Immigration, Trade, & Technology Capital

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Abstract

Recent US policy has made both trade and skilled immigration into the US more restrictive. While the impact of these policies on some macroeconomic variables is evident, their joint impact on innovative activities is not. In this paper, we incorporate both policy levers into a dynamic general equilibrium model in which final goods producers make costly investments in technology capital. Domestic and foreign intermediate goods producers rent this technology capital, which augments both native and foreign born skilled labor. We parameterize the model to match data from the US and China and then run counterfactual exercises to understand the joint impact that the two policies have on production and investment in technology capital. We find that while both policies reduce the accumulation of technology capital, trade restrictions reduce it by more than a reduction in skilled immigration. Moreover, when the two policies are combined, both the domestic and the foreign stock of technology capital fall, reducing domestic production, as well as bilateral trade flows. This has implications for how these policies impact long run productivity in both countries.

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1 Introduction

College-educated foreign-born workers in the US currently make up more than 20% of the total skilled employed US workforce and have crucial impacts on firm productivity and knowledge creation (Glennon (2024b).[1] Furthermore, industries that have been identified as being strategically important, such as the technology sector or the advanced manufacturing sector are disproportionately likely to employ foreign-born workers.[2] However, given the growing share of such workers, there have been increasing debates on skilled immigration policy and its impacts. Recent policy changes have tended to be protectionist and restrictive, creating significant barriers for skilled foreign workers (for instance, the $100k H-1B visa fee) and higher scrutiny, slowing down talent inflows. There has been a notable plunge in the 2025 global demand for US degrees, which could translate to lower US firm access to foreign skilled workers.[3]

The impacts of reduced inflows of skilled foreign workers on firm knowledge production can be exacerbated in an environment where firms also face tighter restrictions on imported intermediate inputs through higher tariffs. Many firms, particularly multinationals, have a disproportionate engagement in both trade flows and in foreign worker hiring and are plausibly most impacted by restrictive immigration and trade policies. Multinationals account for 42% of all imports in the US and while the exact share of foreign born multinational employees is not regularly reported, multinationals are disproportionately represented in industries that have high shares of foreign born workers.[4] In addition, these firms tend to engage more actively in the production of know-how, innovation, and new technology capital. In fact, US multinational parents accounted for 67% of all R&D expenditures in the US in 2021 and are concentrated in R&D-intensive industries. Therefore, the firms that are most heavily impacted by trade and immigration policies are also those that are the drivers of the production of new technology capital within the economy.

Motivated by this, we study the general equilibrium impacts of i) policies that reduce foreign-worker inflows into the US and ii) policies that increase trade restrictions, in an environment where firms hire foreign skilled workers, import intermediate inputs and export

[1] Skilled foreign workers include foreign-born workers with a bachelors degree or higher compiled from the Current Population Survey.

[2] O'Brien and Ozimek (2024) reports that strategic industries have workforces that are composed of 20% workers with graduate degrees and foreign-born workers make up 36% of of the workforce in strategic industries that hold a graduate degree or higher.

[3] `https://thepienews.com/global-demand-for-us-masters-degrees-plunges-by-60/`

[4] `https://apps.bea.gov/scb/issues/2024/09-september/0924-multinational-enterprises.htm` reports that multinationals are heavily concentrated in computer systems (27.9% foreign born), scientific research (27.1% foreign born), and medical equipment and supplies (24.8% foreign born), where the share of the workforce that is foreign born is reported by O'Brien and Ozimek (2024).

intermediates. Crucially, we consider final goods producing firms which make costly investments in a stock of technology capital that can be rented out to intermediate goods producers and used non-rivalrously in multiple locations. One example of non-rivalrous technology capital is a blueprint necessary to produce a particular good. The final goods producer develops the plans for the production of the final good and its parts and then rents that plan to all producers of its intermediate goods, whether they are producing domestically or abroad. Therefore, intermediate good producers in each country may produce for a domestic final goods producer or produce and export to a foreign final goods producer simultaneously, operating two different technologies within a single firm.

For a final goods producer, the ability to deploy the technology capital increases the effective returns to investing in it.[5] We will assume that this technology capital is skill-labor augmenting and that firms in the US employ both native and foreign born workers. As such, the final goods producer may enjoy increased returns to investing in the technology capital when they are able to deploy it abroad *and* when the supply of foreign born workers is higher in the US, increasing the stock of workers available to utilize it. In a standard model with multi-country production, one can imagine that employment of foreign born workers might substitute for imported intermediates that also use foreign born labor in their production. However, in a setting like ours, it could also be the case that domestic production of intermediates employing foreign born workers complements foreign production of intermediates. We believe that a setting that allows for both possibilities is more representative of the experience of firms that both import intermediates and hire foreign skilled workers and, therefore, more relevant for the examination of how trade and immigration policies interact to impact investment decisions by the final goods producer.

Our main contribution is providing a unified framework in which to explore the interplay between policies governing international trade and skilled immigration, and the impact these policies have on domestic production, trade, and most importantly on technological advancement. In order to do this, we adapt the model developed in Waddle (2021) to incorporate both skilled immigration and diffusion of technology capital through trade. As in Waddle (2021), technology capital is rented by intermediate goods producers from the final goods producer, which owns and invests in it. Here, our model features both skilled native and skilled foreign born workers. We model increasing trade restrictions as an increased iceberg transportation cost and stricter immigration policy as a decrease in the cap of skilled foreign workers available to work in the US.[6] We parameterize the model to match data from the United States and China. In our baseline counterfactual exercises, we find that increasing the trade costs cause a decrease in accumulated technology capital in the US, resulting in an increase in domestic production of the intermediate good and decreased imported inter-

[5]Following Waddle (2021) and Mandelman and Waddle (2020) we allow for the transfer of technology capital to occur through arms-length transactions, through rental, so the final goods producer can be thought of as either a multinational or a firm that sources intermediate both domestically and abroad.

[6]The main channel for hiring foreign workers in the US is the H-1B visa policy, which has a cap of 85,000 visas for private firms per fiscal year. This cap has been binding since 2004 and therefore we can also think of a lower cap as a lower supply of foreign skilled workers in the US.

mediates, as one would expect. Interestingly, in general equilibrium, an increase in import tariffs also reduces exports of domestic intermediates. If instead, we decrease the cap on high skilled immigration, we also find a decrease in technology capital in the US and the foreign country, but a decrease in domestically produced intermediates and a slight increase in imported intermediates. Note that when the cap on skilled immigrants to the US falls, this results in fewer workers available to produce intermediate goods in the US for both the domestic production line and the foreign one. Therefore, we expect to see the returns to investing in technology capital, which is skill augmenting, fall as a result. Foreign born workers in the US produce for both the domestic and the foreign production line, so this impacts investment in both stocks of technology capital.

