International Trade and Regional Unemployment

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Abstract

How does productivity improvement in China affect unemployment across the US states? I develop a many-region model that comprises involuntary unemployment, and quantify it for 30 countries and the 50 US states. The model merges the efficiency wage model of Shapiro and Stiglitz (1984) and a quantitative general equilibrium model of international trade and spatial economy. In the model, workers shirk rather than contribute to production for the market clearing wage. To prevent shirking, firms set a wage that is higher than the market clearing wage. This causes involuntary unemployment. I take the model to data, and compute the counterfactual of the 5% increase in China's productivity. From the factual to the counterfactual, real wages increase, but unemployment rates also increase in all the US states. States in the heartland have a larger increase in unemployment than states in the west coast. The overall US welfare decreases.

1 Introduction

Does the United States lose jobs because of competition with China? Empirical literature has pursued this question (Autor et al., 2013; Pierce and Schott, 2016; Bloom et al., 2019). Especially Autor et al. (2013) and Bloom et al. (2019) relate characteristics of geographic units in the US and labor market outcomes. The papers in this literature are reduced-form studies, and general equilibrium effects of China-US trade on the US unemployment remain to be explored. A goal of this paper is to complement these studies with general equilibrium analysis.

Since Eaton and Kortum (2002) and Anderson and van Wincoop (2003), however, quantitative trade models have assumed full employment. Therefore, although they are a

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standard toolkit to evaluate trade policy, existing many-region quantitative trade models cannot evaluate an effect of international trade on unemployment.

This paper aims to develop a many-region general equilibrium model that comprises involuntary unemployment. To model unemployment, I rely on the theoretical apparatus developed by Shapiro and Stiglitz (1984). In the model, a worker can either shirk or make an effort for her employer. If she shirks, she does not contribute to production of a firm, but if she makes an effort, she contributes to production. Firms can imperfectly monitor workers. That is, firms can catch and fire a shirker with probability less than one. The market clearing wage is not high enough to make workers voluntarily make an effort. Firms set a wage that is higher than the market clearing wage. This causes involuntary unemployment. The equilibrium wage set by firms is called the efficiency wage.

I integrate the efficiency-wage model of Shapiro and Stiglitz (1984) into a standard quantitative general equilibrium model of international trade (Ossa, 2014) and spatial economy (Allen and Arkolakis, 2014). The model economy consists of the US states and countries that are not the US. I assume that individuals in the US can freely migrate across the US states, but individuals in a non-US country cannot emigrate from their countries. In each location, a fixed mass of firms monopolistically compete, and earn positive profits. Endogenous objects determined in equilibrium are nominal wages, price indices, profits and unemployment rates in any country and any US state, and labor forces in any US state.

I take the model to data of 29 OECD countries, China and the 50 US states. The model is matched with trade values, labor forces, wages, unemployment benefits and unemployment rates. Following Dekle et al. (2007), I express a counterfactual equilibrium as a system of equations for relative changes in endogenous variables from the factual equilibrium. This collapses some of model primitives and circumvents estimation of them.

This paper conducts two counterfactual experiments. First, I compute the counterfactual equilibrium with the 5% increase in China's productivity. In all the US states, real wages increase, but unemployment also increases. States of the west coast experience a larger increase in real wages than states in the heartland. States in the west coast experience a smaller increase in unemployment than states in the heartland. Overall, the US welfare decreases by 0.14%. Welfare increases only in China, Czech Republic and Korea, and welfare decreases in the other 27 non-US countries.

Second, I compute the counterfactual equilibrium with the 5% decrease in trade costs between China and the US. That is, I consider the 5% decrease in trade costs from China to any US state, and in trade costs from any US state to China. In all the US states, real wages increase, and in 39 states out of the 50, unemployment decreases. The model predicts that unemployment decreases in states of both the west and east coast, but unemployment increases in states in the heartland Overall, the US welfare increases by 0.43%. China's welfare also increases, but welfare of all the other countries decreases.

Related Literature

This paper is not the first attempt to study the effect of China-US trade on the US labor market with a general equilibrium model. Caliendo et al. (2019) construct a dynamic multi-sector version of Eaton and Kortum (2002) to study it. In the model, individuals choose a pair of a state to live in and a sector to work in as a dynamic discrete choice problem. Sector 0 is labeled as nonemployment, and an individual voluntarily chooses nonemployment if it is her optimal choice. Therefore, they consider only voluntary nonemployment. In contrast, the goal of this paper is to develop a multi-region model with involuntary unemployment.

