B Petition Filing Period in Each Fiscal Year

Fiscal Year	Final Receipt Date	Days in Filing Period	Number of Lottery-Subject H-1B Petitions Received During the Filing Period
2004	February 17, 2004	323	
2005	October 1, 2004	184	
2006	August 10, 2005	132	
2007	May 26, 2006	56	
2008*	April 3, 2007	3	150,000
2009*	April 7, 2008	7	163,000
2010	December 21, 2009	265	
2011	January 26, 2011	301	
2012	November 22, 2011	236	
2013	June 11, 2012	72	
2014*	April 7,2013	7	124,000
2015*	April 7, 2014	7	172,500
2016*	April 7, 2015	7	233,000
2017*	April 7, 2016	7	236,000
2018*	April 7, 2017	5	199,000
2019*	April 6, 2018	5	190,098

Figure 3 presents the fact that there is a positive relation between firm H-1B visa filing and oversea affiliate R&D effort. The data is in 2 digit industry. Since the H-1B visa is distributed by lottery, this figure may suggests when firms find it hard to bring the high-skilled foreign workers to the US headquarter, they increase the R&D in affiliates.

Lastly, Figure 4 shows that there is an increasing trend for MNEs to engage R&D in the affiliates. It also shows the affiliates are not the pure recipient of the R&D carry out by the headquarter.

Figure 3: MNEs demand for H-1B visa and effort on R&D in oversea affiliates (sector level)

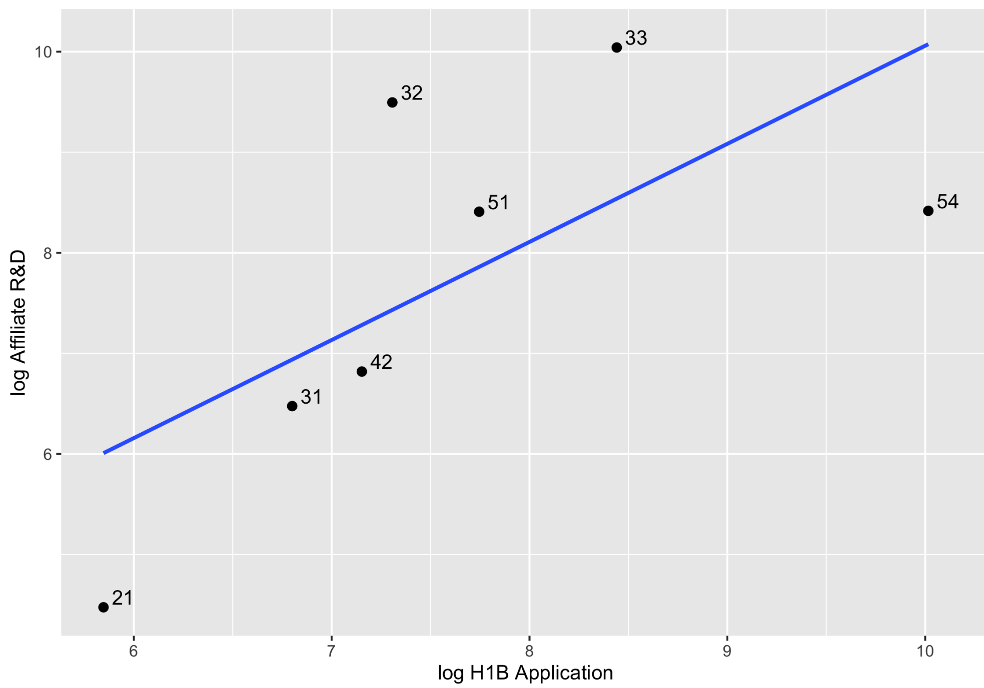
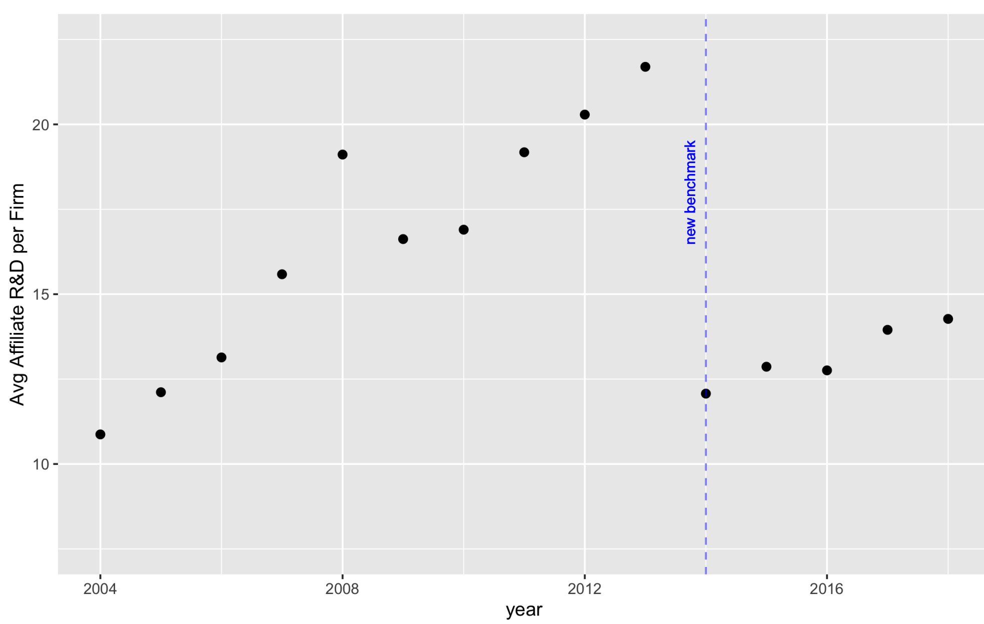