These results together would suggest that the final goods producer is using domestic production which employs foreign workers as a substitute for foreign production. When we both reduce the immigration cap and increase trade costs to reflect recent US policy changes, we find the largest impact on the stocks of technology capital, though some mitigation in the impacts on the production of intermediates, with the production of both domestic and foreign varieties falling.

We contribute to a large strand of literature that studies the interplay between trade and productivity (see, for example Helpman et al. (2004)) which studies the impact that reduction in trade costs has on productivity through reallocation toward more productive firms. We draw heavily on the seminal works of McGrattan and Prescott (2009) and Holmes et al. (2015), which develop the idea of technological investment and diffusion of technology capital through foreign direct investment. We contribute more specifically to the literature that focuses on the impact the reductions in trade costs have on *investments* in productivity-increasing technology capital in settings where technology is diffused through trade with arms-length trade partners. Most closely related is Waddle (2021), which studies the interplay between international trade policy and the investment in and diffusion of intellectual property in the form of technology capital. In that paper, reductions in trade costs spur investment in technology capital in both countries, as we find here. Another related paper is Mandelman and Waddle (2020) which studies the impact of trade and intellectual property protection policies on the diffusion of and investment in technology capital. Papers such as Akcigit et al. (2018) also show that trade costs can impact R&D expenditures by firms.

Our paper also adds to the growing literature that studies the impacts of U.S. skilled immigration. For instance, Bound et al. (2017), Mehra and Shen (2022), Waugh (2017), Mehra and Kim (2023), Mandelman et al. (2025), study the impacts of US skilled immigration policies in a general equilibrium framework. We also contribute to empirical literature on the impacts of skilled immigration on offshoring, productivity, and employment (for instance, Peri et al. (2015), Glennon (2024a), Doran et al. (2022)). To the best of our knowledge, our paper is the first to incorporate skilled immigration, intermediate-input trade, and technology capital investment in a two-country general equilibrium framework. This allows us to explicitly study the interactions between trade and skilled immigration policy changes on domestic and foreign technology capital investment as well as on trade.

The paper is organized as follows: In Section 3, we provide evidence of the relationship between skilled immigration and investment in new ideas; Section 3 presents the model; Section 4 contains comparative statics exercises to highlight the role of the two policy levers and key mechanisms in the model; Section 5 contains the parameterization and results; and Section 6 concludes.

2 Motivating Evidence

To motivate our focus on skilled foreign workers in this framework, we introduce some suggestive evidence to show that foreign skilled workers are potentially important for R&D investment, a measure of technology capital because it is spending on creating or improving knowledge. For the motivating evidence, we focus on firms that use the H-1B visa policy.[7] First, firms that hire foreign skilled workers tend to be concentrated in R&D intensive sectors (Table 1).

Table 1: Industry R&D and Firm Demand for Foreign Skilled Workers

NAICS4	Industry	Avg Firm Demand (%)	R&D Intensity (%)	R&D Emp. Prop. (%)
5415	Computer systems design	50.35	12	21.14
3344	Semiconductor	1.99	24	29.90
3342	Communication equipment	1.50	12	27.48
5112	Software publishers	1.26	14	30.32
5417	Scientific R&D services	0.93	29	36.70
3254	Pharmaceuticals	0.24	17	25.90
3364	Aerospace products	0.05	10	9.27

Notes: Average firm demand is calculated as the average proportion of Labor Condition Applications (LCA) filed by firms between 2013-2019 (USCIS). R&D employment proportion (column 5) refers to the share of R&D employment in total employment. Sector level R&D variables are compiled from National Center for Science and Engineering Statistics, NSF (2022).

Second, it has been shown by previous literature that foreign skilled workers increase firm innovation (for instance, Kerr and Lincoln (2010)). We contribute to these results by studying the impact of hiring new H-1B workers on firm R&D investment. We focus on the impact of positive 'New Approvals' of H-1B workers in fiscal years 2014 and 2015 (from the publicly available United States Citizenship and Immigration Services (USCIS) H-1B

[7]Firms play a crucial role in hiring, sponsoring, and incurring costs at each stage of the H-1B application process for a foreign worker. The first step requires a firm that wants to hire a foreign worker to file a Labor Condition Application (LCA) with the Department of Labor in which one of the items that they need to specify is the number of foreign workers they would like to hire for a particular occupation. These LCAs signal vacancies or firm demand for foreign skilled labor.

Employer Data Hub).[8] We combine foreign worker hiring outcomes with data on R&D investment in Compustat using name matching algorithms and firm location.

We use the following event study approach to illustrate the impact of hiring foreign skilled workers in the reference fiscal years on firm R&D investment in the following years.

$$\ln(y_{i,t}) = \sum_{\tau \neq b} \beta_\tau [NewApproval_i \times 1(\tau = t)] + \gamma_i + \gamma_t + \epsilon_{i,t} \quad (1)$$

where i denotes the firm and the base year is $b = 2014$.[9] $NewApproval_i = 1$ if firm i gets a positive approval for an H-1B worker in fiscal years 2014 or 2015, and zero otherwise. The specification includes firm (γ_i) and year (γ_t) fixed effects. The outcome $y_{i.t}$ includes firm R&D investment in year t.

Figure 1: Impact on R&D Investment

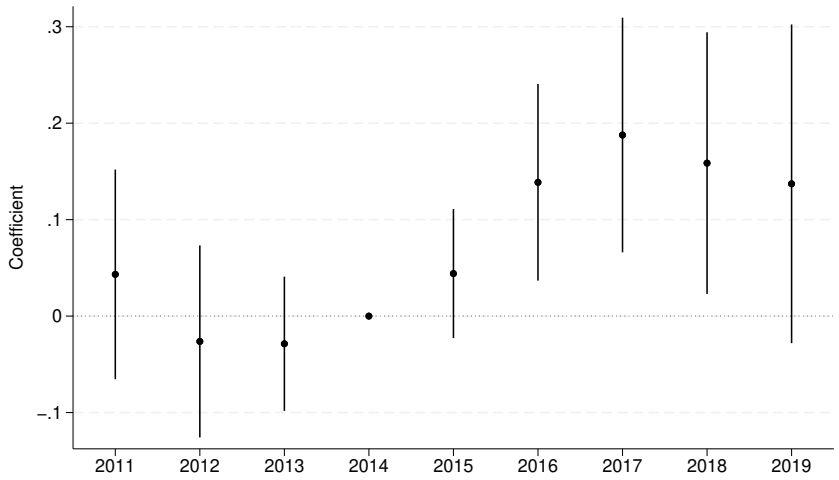


Figure 1 reports the β coefficient estimates and their 95% confidence intervals. The results indicate that firms that received new foreign skilled workers in fiscal years 2014/2015 saw a significant increase in firm R&D investment in the immediate post years, compared to firms that did not receive new foreign workers. The effect decreases over time. Importantly, for this analysis, the results support our hypothesis that getting a new foreign skilled worker in FY 2014/2015 was not correlated with firm R&D outcomes in the previous calender years (2011-2013), while this did positively impact R&D investment in immediate post years.