To the best of my knowledge, this paper is one of the three independent pieces of work that pursue a multi-region quantitative model with unemployment. I contrast this paper with the other two. Bilal (2019) develops a dynamic macro model where both firms and individuals choose locations. Individuals and firms randomly encounter in each labor market, which causes unemployment. He assumes free trade between any two places, and he does not match the model with trade data. In contrast, the model of this paper is built on a quantitative trade model and can be matched with trade data. Rodriguez-Clare et al. (2019) combines new Keynesian nominal wage rigidity and a multi-sector static Ricardian model (Caliendo and Parro, 2015). A static equilibrium holds in every period, and the authors assume that the wage in a period cannot be very low relative to the wage in the previous period (downward nominal wage rigidity). Although they refer to new Keynesian macro literature for a microfoundation, they do not explicitly show the microfoundation for nominal wage rigidity. In contrast, this paper explicitly presents the microfoundation that generates unemployment and how it fits into a monopolistic competition model.

Davis and Harrigan (2011) integrate the efficiency-wage model to the Melitz model (Melitz, 2003). Their model is of two countries. They theoretically analyze the model and simulate equilibria numerically. In comparison, this paper matches the model with actual data of 30 countries and the 50 US states.

The remainder of the paper is organized as follows. Section 2 develops the model. Section 3 takes the model to data. Section 4 presents counterfactuals. Section 5 concludes.

2 Model

Let N_{US} be the set of the 50 US states and N_{NUS} be the set of countries but the US, where the subscript NUS stands for "not the US." Let $n_{US} = |N_{US}|$ and $n_{NUS} = |N_{NUS}|$, where $|\cdot|$ denotes the cardinality of a set. The economy consists of the set of locations $N = N_{US} \cup N_{NUS}$, and a location $j \in N$ is either a US state or a non-US country. Let n be such that $n = |N| = n_{US} + n_{NUS}$. The mass L_{US} of individuals are populated in the US, and they are freely mobile across the US states $j \in N_{US}$. The mass L_k of individuals are populated in any non-US country $k \in N_{NUS}$, and they cannot emigrate from country k.

Each individual in the US first chooses a state to live in, taking into account her idiosyncratic amenity shock, the amenity and her rational expectation of nominal wages, profits, price levels and employment rates. After individuals in the US choose their locations, consumption and production take place, and unemployment occurs in any location. Anyone is either employed or unemployed. Once an individual in the US chooses her state to live in, she can no longer emigrate from her place even if she is unemployed. In each location, firms produce goods and demand labor as only the production factor. Employees of a firm choose either to make an effort or to shirk by comparing the expected benefits of these two. For the labor market clearing wage, employees do not make an effort, and the firm cannot produce products. Therefore the firms set an efficiency wage that is higher than the market clearing wage, and labor demand is less than labor supply for the efficiency wage. This is the source of involuntary unemployment. Realized unemployment rates coincide with the unemployment rates that individuals in the US expexted at the time of their location choices. This guarantees belief consistency. I obtain equilibrium conditions backward. That is, I first derive equilibrium conditions of demand and supply of goods and labor given labor forces in the US states, and then I turn to location choices of individuals in the US.

This section proceeds as follows. Subsection 2.1 describes consumers' utility maximization and firms' profit maximization after labor forces settle down in the US states. Subsection 2.2 states location choices of individuals in the US, which pins down the distribution of labor forces over the US states. Subsection 2.3 defines an equilibrium. Subsection 2.4 characterizes a counterfactual equilibrium in terms of changes from the factual.

2.1 Consumer and Firm Behavior

Utility maximization

I consider the economy after people in the US choose states to live in, and the populations in the US states $\{L_k\}_{k \in N_{US}}$ are determined. If individual i lives in location $j \in N$, her utility is

$$U_{i,j} = \frac{1}{\tilde{\eta}_i} C_{i,j} A_j \nu_{i,j}, \tag{1}$$

where $C_{i,j}$ is the composite good consumed by individual i who lives in location j, $\tilde{\eta}_i$ captures the disutility from making an effort, A_j is the amenity of location j that is common to anyone, and $\nu_{i,j}$ is individual i's idiosyncratic amenity shock for location i.[1] The composite good $C_{i,j}$ for individual i in location j is defined by

$$C_{i,j} = \left(\sum_{k \in N} \int_0^{M_k} C_{i,k,j}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}},$$

where M_k is the mass of varieties produced in location $k \in N$, $C_{i,k,j}(\omega)$ is individual i's consumption of variety ω shipped from location k to her location j, and σ is the parameter of constant elasticity of substitution (CES). The mass M_k of firms are located in $k \in N$, and each firm produces one variety. M_k is exogenously given for any location $k \in N$.