Figure 4: Increasing trend of affiliate R&D



B Solve the equilibrium

To solve the equilibrium, first I will show firm decisions are the solution to a one-dimensional fixed point problem given the term of trade and high skill wage ratio. Together with the aggregate quantities and prices, the equilibrium can be uniquely pinned down. The "term of trade" variable is defined as

$$u = \frac{(P_2)^{\rho} \cdot Y_2}{(P_1)^{\rho} \cdot Y_1} \tag{19}$$

which summarizes the size and price level differences across countries. I set $w_1^H = 1$ as the numeraire.

To solve for firm's steady-state, we must solve the firm's Bellman equation (13) and (14), removing the time subscripts from all variables, and letting $R_t = 1/\beta$. I start with RoW. With the guess on w_2^H and u, RoW static profit can be expressed as

$$\Pi_2^d(z) = \Pi_2^d \exp(z); \quad \Pi_{21}^x(z) = \Pi_2^d \frac{D^{1-\rho}}{u} \exp(z) - F_x^2 \cdot w_2^H$$

Π_2^d is the only unknown. Standard arguments give that the Bellman equation has a unique solution $V^2(s)$, corresponding to any given value of Π_2^d under appropriate parameter restrictions. In addition, the solution for $V(s)$ is weakly increasing in Π_2^d, and the value for operating firm $\bar{V}^2(z)$ is strictly increasing in Π_2^d.

Next, to pin down the Π_2^d, we need to use the free-entry condition (15). Notice (i) the right-hand side of the free entry condition is weakly increasing in Π_2^d, and if it is strictly positive, it is also strictly increasing in Π_2^d; (ii) right-hand side will equal zero if $\Pi_2^d = 0$. These two conditions guarantee the existence and uniqueness of Π_2^d.

After solve Π_2^d, the affiliate profit for U.S firm $\Pi_{12}^a(z)$ is known for each z by (10). The US firm static profits for domestic sales and export sales can be expressed as

$$\Pi_1^d(z) = \Pi_1^d \exp(z); \quad \Pi_{12}^x(z) = \Pi_1^d \cdot u D^{1-\rho} \exp(z) - F_x^1$$

Π_1^d is the only unknown. With the same argument, one can use free-entry condition (15) for the U.S to uniquely pin down Π_1^d. The solutions to these two Bellman equations also give us firms' exit, export, MNE decisions, as well as price, output decision and the demand for low skill production workers and high skill researchers.

By (16), the firm side solutions imply a steady-state distribution scaled by the mass of entering firms, $\tilde{M}^i(z) = M^i(z)/M_e^i$, for each country. Recall the definitions of three indices of aggregate productivity in the U.S:

$$Z_d^1 = \int 1_d^1(z)\exp(z)\tilde{M}^1(z)dz \tag{20}$$

$$Z_x^1 = \int 1_x^1(z)\exp(z)\tilde{M}^1(z)dz \tag{21}$$

$$Z_a^1 = \int 1_a^1(z)\exp(z)\tilde{M}^1(z)dz \tag{22}$$

where Z_d^1 is an index of productivity aggregated across all operating, domestic-only firms, Z_x^1 is an index of productivity aggregated across all US firms that export, and the last one Z_a^1 is across all U.S multinationals, all scaled by the mass of entering firms. Similarly, one can define Z_d^2 and Z_x^2 for the RoW.

The unknown aggregates are $M_e^1,\ M_e^2,\ P_1,\ P_2,\ Y_1,\ Y_2,\ w_1^L,\ w_2^L,\ H_f$ and we need two extra equations to update the guess w_2^H and u. Labor market clearing conditions give us 4 equations, price index and final good production function give us another 4. All these plus the equation (3), trade balance (17) and the definition of u guarantees the solution.