[8]As mentioned above, there is a cap of 85,000 new H-1B workers in each fiscal year that are allotted across private firms via a random lottery when the quota is met, which has been the case in most years since 2004. 'New Approvals =1' in this context implies that the firm was allocated a new H-1B worker in that period.

[9]Note that H-1B lottery outcomes for fiscal years 2014 and 2015 were announced in April 2013 and April 2014, with an employment start date in October 2013 and October 2014, respectively. Therefore, the lottery outcomes in fiscal years 2014 and 2015 correspond to outcomes in calendar years 2013 and 2014, respectively.

3 The Model Environment

The model economy is a modification of the model in Waddle (2021) and features two countries, the United States (denoted by u) and the rest of the world (denoted by r). In each country, there is a non-tradeable final good produced by perfectly competitive firms. This final good is a CES aggregate of a continuum of varieties, some of which are produced domestically and some of which are imported and subject to an iceberg trade cost. The final good can be used either for consumption or for investment in the stock of technology capital, which is used in the production of the intermediate varieties. The production of these varieties requires skilled domestic and foreign labor, as well as the aforementioned technology capital. The producer of an individual variety is a monopolistic competitor and may produce that variety for a domestic final goods producer and for a foreign final goods producer at the same time, meaning that they may operate two different technologies within a single firm. We will refer to the operation of different technologies within a single variety as production lines within that variety or firm. Aggregate labor of each type is inelastically supplied and is perfectly mobile across production lines.

3.1 Final Goods Producers

In each industry and each country, there are perfectly competitive producers of a non-tradable final good which seek to maximize the infinite sum of discounted dividends. The final good in country k is denoted Y_k and is composed of a CES aggregation of intermediate varieties $y^d_{kj}(\omega)$, where the variety is denoted by ω and the country of origin for that particular variety is indexed by j. The final goods producer owns and invests in a stock of technology capital, Z_k, which it rents to the producers of the intermediate varieties of which its final good is composed. It earns returns r_{kk} and r_{kj} from renting its technology capital to domestic and foreign producers of intermediate varieties, respectively. To economize on notation, we suppress the time subscript. These final goods producers in country $k \in \{u, r\}$ maximize the sum of discounted dividends by solving the following problem:

$$max \sum_{t=0}^{\infty} P_k D_k \tag{2}$$

s.t.

$$D_k = Y_k + Z_k \left(r_{kk} + r_{kj}\right) - I_k - \int p_{kj}(\omega) y^d_{kj}(\omega) d\omega, \tag{3}$$

$$I_k = Z_k^{'} - (1-\delta) Z_k, \tag{4}$$

$$Y_k = \left[\int y^d_{kj}(\omega)^{\rho} d\omega\right]^{1/\rho}. \tag{5}$$

The dividend is equal to the producer's total output (Y_k), plus rental income earned by renting the technology capital to domestic producers ($Z_k r_{kk}$) and to foreign producers ($Z_k r_{kj}$), minus investments in technology capital (I_k), minus payments for intermediate goods. Technology capital is accumulated via a standard law-of-motion, in which today's stock of technology capital depreciates at a rate δ, so that tomorrow's stock of technology capital, $Z_k^{'}$, is equal to undepreciated technology capital Z_k plus investment, I_k. A variety ω is producer country-specific, and the final producer will purchase varieties from both countries, substituting towards more domestic varieties if the cost of foreign intermediates is higher. All varieties are aggregated to make the final good in the industry and $\frac{1}{1-\rho}$ is the elasticity of substitution between these varieties within the industry. P_k is the price of the final good produced to be consumed in country k.

Technology Capital: Investment and Rental

The technology capital that we consider, Z_k, can be thought of as a stock of ideas, blueprints, or production techniques and, as such, is non-rivalrous in nature. These ideas and production techniques are the ones that are necessary in order to make an intermediate part for the final product so that when the final goods producer begins to purchase more intermediates from foreign producers, the foreign producer will have to rent more of this technology capital in order to produce these parts. This causes the rate of return on technology capital to increase for the final goods producer, thus inducing them to increase investment in it. Moreover, the rental of technology capital in order to produce the appropriate part for the foreign final goods producer is the channel by which this technology capital will be diffused across borders.

We assume that this technology augments both native high-skill labor (h) and foreign-born high-skill labor (f), though we allow for the parameters governing the extent to which this is true to differ across the two types of labor.

3.2 Production of Varieties

The problem of the intermediate goods producers vary by country. The intermediate goods producer that produces an intermediate variety ω in country u can produce both for the domestic market (u) and for the foreign market (r). They choose the output for the domestic market ($y_{uu}(\omega)$), the output for the foreign market ($y_{ru}\omega$)), domestic labor to produce for the domestic market ($h_{uu}(\omega)$), domestic labor to produce for the foreign market ($h_{ru}(\omega)$), foreign-born labor to produce for the domestic market ($f_{uu}(\omega)$), foreign-born labor to produce for the foreign market ($f_{ru}(\omega)$), and an amount of domestic and foreign technology (Z_u, Z_r) to maximize profits, taking the inverse demand function, wages (w_u^h, w_u^f), and the rental rates for technology (r_{uu}, r_{ru}) as given. The first subscript refers to the country for which the intermediate variety is produced and the second refers to the country in which production takes place.

The producer of the intermediate good must use the technology of the supply chain

for which they are producing to make the variety for that firm. The intermediate-goods producing firm in country u therefore solves the following problem:

$$\max p_{uu}(\omega)y_{uu} + \frac{p_{ru}(\omega)}{\tau_{ru}}y_{ru}(\omega) - w_u^h\left(h_{uu}(\omega) + h_{ru}(\omega)\right) - w_u^f\left(f_{uu}(\omega) + f_{ru}(\omega)\right) - Z_u r_{uu} + Z_r r_{ru} \tag{6}$$

s.t.

$$y_{ju}(\omega) = A_u\left[\theta\left(Z_j^{\alpha}h_{ju}^{1-\alpha}(\omega)\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta)\left(Z_j^{\gamma}f_{ju}^{1-\gamma}(\omega)\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \qquad \forall j \in \{u,r\} \tag{7}$$

$$y_{ju}(\omega) = \left(\frac{p_{ju}(\omega)}{P_j}\right)^{\frac{1}{\rho-1}}Y_j \qquad \forall j \in \{u,r\}, \tag{8}$$

where $\sigma > 0$ is the elasticity of substitution between domestic and foreign-born labor. $A_u > 0$ is the level of the country-specific total factor productivity (TFP) and P_j is the cost of the final good produced in country j, the country for whose supply chain the intermediate variety is being produced. There is an iceberg trade cost on goods produced in r, τ_{ru}.