Each individual is either employed or unemployed. If individual i is employed, she chooses to make an effort or to shirk. If she makes an effort, her utility is divided by $\eta > 1$, but if she shirks, she does not incur this disutility. That is, using the notation $\tilde{\eta}_i$ in equation (1),

$$\tilde{\eta}_i = \begin{cases} \eta > 1 & \text{if } i \text{ makes an effort,} \\ 1 & \text{if } i \text{ shirks.} \end{cases}$$

If individual i is unemployed, she does not incur the disutility from making an effort, $\tilde{\eta}_i = 1$.

If an individual in location j is employed (and is not caught shirking), she receives the nominal wage w_j. If she is unemployed, she receives the nominal unemployment benefit $b_j P_j$, where b_j is the real unemployment benefit in location j, and P_j is the CES price index

$$P_j = \left[\sum_{k \in N} \int_0^{M_k} (p_k(\omega) t_{k,j})^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}, \tag{2}$$

where $p_k(\omega)$ is the f.o.b. price that firm ω in location k sets, and $t_{k,j}$ is the iceberg trade costs of any variety shipped from location k to location j. Note that the price of variety ω from location k that consumers in location j face is $p_k(\omega)t_{k,j}$.

Any firm in location j can catch shirking with probability $q_j \in (0,1)$. If a shirker is caught, she is fired and ends up unemployed. Her shirking is not caught with probability $1 - q_j$, then the shirker receives the same wage w_j as those who make an effort. The parameter q_j represents imperfect contract in the labor market in location j.

[1] The form of the utility function (1) follows Davis and Harrigan (2011), who assume that the disutility from making an effort is multiplicative. It is slightly different from the specification in Shapiro and Stiglitz (1984), who assume that the disutilty from making an effort is subtractive.

Besides the wage or unemployment benefit, no matter whether she is employed or not, an individual receives a share of profits. Let π_j be total profits of firms in location j, and L_j be the mass of labor force in location j. If she lives in non-US country $j \in N_{NUS}$, she receives the share of profits $\frac{\pi_j}{L_j}$. If she lives in US state $j \in N_{US}$, she receives the share of profits $\frac{\pi_{US}}{L_{US}}$, where $\pi_{US} = \sum_{k \in N_{US}} \pi_k$ is total profits in the US. In other words, anyone in non-US country $j \in N_{NUS}$ owns the same share of ownership of firms in her country j. Anyone in the US owns the same share of ownership of firms in the US, wherever she lives in the US.

Let $\tilde{w}_{i,j}$ be the nominal wage or unemployment benefit that individual i receives in location j, then

$$\tilde{w}_{i,j} = \begin{cases} w_j & \text{if } i \text{ is employed,} \\ b_j P_j & \text{if } i \text{ is unemployed.} \end{cases}$$

Using this notation, the nominal income for individual i in location j, $I_{i,j}$ is

$$I_{i,j} = \begin{cases} \tilde{w}_{i,j} + \frac{\pi_j}{L_j} & \text{for } j \in N_{NUS}, \\ \tilde{w}_{i,j} + \frac{\pi_{US}}{L_{US}} & \text{for } j \in N_{US}. \end{cases} \tag{3}$$

Then, the budget constraint for individual i in location $j \in N$ is

$$\sum_{k \in N} \int_0^{M_k} p_k(\omega) t_{k,j} C_{i,k,j}(\omega) d\omega \leq I_{i,j}. \tag{4}$$

To solve utility maximization, first I consider consumers' choice of consumption bundle subject to the budget constraint, and then I turn to consumers' choice on whether to make an effort or not.