The intermediate goods producer in country r also produces a variety ω for both the final goods producer in r, $y_{rr}(\omega)$, and for the final goods producer in u, $y_{ur}(\omega)$. As in country u , the intermediate goods producer will produce for both production lines, but must do so using the technology of the final goods producer for which they are producing. The main difference here is that the firms will only use f-type labor, not hiring any workers who are native to u. Therefore, the intermediate goods producers in r solve:

$$\max p_{rr}(\omega)y_{rr} + \frac{p_{ur}(\omega)}{\tau_{ur}}y_{ur}(\omega) - w_r^f\left(f_{rr}(\omega) + f_{ur}(\omega)\right) - Z_u r_{ur} + Z_r r_{rr} \tag{9}$$

s.t.

$$y_{jr}(\omega) = A_r\left[Z_j^{\gamma}f_{jr}^{1-\gamma}(\omega)\right] \qquad \forall j \in \{u,r\} \tag{10}$$

$$y_{jr}(\omega) = \left(\frac{p_{jr}(\omega)}{P_j}\right)^{\frac{1}{\rho-1}}Y_j \qquad \forall j \in \{u,r\}, \tag{11}$$

$A_r > 0$ is the level of the country-specific total factor productivity (TFP) and P_j is the cost of the final good produced in country j, the country for whose supply chain the intermediate variety is being produced. There is an iceberg trade cost on goods produced in u for the final goods producer in country r, τ_{ur},. which may be different from the iceberg trade cost on intermediates flowing in the opposite direction.

3.3 Households

Households in country u own all firms in their own country and therefore are the residual claimants of all profits and dividends earned therein. They choose consumption, c_u, share

holdings of domestic final goods producing firms $S_u^{'}$, and bond holdings ($b_u^{'}$) to solve the following problem:

$$\max \sum_{t=0}^{\infty} \beta^t c_u \tag{12}$$

s.t.

$$P_u c_u + b_u^{'} - b_u + V_u \left(S_u^{'} - S_u \right) = w_u^h H_u + w_u^f F_u + (1+r) b_u + S_u D_u + \int_{\Omega_i} \pi_u(\omega) d\omega, \tag{13}$$

where D_u denotes the dividends and V_u is the share price of firms in country u and $\pi_u(\omega)$ are the profits from the intermediate producer of variety ω producing for the final goods producer in country u. Households in country u include domestically-born laborers and foreign-born laborers. This is without loss of generality and implies risk-sharing across all households.

Households in country r solve a very similar problem, but only include laborers born in country r. The households solve the following problem:

$$\max \sum_{t=0}^{\infty} \beta^t c_r \tag{14}$$

s.t.

$$P_r c_r + b_r^{'} - b_r + V_r \left(S_r^{'} - S_r \right) = +w_r^f (\overline{F} - F_u) + (1+r) b_r + S_r D_r + \int_{\Omega_i} \pi_r(\omega) d\omega, \tag{15}$$

where now the total share of f-type households is the total number of laborers born in r, $\overline{F}$, minus those who emigrate to country u, F_u. The rest of the problem mirrors that of the households in country u.

3.4 Aggregation and Market Clearing

Final output in each country k must equal domestic demand for consumption and investment

$$Y_k \;\; = \;\; c_k + I_k \qquad k \in u, r, \tag{16}$$

and total output for each variety ω must equal its world demand,

$$y_{kk}(\omega) + y_{jk}(\omega) \;\; = \;\; y_{kk}^d(\omega) + \tau_{jk} y_{kj}^d(\omega). \tag{17}$$

Labor market clearing in each country requires that the labor used in country k to produce all varieties for the domestic production line and all varieties for the foreign production line

is equal to the aggregate inelastic supply of labor of each type. The labor market clearing conditions are expressed:

$$H_u = \int_\Omega \left(h_{uu}(\omega) + h_{ru}(\omega)\right) d\omega \tag{18}$$

$$F_u = \int_\Omega \left(f_{uu}(\omega) + f_{ru}(\omega)\right) d\omega \tag{19}$$

$$\overline{F} - F_u = \int_\Omega \left(f_{rr}(\omega) + f_{ur}(\omega)\right) d\omega, \tag{20}$$

where the final condition requires that the total supply of labor that remains in country r after emigration, F_u, equals the total demand for labor in country r. Note that F_u is the cap on immigration into country u and will be treated as a policy variable. Recall also that a firm producing variety ω may produce both for the domestic production line, $y_{kk}(\omega)$, and for the foreign one, $y_{jk}(\omega)$.

In a given country, the households are identical and so no bonds will be traded within a country's borders. However, the bond market must clear across countries:

$$b_u + b_r = 0. \tag{21}$$

4 Understanding the Impact of Policy Changes

In the model, there are three separate policy parameters: $F_u, \tau_{ur}, \tau_{ru}$. The first is the cap on skilled immigration into the U.S. and the τ's are the iceberg trade costs associated with imported intermediates. We will focus on τ_{ur} first, which is the iceberg trade cost on imports into the U.S. In order to understand how each policy variable may impact variables of interest, we will make some simplifying assumptions. Here, we will consider a case where both countries only employ foreign-born labor, so that the problem of intermediate goods producers in the United States becomes:

$$\max p_{uu}(\omega) y_{uu} + \frac{p_{ru}(\omega)}{\tau_{ru}} y_{ru}(\omega) - w_u^f \left(f_{uu}(\omega) + f_{ru}(\omega)\right) - Z_u r_{uu} + Z_r r_{ru} \tag{22}$$

s.t.

$$y_{ju}(\omega) = A_u \left[Z_j^\gamma f_{ju}^{1-\gamma}(\omega)\right] \qquad \forall j \in \{u, r\} \tag{23}$$

$$y_{ju}(\omega) = \left(\frac{p_{ju}(\omega)}{P_j}\right)^{\frac{1}{\rho-1}} Y_j \qquad \forall j \in \{u, r\}, \tag{24}$$

We will further assume, for the moment, that the prices of intermediate goods are static. Therefore we focus on partial equilibrium impacts to gain intuition. The equations that characterize the solution are then:

$$\delta = p_{uu}\rho A_u Z_u^{\gamma-1} f_{uu}^{1-\gamma} + \frac{p_{ur}}{\tau_{ur}}\rho A_r Z_u^{\gamma-1} f_{ur}^{1-\gamma} \tag{25}$$

$$\delta = p_{rr}\rho A_r Z_r^{\gamma-1}(\overline{F} - F_u - f_{ur})^{1-\gamma} + \frac{p_{ru}}{\tau_{ru}}\rho A_u Z_r^{\gamma-1}\left(F_u - f_{uu}\right)^{1-\gamma} \tag{26}$$

$$0 = \frac{p_{ru}}{\tau_{ru}} Z_r^{\gamma}\left(F_u - f_{uu}\right)^{-\gamma} - p_{uu} Z_u^{\gamma} f_{uu}^{-\gamma} \tag{27}$$

$$0 = \frac{p_{ur}}{\tau_{ur}} Z_u^{\gamma} f_{ur}^{-\gamma} - p_{rr} Z_r^{\gamma}\left(\overline{F} - F_u - f_{ur}\right)^{-\gamma}. \tag{28}$$

We can use equations 27 and 28 to solve directly for f_{uu} and f_{ur}:

$$f_{uu} = F_u \frac{Z_u p_{uu}^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} \tag{29}$$

$$f_{ur} = (\overline{F} - F_u)\frac{Z_u (p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}. \tag{30}$$

Then the equations that characterize the solution can be re-written as:

$$\begin{aligned} F_1 = \delta &- p_{uu}^{\frac{1}{\gamma}}\rho A_u F_u^{1-\gamma}\left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}\right]^{\gamma-1} \\ &- \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}}\rho A_r (\overline{F} - F_u)^{1-\gamma}\left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} \end{aligned} \tag{31}$$

$$\begin{aligned} F_2 = \delta &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}}\rho A_u F_u^{1-\gamma}\left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}\right]^{\gamma-1} \\ &- p_{rr}^{\frac{1}{\gamma}}\rho A_r (\overline{F} - F_u)^{1-\gamma}\left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} \end{aligned} \tag{32}$$

Applying the implicit function theorem, we can show that $\frac{\partial Z_u}{\tau_{ur}} < 0$.[10] The intuition here is that as τ_{ur} increases, there is a direct effect on the return to investing in Z_u falls, which can most easily be seen in Equation 33, where we see that $\frac{p_{ur}}{\tau_{ur}}$ falls as τ_{ur} increases. This is standard in models with non-rivalrous technology capital, wherein technology capital essentially enjoys increasing returns to scale by the nature of being able to use it in a non-rivalrous way in multiple locations. Therefore, when the profitability of its use in one location falls, the return to investing in it overall also falls. Notice that here, the tariff also affects the quantity of labor hired by the intermediate goods producer producing in country r for imports into country u, f_{ur}. From Equation 30 it can be shown that f_{ur} falls as τ_{ur} increases. This comes primarily from the reduction in revenues to that production line, meaning that less output is produced and thus fewer inputs are required.

[10] Details are available in Appendix A.

We can also use this set of equations to understand the impact of immigration policy, represented by F_u. We again analyze Equations 31 and 32 to evaluate this impact and find that changing F_u has an ambiguous impact on Z_u. The intuition is that a decrease in F_u decreases available workers in the U.S. while increasing available workers in r, meaning that the increase in production costs in u that would be associated with lesser supply of workers would be offset by a corresponding decrease in production costs in r. This effect is mitigated somewhat in the full model, as firms are able to substitute across types of workers in the U.S., meaning that as supply of foreign workers falls, thereby driving up the foreign worker's wage in u, firms will substitute toward native-born workers. So, in the full model, all else equal, a decrease in F_u results in lower wages in r but has less of an effect on production costs in u, as firms have the option to substitute toward native-born workers.

5 Results

We solve the model stationary equilibrium and calibrate the steady state parameters to match data from US (Home) and China (Foreign) in recent years. The calibration is a work in progress and magnitudes are suggestive at this point. Structural parameters $(\delta, \rho, \sigma, \alpha, \theta)$ follow related quantitative trade/technology-capital literature including Waddle (2021). The US TFP level is normalized ($A_u = 1$), while China relative TFP A_r is proxied using Penn World Table TFP-at-PPP measures (via FRED). We set iceberg trade costs τ_{ru} and τ_{ur} to match average bilateral tariffs in 2023, and assume the cost of using foreign technology $\tau_z = 0$. Endowments are scaled by normalization ($H_u = 1$); $(F_u, \bar{F})$ set the baseline size of foreign skilled labor located in the US versus abroad. We set aggregate prices for the US final good producer as the numeraire i.e. $P_u = 1$ and therefore solve for relative prices. Table 2 summarizes the parameter values.

Table 2: Baseline calibration

Parameter	Value	Description
δ	0.08	Depreciation rate of technology capital
ρ	0.63	CES parameter in final-good aggregator
σ	1.51	Elasticity in US nested CES production
α	0.15	Tech exponent (domestic-labor block)
γ	0.15	Tech exponent (foreign-labor block)
θ	0.60	Weight on domestic-labor block (US)
A_u	1.00	US TFP level (normalization)
A_r	0.44	China TFP relative to US
$\tau_{u,r}$	1.21	Iceberg cost for US imports from China
$\tau_{r,u}$	1.19	Iceberg cost for US exports to China
τ^z	0	Wedge on foreign use of technology
H_u	1.00	US skilled-labor endowment (normalization)
F_u	0.3	Foreign-skilled labor located in US
$\bar{F}$	3.00	Total foreign-skilled labor

We study the impacts of policy counterfactuals that are motivated by recent restrictive policy changes/outcomes in trade and skilled immigration policy — i) a tighter immigration policy or a lower cap on foreign skilled workers proxied through a decrease in foreign skilled labor in the US (F_u falls by 10%), ii) 10% increase in import tariffs $\tau_{u,r}$, and iii) a combination of i) and ii). Table 3 gives the counterfactual results.

Table 3: Counterfactuals (10% shocks): Percent deviations from baseline

Scenario	Z_u	Z_r	Domestic Intermediate	Imported Intermediate	Exported Intermediate
(i) $F_u \downarrow 10\%$	-1.305	-0.483	-3.055	0.475	-2.794
(ii) $\tau_{u,r} \uparrow 10\%$	-5.357	-7.200	1.519	-3.764	-4.064
(iii) (i)+(ii)	-6.127	-7.643	-1.598	-3.347	-6.740

A decrease in F_u tightens the foreign-skilled labor market in the US, reducing the scale of US-located production lines that employ foreign skilled labor. Since F_u is used in both production lines – y_{uu} (that uses domestic technology capital Z_u) and y_{ru} (that uses foreign technology capital Z_r), this channel reduces returns associated with both technologies and therefore negatively impacts domestic and foreign technology investment. Domestic intermediate output (y_{uu}) and exports (y_{ru}) also fall but imported intermediates (y_{ur}) increase, signaling the substitutability of foreign skilled workers and imported intermediates.