Individual i's demand for variety ω shipped from location k to location j, $C_{i,k,j}(\omega)$, is

$$C_{i,k,j}(\omega) = \left(\frac{p_k(\omega) t_{k,j}}{P_j} \right)^{-\sigma} \left(\frac{I_{i,j}}{P_j} \right). \tag{5}$$

Since the budget constraint (4) is binding, the CES demand aggregator for individual i in location j, $C_{i,j}$, satisfies

$$P_j C_{i,j} = I_{i,j}. \tag{6}$$

Substituting $C_{i,j} = \frac{I_{i,j}}{P_j}$ into utility (1), I obtain the following expressions for indirect utilities. If individual i in location j is unemployed, her indirect utility is

$$\begin{aligned} \left(b_j + \frac{\pi_j}{L_j P_j}\right) A_j \nu_{i,j} \ \text{ for } j \in N_{NUS}, \\ \left(b_j + \frac{\pi_{US}}{L_{US} P_j}\right) A_j \nu_{i,j} \ \text{ for } j \in N_{US}. \end{aligned} \tag{7}$$

If individual i in location j is employed and makes an effort, her indirect utility is

$$\begin{aligned} \frac{1}{\eta}\left(\frac{w_j}{P_j} + \frac{\pi_j}{L_j P_j}\right) A_j \nu_{i,j} \ \text{ for } j \in N_{NUS}, \\ \frac{1}{\eta}\left(\frac{w_j}{P_j} + \frac{\pi_{US}}{L_{US} P_j}\right) A_j \nu_{i,j} \ \text{ for } j \in N_{US}. \end{aligned} \tag{8}$$

If individual i in location j is employed and shirks, her expected indirect utility is[2]

$$\begin{aligned} (1-q_j)\cdot\left(\frac{w_j}{P_j} + \frac{\pi_j}{L_j P_j}\right) A_j \nu_{i,j} + q_j \cdot \left(b_j + \frac{\pi_j}{L_j P_j}\right) A_j \nu_{i,j} \ \text{ for } j \in N_{NUS}, \\ (1-q_j)\cdot\left(\frac{w_j}{P_j} + \frac{\pi_{US}}{L_{US} P_j}\right) A_j \nu_{i,j} + q_j \cdot \left(b_j + \frac{\pi_{US}}{L_{US} P_j}\right) A_j \nu_{i,j} \ \text{ for } j \in N_{US}. \end{aligned} \tag{9}$$

Individual i makes an effort if the indirect utility of making an effort (8) is greater than the expected indirect utility of shirking (9). She shirks if (8) is less than (9). She is indifferent between making an effort and shirking if (8) is equal to (9).

Production function

The fixed mass M_j of firms exist in location $j \in N$. One firm produces one and only one variety, and varieties are different across firms. Suppose that firm ω in location j hires the measure $l_j(\omega)$ of workers. If the measure $l'_j(\omega) \in [0, l_j(\omega)]$ of employees make an effort, the production of firm ω in location j, $y_j(\omega)$, is

$$y_j(\omega) = z_j l'_j(\omega). \tag{10}$$

where z_j is the productivity that is common to all firms in location j. The production function is linear in the mass of employees who make an effort.

[2] The function defined by equation (1) is a Bernoulli utility function in the language of Mas-Colell et al. (1995).

No shirking condition

Assume that any individual receives a wage offer with probability e_j, once she chooses her location j.[3] The probabilities $\{e_j\}_{j\in N}$ are endogenous objects and determined in equilibrium.[4] A wage offer arrives from at most one firm to an individual. Firms have the full bargaining power, and a wage offer is a take-it-or-leave-it offer. If an individual receives a wage offer and accepts it, she will be hired by a firm. If an individual receives a wage offer and rejects it, she will be unemployed. If an individual does not receive a wage offer, she will be unemployed.

Suppose that the indirect utility of making an effort (8) and the expected indirect utility of shirking (9) are equal, that is,

$$\begin{aligned}\frac{1}{\eta}\left(\frac{w_j}{P_j}+\frac{\pi_j}{L_jP_j}\right)A_j\nu_{i,j} &= (1-q_j)\cdot\left(\frac{w_j}{P_j}+\frac{\pi_j}{L_jP_j}\right)A_j\nu_{i,j}+q_j\cdot\left(b_j+\frac{\pi_j}{L_jP_j}\right)A_j\nu_{i,j} \ \text{ for } j\in N_{NUS},\\ \frac{1}{\eta}\left(\frac{w_j}{P_j}+\frac{\pi_{US}}{L_{US}P_j}\right)A_j\nu_{i,j} &= (1-q_j)\cdot\left(\frac{w_j}{P_j}+\frac{\pi_{US}}{L_{US}P_j}\right)A_j\nu_{i,j}+q_j\cdot\left(b_j+\frac{\pi_{US}}{L_{US}P_j}\right)A_j\nu_{i,j} \ \text{ for } j\in N_{US}.\end{aligned} \tag{11}$$