An increase in τ_{ur} raises the effective cost wedge on the production line in China that exports to the US, which tends to reduce imports y_{ur} and reallocate demand toward the US domestic line y_{uu} through the CES final-good demand system. In general equilibrium, reallocation of labor towards the domestic production line makes the foreign exporting line less competitive, reducing the export of intermediate goods. Consistent with our intuition from Section 4, domestic technology capital Z_u falls.

Combining a tighter foreign-skilled constraint in the US with a higher import barrier produces a larger overall contraction. Mechanically, both shocks reduce the scale of traded activities that rely on foreign-skilled labor and imported varieties, amplifying declines in technology incentives. To summarize, foreign skilled labor in the US is a complement to both technologies in this model. Tariffs shift activity inward, but their effect on technology capital investment is negative. Combining both policies together can have important negative impacts for domestic and foreign technology capital, as well as domestic intermediate production, imports, and exports. We are in the process of evaluating further counterfactual results and welfare analysis.

6 Conclusion

In this paper we explore the interaction of trade and immigration policy and their impact on domestic investment in technology capital, domestic production, and trade in a model that is parameterized to match data from the United States and China. We find that

restricting immigration flows negatively affects the stock of technology in both countries, while encouraging an increase in imported intermediates and reducing the production of intermediate domestically, as well as exports of intermediate goods. An increase in trade costs also negatively affects the accumulation of technology capital, by more than in the case of a similar size reduction in immigration. However, as one would expect, an increase in trade costs for goods imported into the US increases domestic production of intermediates, while decreasing both imported intermediates and exports from the US to China. In each of these cases, the reduction in technology capital is due to an increase in the cost of production, which results in a decrease in the returns to investing in technology capital, thereby reducing the incentive to invest. When we combine the two policies, we see the greatest impact on all variables, causing a decrease in both stocks of technology capital, domestic production of intermediates, and bilateral trade between the two countries.

Our results indicate that, in addition to an increase in costs associated with increasing tariffs and decreased immigration to the US, these policies can be a drag on productivity and long-run growth due to their impacts on firms' willingness to invest in productivity-increasing innovative activities.

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Appendix

A Comparative Statics

In this section, we provide details for the comparative statics exercises in the paper. Recall that the equations that characterize the solution for the modified problem are:

$$\delta = p_{uu}\rho A_u Z_u^{\gamma-1} f_{uu}^{1-\gamma} - \frac{p_{ur}}{\tau_{ur}}\rho A_r Z_u^{\gamma-1} f_{ur}^{1-\gamma} \tag{33}$$

$$\delta = p_{rr}\rho A_r Z_r^{\gamma-1}(\overline{F} - F_u - f_{ur})^{1-\gamma} - \frac{p_{ru}}{\tau_{ru}}\rho A_u Z_r^{\gamma-1}\left(F_u - f_{uu}\right)^{1-\gamma} \tag{34}$$

$$0 = \frac{p_{ru}}{\tau_{ru}} Z_r^{\gamma}\left(F_u - f_{uu}\right)^{-\gamma} - p_{uu} Z_u^{\gamma} f_{uu}^{-\gamma} \tag{35}$$

$$0 = \frac{p_{ur}}{\tau_{ur}} Z_u^{\gamma} f_{ur}^{-\gamma} - p_{rr} Z_r^{\gamma}\left(\overline{F} - F_u - f_{ur}\right)^{-\gamma}. \tag{36}$$

We can use equations 27 and 28 to solve directly for f_{uu} and f_{ur}:

$$f_{uu} = F_u \frac{Z_u p_{uu}^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} \tag{37}$$

$$f_{ur} = (\overline{F} - F_u)\frac{Z_u (p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}. \tag{38}$$

From there, we can use these solutions for f_{uu}, f_{ur} to re-write equation F_1 as follows:

$$\begin{aligned} F_1 = \delta &- p_{uu}\rho A_u Z_u^{\gamma-1}\left[F_u \frac{Z_u p_{uu}^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}}\right]^{1-\gamma} \\ &- \frac{p_{ur}}{\tau_{ur}}\rho A_r Z_u^{\gamma-1}\left[(\overline{F} - F_u)\frac{Z_u (p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}\right]^{1-\gamma} \end{aligned} \tag{39}$$

$$\begin{aligned} = \delta &- p_{uu}^{\frac{\gamma+1-\gamma}{\gamma}}\rho A_u Z_u^{\gamma-1+1-\gamma}\frac{F_u^{1-\gamma}}{\left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}\right]^{1-\gamma}} \\ &- \frac{p_{ur}}{\tau_{ur}}^{\frac{\gamma+1-\gamma}{\gamma}}\rho A_r Z_u^{\gamma-1+1-\gamma}\frac{(\overline{F} - F_u)^{1-\gamma}}{\left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{1-\gamma}} \end{aligned} \tag{40}$$

$$\begin{aligned} = \delta &- p_{uu}^{\frac{1}{\gamma}}\rho A_u F_u^{1-\gamma}\left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}\right]^{\gamma-1} \\ &- \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}}\rho A_r (\overline{F} - F_u)^{1-\gamma}\left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} \end{aligned} \tag{41}$$

Similarly,

$$\begin{aligned} F_2 = \delta &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} \rho A_u F_u^{1-\gamma} \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-1} \\ &- p_{rr}^{\frac{1}{\gamma}} \rho A_r (\overline{F} - F_u)^{1-\gamma} \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-1} \end{aligned} \tag{42}$$

We can then define $C_u = \rho A_u F_u^{1-\gamma}$ and $C_r = \rho A_r (\overline{F} - F_u)^{1-\gamma}$ and write these more simply as

$$\begin{aligned} G_1 = \delta &- p_{uu}^{\frac{1}{\gamma}} C_u \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-1} \\ &- \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-1} \end{aligned} \tag{43}$$

$$\begin{aligned} G_2 = \delta &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} C_u \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-1} \\ &- p_{rr}^{\frac{1}{\gamma}} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-1} \end{aligned} \tag{44}$$

Now, we can take the derivatives of these two equations WRT $Z_u, Z_r, \tau_{ur}, \tau_{ru}$:

$$\begin{aligned} \frac{\partial G_1}{\partial Z_u} = &- p_{uu}^{\frac{1}{\gamma}} C_u (\gamma - 1) \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-2} p_{uu}^{1/\gamma} \\ &- \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} C_r (\gamma - 1) \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-2} (p_{ur}/\tau_{ur})^{1/\gamma} \end{aligned} \tag{45}$$

$$\begin{aligned} \frac{\partial G_1}{\partial Z_r} = &- p_{uu}^{\frac{1}{\gamma}} C_u (\gamma - 1) \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-2} (p_{ru}/\tau_{ru})^{1/\gamma} \\ &- \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} C_r (\gamma - 1) \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-2} p_{rr}^{1/\gamma} \end{aligned} \tag{46}$$

$$\begin{aligned} \frac{\partial G_2}{Z_u} = &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} C_u (\gamma - 1) \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-2} p_{uu}^{1/\gamma} \\ &- p_{rr}^{\frac{1}{\gamma}} C_r (\gamma - 1) \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-2} (p_{ur}/\tau_{ur})^{1/\gamma} \end{aligned} \tag{47}$$

$$\begin{aligned} \frac{\partial G_2}{Z_r} = &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} C_u (\gamma - 1) \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-2} (p_{ru}/\tau_{ru})^{1/\gamma} \\ &- p_{rr}^{\frac{1}{\gamma}} C_r (\gamma - 1) \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-2} p_{rr}^{1/\gamma} \end{aligned} \tag{48}$$

Since $\gamma < 1$, all of these will be positive. We then take derivatives of G_1, G_2 wrt policy

variables $\tau_{ur}, \tau_{ru}, F_u$. First, I'll focus on τ_{ur}:

$$\begin{aligned}
\frac{\partial G_1}{\partial \tau_{ur}} = & - p_{ur}^{\frac{1}{\gamma}} \left(-\frac{1}{\gamma}\right) \tau_{ur}^{\frac{-1}{\gamma}-1} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} && (49)\\
& - \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} C_r (\gamma-1) \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-2} Z_u p_{ur}^{\frac{1}{\gamma}} \left(-\frac{1}{\gamma}\right) \tau_{ur}^{\frac{-1}{\gamma}-1} && (50)\\
= & - p_{ur}^{\frac{1}{\gamma}} \left(-\frac{1}{\gamma}\right) \tau_{ur}^{\frac{-1}{\gamma}-1} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} \left[1 + \frac{(\gamma-1)\frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} Z_u}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}\right] &&\\
= & - p_{ur}^{\frac{1}{\gamma}} \left(-\frac{1}{\gamma}\right) \tau_{ur}^{\frac{-1}{\gamma}-1} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} \left[\frac{Z_u \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} + Z_r p_{rr}^{\frac{1}{\gamma}} + (\gamma-1)\frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} Z_u}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}\right] &&\\
= & - p_{ur}^{\frac{1}{\gamma}} \left(-\frac{1}{\gamma}\right) \tau_{ur}^{\frac{-1}{\gamma}-1} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-1} \left[\frac{Z_r p_{rr}^{\frac{1}{\gamma}} + \gamma \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} Z_u}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}\right] && (51)
\end{aligned}$$

which is positive.

$$\frac{\partial G_2}{\partial \tau_{ur}} = - p_{rr}^{\frac{1}{\gamma}} C_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}\right]^{\gamma-2} (\gamma-1) Z_u (p_{ur}/\tau_{ur})^{1/\gamma} \left(\frac{-1}{\gamma}\right) \tau_{ur}^{-1} \quad (52)$$

which is negative.

Now we're ready to analyze the full effects of τ_{ur} which is the tariff on imports to the U.S., on our equilibrium objects. We can use the Implicit Function Theorem (IFT) to understand the effect of a change in τ_{ur} on Z_u and Z_r. Recall that the elements of the Jacobian are:

$$\begin{aligned}
J_{11} &= \frac{\partial G_1}{\partial Z_u} = a\\
J_{12} &= \frac{\partial G_1}{\partial Z_r} = b\\
J_{21} &= \frac{\partial G_2}{\partial Z_u} = c\\
J_{22} &= \frac{\partial G_2}{\partial Z_r} = d
\end{aligned}$$

Recall that these are all positive. We assign a, b, c, d above for simplicity of notation. Recall that the inverse of this matrix will be:

$$J^{-1} = \frac{1}{ac - bd} \begin{pmatrix} d & -b \\ -c & a \end{pmatrix} \quad (53)$$

So according to IFT

$$\frac{\partial Z_u}{\partial \tau_{ur}} = \frac{-1}{ac - bd} \left[d \frac{\partial G_1}{\partial \tau_{ur}} - b \frac{\partial G_2}{\partial \tau_{ur}}\right] \quad (54)$$

Recall that $\frac{\partial G_1}{\partial \tau_{ur}} > 0$ and $\frac{\partial G_2}{\partial \tau_{ur}} < 0$, and $b, d > 0$, making the terms inside the parentheses positive. Thus, $\frac{\partial Z_u}{\partial \tau_{ur}}$ is negative.

Similarly,

$$\frac{\partial Z_r}{\partial \tau_{ur}} = \frac{-1}{ac - bd}\left[-c\frac{\partial G_1}{\partial \tau_{ur}} + a\frac{\partial G_2}{\partial \tau_{ur}}\right] \tag{55}$$

Recall that $\frac{\partial G_1}{\partial \tau_{ur}} > 0$ and $\frac{\partial G_2}{\partial \tau_{ur}} < 0$, and $a, c > 0$, making the terms inside the parentheses negative. Thus, $\frac{\partial Z_u}{\partial \tau_{ur}}$ is positive.

Therefore, Z_u decreases as τ_{ur} increases and Z_r increases. I believe that part of the reason that we get different results in the calibrated exercise is that here we are leaving out the alternative source of workers for the intermediate producers in u, h.

In order to get a full picture of the effects of policy changes, we also need to understand how labor allocations change as policies change. First, we analyze the impact of a change in τ_{ur} on f_{uu}. Recall that

$$\begin{aligned} f_{uu} &= F_u \frac{Z_u p_{uu}^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} \\ &= F_u Z_u p_{uu}^{1/\gamma} \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}\right]^{-1} \end{aligned}$$

Then

$$\begin{aligned} \frac{\partial f_{uu}}{\partial \tau_{ur}} &= \frac{\partial f_{uu}}{\partial Z_u} Z_u'(\tau_{ur}) + \frac{\partial f_{uu}}{\partial Z_r} Z_r'(\tau_{ur}) \\ &= \frac{F_u p_{uu}^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} \left[1 - \frac{Z_u p_{uu}^{1\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}}\right] Z_u'(\tau_{ur}) \\ &- \frac{F_u Z_u p_{uu}^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} \frac{(p_{ru}/\tau_{ru})^{1/\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} Z_r'(\tau_{ur}) \end{aligned} \tag{56}$$

The first term will be negative since $Z_u'(\tau_{ur}) < 0$ and $\frac{Z_u p_{uu}^{1\gamma}}{Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma}} < 1$. Likewise, the second term will be negative since it carries a negative coefficient in front and $Z_u'(\tau_{ur}) > 0$. Therefore, f_{uu} falls as τ_{ur} increases.