Solving this for w_j, I obtain

$$w_j=\begin{cases}\frac{1}{1-\eta(1-q_j)}\left(\eta q_j b_j P_j+(\eta-1)\frac{\pi_j}{L_j}\right) & \text{for } j\in N_{NUS},\\ \frac{1}{1-\eta(1-q_j)}\left(\eta q_j b_j P_j+(\eta-1)\frac{\pi_{US}}{L_{US}}\right) & \text{for } j\in N_{US}.\end{cases} \tag{12}$$

The idiosyncratic amenity shock $\nu_{i,j}$ does not appear in the wage (12). That is, the nominal wage (12) equalizes the indirect utility of making en effort and the expected indirect utility of shirking not only for individual i. but also for anyone in location j. In any firm $\omega\in[0,M_j]$ in location j, all employees make an effort if its wage $w_j(\omega)$ is strictly higher than (12). All employees of ω shirk if its wage $w_j(\omega)$ is strictly lower than (12).

In equilibrium, indeed, the nominal wage in location j satisfies (12). That is, any firm $\omega\in[0,M_j]$ offers the wage (12). I show this by the way of contradiction. Let w_j be the wage defined by (12), and $w_j(\omega)$ generically denote the wage set by firm ω in location j. Suppose, to the contrary, that there exists firm ω such that $w_j(\omega)\neq w_j$. On the one hand, suppose that $w_j(\omega)>w_j$. Then firm ω would have an incentive to decrease the wage to, say, $w_j'(\omega)\in[w_j,w_j(\omega))\neq\emptyset$. This is because, if the firm reduces the wage to $w_j'(\omega)$, any employee would make an effort so that the firm would sustain the production level as of $w_j(\omega)$, and

[3] Location choices do not take place in non-US countries $j\in N_{NUS}$. Thus the timing assumption of location choices and wage offers does not apply in $j\in N_{NUS}$.

[4] I will show that e_j is the employment rate in location j, because no one rejects a wage offer in equilibrium.

the firm would reduce the labor cost. On the other hand, suppose that $w_j(\omega) < w_j$. Then no employee makes an effort, and by the production function (10), the production level is zero. Therefore the firm has an incentive to increase the wage to $w_j'(\omega) \in [w_j, \infty)$, so that the firm can produce a positive amount of the product. Later I will see that any firm makes positive profits as long as it produces a positive amount, because of monopolistic competition and CES demand.

Since $\eta > 1$ and $0 < q_j < 1$ for any $j \in N$, the no-shirking wage (12) is strictly greater than the nominal unemployment benefit,

$$w_j > b_j P_j.$$[5]

Therefore anyone accepts a wage offer, if she receives it. As a result, e_j represents the employment rate in location j as well as the probability that an individual in location j receives a wage offer.

I have shown that in equilibrium, the nominal wage in location j, w_j, satisfies (12). Moreover, the measure of employees who shirk is zero, for the wage (12). Suppose, to the contrary, that a positive measure of employees of firm $\omega \in [0, M_j]$ shirk for the wage (12). Then the firm would increase the wage slightly, so that any employee makes an effort, then the production level and the profits would discontinuously increase. Therefore the case where a positive measure of employees shirk for the wage (12) is not sustained in equilibrium. In other words, in equilibrium, if the $l_j(\omega)$ measure of workers are hired by firm $\omega \in [0, M_j]$ in location j, the same $l_j(\omega)$ measure of employees make an effort, for the nominal wage (12). I refer to equation (11) as the no shirking condition, and the equilibrium nominal wage (12) as the no shirking wage.

Suppose temporarily that the price index P_j and profits π_j are held fixed in the no-shirking wage (12) for $j \in N_{NUS}$, although they are actually general equilibrium objects. Then, two properties hold. First, the no-shirking wage w_j is increasing in η, the disutility from making an effort. If the disutility from making an effort is larger, firms have to compensate employees with a higher wage. Second, the no-shirking wage w_j is decreasing in q_j, the probability that firms catch shirking. If shirkers are more likely to be caught, workers voluntarily make an effort with a lower wage. Then firms do no longer have to offer a high wage. Now I return to the general equilibrium model where $\{P_j\}_{j \in N}$ and $\{\pi_j\}_{j \in N}$ are endogenous.

[5]A sufficient condition for this is $1 - 2\eta + \eta q_j < 0$.

Aggregate nominal income

The aggregate nominal income in location j, X_j, is given by

$$\begin{aligned} X_j &= e_j L_j \left(w_j + \frac{\pi_j}{L_j} \right) + (1-e_j) L_j \left(b_j P_j + \frac{\pi_j}{L_j} \right) \text{ for } j \in N_{NUS}, \\ X_j &= e_j L_j \left(w_j + \frac{\pi_{US}}{L_{US}} \right) + (1-e_j) L_j \left(b_j P_j + \frac{\pi_{US}}{L_{US}} \right) \text{ for } j \in N_{US}. \end{aligned} \tag{13}$$

This is the sum of the aggregate nominal incomes of employed people (the first term) and unemployed people (the second term).

Profit maximization - Constant markup

Let $C_{j,k}(\omega)$ be the aggregate demand of variety ω shipped from location j to location k. Since preferences are homothetic, by replacing an individual's nominal income $I_{i,j}$ in equation (5) with the aggregate nominal income X_k, I obtain the aggregate demand for variety ω from location j in location k, $C_{j,k}(\omega)$, by

$$C_{j,k}(\omega) = \left(\frac{p_j(\omega) t_{j,k}}{P_k} \right)^{-\sigma} \left(\frac{X_k}{P_k} \right). \tag{14}$$

From the viewpoint of monopolistic firm ω in location j, equation (14) means that how much the demand in location k would be if firm ω sets the f.o.b. price $p_j(\omega)$.

Note that firm ω in location k needs to ship $t_{k,j} C_{k,j}(\omega)$ to meet the demand $C_{k,j}(\omega)$ in location j, because of the iceberg trade costs $t_{k,j}$. Thus to meet the demands from all destinations, firm ω in location j must produce the amount

$$y_j(\omega) = \sum_{k \in N} t_{j,k} C_{j,k}(\omega). \tag{15}$$

Given the no-shirking wage (12), firm $\omega \in [0, M_j]$ in location j maximizes its profits $\pi_j(\omega)$

given by

$$\begin{aligned}\pi_j(\omega) &= p_j(\omega)y_j(\omega) - w_j l_j \\ &= p_j(\omega)y_j(\omega) - w_j \frac{y_j(\omega)}{z_j} \\ &= \left(p_j(\omega) - \frac{w_j}{z_j}\right)\left(\sum_{k\in N} t_{j,k} C_{j,k}(\omega)\right) \\ &= \left(p_j(\omega) - \frac{w_j}{z_j}\right)\left[\sum_{k\in N} t_{j,k}\left(\frac{p_j(\omega)t_{j,k}}{P_k}\right)^{-\sigma}\frac{X_k}{P_k}\right],\end{aligned} \tag{16}$$

where the second line follows from the production function (10), the third line follows from the goods market clearing (15), and the fourth line follows from the CES aggregate demand (14). Taking the first order condition with respect to $p_j(\omega)$, for any $\omega \in [0, M_j]$, the optimal price for monopolistic firm ω in location j is

$$p_j(\omega) = \frac{\sigma}{\sigma-1}\frac{w_j}{z_j}, \tag{17}$$

which is the constant markup $\frac{\sigma}{\sigma-1}$ multiplied by the nominal wage in terms of the efficiency units $\frac{w_j}{z_j}$. Substituting the optimal price (17) into the price index (2) (with modifying subscripts), the price index in location j is

$$P_j = \left[\sum_{k\in N} M_k\left(\frac{\sigma}{\sigma-1}\frac{w_k}{z_k}t_{k,j}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{18}$$

The optimal prices (17) determine the demands in locations (given the aggregate economic variables in destinations). This, in turn, determines the production levels and the associated labor demands of firms. The total labor demand from firms in location j is equal to the mass of the employed people in location j, that is,

$$\frac{1}{z_j}M_j\sum_{k\in N} t_{j,k}\left(\frac{\sigma}{\sigma-1}\frac{w_j t_{j,k}}{z_j}\right)^{-\sigma} P_k^{\sigma-1}X_k = e_j L_j. \tag{19}$$

for any $j \in N$.[6]