Likewise, f_{ur} will fall as τ_{ur} increases. Recall that

$$f_{ur} = (\overline{F} - F_u) \frac{Z_u (p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}}. \tag{57}$$

Then

$$\begin{aligned}
\frac{\partial f_{ur}}{\partial \tau_{ur}} &= \frac{\partial f_{ur}}{\partial Z_u} Z_u'(\tau_{ur}) + \frac{\partial f_{ur}}{\partial Z_r} Z_r'(\tau_{ur}) + \frac{\partial f_{ur}}{\partial \tau_{ur}} \\
&= (\overline{F} - F_u) \frac{(p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} \left[1 - \frac{Z_u(p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} \right] Z_u'(\tau_{ur} \\
&- (\overline{F} - F_u) \frac{Z_u(p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} \frac{p_{rr}^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} Z_r'(\tau_{ur}) \\
&- \frac{1}{\gamma} (\overline{F} - F_u) \frac{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} \tau_{ur}^{-1}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} \left[1 - \frac{Z_u(p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} \right] \qquad (58)
\end{aligned}$$

Again, the first term is negative since $\frac{Z_u(p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} < 1$ and $Z_u'(\tau_{ur}) < 0$. The second term is also negative since it carries a negative coefficient and $Z_r'(\tau_{ur}) > 0$ and the third term is negative since it carries a negative coefficient and $\frac{Z_u(p_{ur}/\tau_{ur})^{1/\gamma}}{Z_u(p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma}} < 1$. Therefore, f_{ur} falls as τ_{ur} increases.

Finally, we turn to analysis of F_u. Recall that F_u is embedded in the terms $C_u = \rho A_u F_u^{1-\gamma}$ and $C_r = \rho A_r (\overline{F} - F_u)^{1-\gamma}$. Substituting these in yields

$$\begin{aligned}
\frac{\partial G_1}{\partial F_u} = &- p_{uu}^{\frac{1}{\gamma}} \rho A_u (1-\gamma) F_u^{-\gamma} \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma - 1} \\
&- \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} \rho A_r (1-\gamma)(-1) \left(\overline{F} - F_u \right)^{-\gamma} \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma - 1} \\
= &- p_{uu}^{\frac{1}{\gamma}} \rho A_u (1-\gamma) F_u^{-\gamma} \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma - 1} \\
&+ \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} \rho A_r (1-\gamma) \left(\overline{F} - F_u \right)^{-\gamma} \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma - 1}.
\end{aligned}$$

The sign here is ambiguous. Similarly,

$$\begin{aligned}
\frac{\partial G_2}{\partial F_u} = &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} \rho A_u (1-\gamma) F_u^{-\gamma} \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma - 1} \\
&- p_{rr}^{\frac{1}{\gamma}} \rho A_r (1-\gamma)(-1) \left(\overline{F} - F_u \right)^{-\gamma} \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma - 1} \\
= &- \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} \rho A_u (1-\gamma) F_u^{-\gamma} \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma - 1} \\
&+ p_{rr}^{\frac{1}{\gamma}} \rho A_r (1-\gamma) \left(\overline{F} - F_u \right)^{-\gamma} \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma - 1} \qquad (59)
\end{aligned}$$

again carries an ambiguous sign. In both cases, we can group terms and make some substitutions to understand under which conditions the effect would be positive or negative. First, define:

$$
\begin{aligned}
A_1 &= p_{uu}^{\frac{1}{\gamma}} \rho A_u \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-1} \\
B_1 &= \frac{p_{ur}}{\tau_{ur}}^{\frac{1}{\gamma}} \rho A_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-1} \\
A_2 &= \frac{p_{ru}}{\tau_{ru}}^{\frac{1}{\gamma}} \rho A_u \left[Z_u p_{uu}^{1/\gamma} + Z_r (p_{ru}/\tau_{ru})^{1/\gamma} \right]^{\gamma-1} \\
B_2 &= p_{rr}^{\frac{1}{\gamma}} \rho A_r \left[Z_u (p_{ur}/\tau_{ur})^{1/\gamma} + Z_r p_{rr}^{1/\gamma} \right]^{\gamma-1}
\end{aligned}
$$

Then we can re-write $\frac{\partial G_1}{\partial F_u}$ and $\frac{\partial G_2}{\partial F_u}$ as:

$$
\begin{aligned}
\frac{\partial G_1}{\partial F_u} &= (1-\gamma) \left[B_1 \left(\overline{F} - F_u \right)^{-\gamma} - A_1 F_u^{-\gamma} \right] \\
&= (1-\gamma) \left[\frac{B_1}{\left(\overline{F} - F_u \right)^{\gamma}} - \frac{A_1}{F_u^{\gamma}} \right] \\
\frac{\partial G_2}{\partial F_u} &= (1-\gamma) \left[B_2 \left(\overline{F} - F_u \right)^{-\gamma} - A_2 F_u^{-\gamma} \right] \\
&= (1-\gamma) \left[\frac{B_2}{\left(\overline{F} - F_u \right)^{\gamma}} - \frac{A_2}{F_u^{\gamma}} \right].
\end{aligned}
$$

We know that $\gamma < 1$, so the sign of these terms will depend on how close F_u is to $\overline{F}$. In our calibrations (as is the case in the world), a small fraction of total population in the foreign country will emigrate to the U.S., so F_u will be much closer to zero than it is to $\overline{F}$. As F_u approaches $\overline{F}$, the first term approaches ∞ , meaning that each derivative will be positive and as F_u approaches zero, the second term in the bracket approaches $-\infty$, making each derivative negative. Because we're most likely to be in the second range, it is likely that $\frac{\partial G_1}{F_u} < 0$ and $\frac{\partial G_2}{F_u} < 0$. Then, again using the IFT,

$$
\frac{\partial Z_u}{\partial F_u} = \frac{-1}{ac - bd} \left[d \frac{\partial G_1}{\partial F_u} - b \frac{\partial G_2}{\partial F_u} \right] \tag{60}
$$

Again, a, b, c, d are all positive.