Moreover, substituting the optimal price (17) into the profits (16) and multiplying it

[6] Another interpretation for equation (19) is as follows. An individual in the US chooses her state to live in, taking into account her expectation of employment rates $\{e_j\}_{j\in N_{US}}$ in the US states. The employment rate that is realized in each location coincides with the expected one at the time of location choices. This guarantees belief consistency.

with the mass M_j of firms in location j, I have total profits in location j as

$$\pi_j = \frac{M_j}{\sigma} \sum_{k \in N} \left(\frac{\sigma}{\sigma - 1} \frac{w_j}{z_j} \frac{t_{j,k}}{P_k} \right)^{1-\sigma} X_k \tag{20}$$

for any $j \in N$.

2.2 Location Choices

I have stated all equilibrium conditions for non-US countries $j \in N_{NUS}$. I turn to location choices of individuals in the US.

Individual i in the US chooses a US state to live in after she draws her idiosyncratic amenity shock $\nu_{i,j}$ for $j \in N_{US}$. The amenity shock $\nu_{i,j}$ follows the Fréchet distribution whose cumulative distribution function is $F(\nu) = e^{-\nu^{-\theta}}$, independently and identically across individuals i's and the US states $j \in N_{US}$. Individual i chooses her location to maximize her expected indirect utility. That is, individual i solves

$$\max\{V_{i,j} : j \in N_{US}\}, \tag{21}$$

where $V_{i,j}$ is her expected indirect utility of living in US state j,

$$\begin{aligned} V_{i,j} &= e_j \cdot \frac{1}{\eta} \left(\frac{w_j}{P_j} + \frac{\pi_{US}}{L_{US} P_j} \right) A_j \nu_{i,j} + (1 - e_j) \cdot \left(b_j + \frac{\pi_{US}}{L_{US} P_j} \right) A_j \nu_{i,j}, \\ &= \Phi_j \nu_{i,j}, \end{aligned} \tag{22}$$

and Φ_j is the baseline expected indirect utility of living in US state j which is common to anyone in the US

$$\Phi_j = \left[e_j \frac{1}{\eta} \left(\frac{w_j}{P_j} + \frac{\pi_{US}}{L_{US} P_j} \right) + (1 - e_j) \left(b_j + \frac{\pi_{US}}{L_{US} P_j} \right) \right] A_j \text{ for } j \in N_{US}. \tag{23}$$

Equation (22) means that the expected indirect utility of living in US state j is the weighted sum of the indirect utilities of being employed/unemployed in US state j, with the weights being the probabilities of being employed/unemployed. Note that an individual foresees that the no-shirking condition will hold and she will make an effort upon being employed.

Since the amenity shocks $\nu_{i,j}$ follow the i.i.d. Fréchet distribution $F(\nu) = e^{-\nu^{-\theta}}$, the labor force in location j is

$$L_j = \frac{\Phi_j^\theta}{\sum_{k \in N_{US}} \Phi_k^\theta} L_{US} \text{ for } j \in N_{US}. \tag{24}$$

I assume that individual i in any non-US country $j \in N_{NUS}$ also draws the amenity shock $\nu_{i,j}$ from the Fréchet distribution $F(\nu) = e^{-\nu^{-\theta}}$ independently across individuals in country j. This affects none of equilibrium outcomes, because individuals in a non-US country cannot emigrate from their country.

2.3 Equilibrium

An equilibrium is defined to be a tuple of price indices $\{P_j\}_{j\in N}$, nominal wages $\{w_j\}_{j\in N}$, employment rates $\{e_j\}_{j\in N}$, aggregate profits $\{\pi_j\}_{j\in N}$, aggregate nominal incomes $\{X_j\}_{j\in N}$, labor forces in the US states $\{L_j\}_{j\in N_{US}}$ that satisfies equations (12), (13), (18), (19), (20), (24) (with (23)). This is a system of $5n + n_{US}$ equations with $5n + n_{US}$ unknowns.

Welfare in the US is given by the ex-ante expected indirect utility before individuals in the US draw idiosyncratic amenity shocks. Let W_{US} be welfare in the US, then

$$W_{US} = E\left[\max_{j\in N_{US}} V_{i,j}\right] = E\left[\max_{j\in N_{US}} \Phi_j \nu_{i,j}\right] = \Gamma\left(1 - \frac{1}{\theta}\right)\left(\sum_{j\in N_{US}} \Phi_j^{\theta}\right)^{\frac{1}{\theta}}, \tag{25}$$

where $\Gamma(\cdot)$ is the gamma function. Welfare in non-US country $j \in N_{NUS}$, W_j, is given by

$$W_j = E[V_{i,j}] = E[\Phi_j \nu_{i,j}] = \Gamma\left(1 - \frac{1}{\theta}\right)\Phi_j, \tag{26}$$

where Φ_j is the baseline expected indirect utility of living in non-US country j which is common to anyone in j

$$\Phi_j = \left[e_j \frac{1}{\eta}\left(\frac{w_j}{P_j} + \frac{\pi_j}{L_j P_j}\right) + (1 - e_j)\left(b_j + \frac{\pi_j}{L_j P_j}\right)\right] A_j \text{ for } j \in N_{NUS}. \tag{27}$$

2.4 Equilibrium in Changes

Following Dekle et al. (2007) and Ossa (2014), I characterize a counterfactual equilibrium as a solution to a system of equations for changes in endogenous variables from the factual equilibrium to a counterfactual equilibrium. For a generic variable x, let $\hat{x} = \frac{x'}{x}$ be the change in the variable x from the factual equilibrium to a counterfactual equilibrium, where x' and x are the counterfactual and factual value of the variable, respectively. In the following, I consider changes in productivity and trade costs from the factual to counterfactuals, and assume that any other parameter does not change.

Taking the ratio of (12) between a counterfactual and the factual, I obtain the changes in no-shirking wages

$$
\begin{aligned}
\hat{w}_j &= \frac{\eta q_j b_j P_j \hat{P}_j + (\eta - 1)\frac{\pi_j \hat{\pi}_j}{L_j}}{\eta q_j b_j P_j + (\eta - 1)\frac{\pi_j}{L_j}} \quad \text{for } j \in N_{NUS}, \\
\hat{w}_j &= \frac{\eta q_j b_j P_j \hat{P}_j + (\eta - 1)\frac{\pi_{US} \hat{\pi}_{US}}{L_{US}}}{\eta q_j b_j P_j + (\eta - 1)\frac{\pi_{US}}{L_{US}}} \quad \text{for } j \in N_{US},
\end{aligned} \tag{28}
$$

where $\hat{\pi}_{US}$ is the change in the US total profits, that is,

$$
\hat{\pi}_{US} = \frac{\pi'_{US}}{\pi_{US}} = \frac{\sum_{j \in N_{US}} \pi_j \hat{\pi}_j}{\sum_{j \in N_{US}} \pi_j}. \tag{29}
$$

Taking the ratio of (13) between a counterfactual and the factual, the changes in aggregate nominal incomes of locations are expressed as

$$
\begin{aligned}
\hat{X}_j &= \frac{e_j \hat{e}_j \left(w_j \hat{w}_j + \frac{\pi_j \hat{\pi}_j}{L_j} \right) + (1 - e_j \hat{e}_j) \left(b_j P_j \hat{P}_j + \frac{\pi_j \hat{\pi}_j}{L_j} \right)}{e_j \left(w_j + \frac{\pi_j}{L_j} \right) + (1 - e_j) \left(b_j P_j + \frac{\pi_j}{L_j} \right)} \quad \text{for } j \in N_{NUS}, \\
\hat{X}_j &= \frac{e_j \hat{e}_j \hat{L}_j \left(w_j \hat{w}_j + \frac{\pi_{US} \hat{\pi}_{US}}{L_{US}} \right) + (1 - e_j \hat{e}_j) \hat{L}_j \left(b_j P_j \hat{P}_j + \frac{\pi_{US} \hat{\pi}_{US}}{L_{US}} \right)}{e_j \left(w_j + \frac{\pi_{US}}{L_{US}} \right) + (1 - e_j) \left(b_j P_j + \frac{\pi_{US}}{L_{US}} \right)} \quad \text{for } j \in N_{US}.
\end{aligned} \tag{30}
$$

For any pair of locations $(k, j) \in N \times N$, define location k's share in location j's imports, $\gamma_{k,j}$, by

$$
\gamma_{k,j} = \frac{X_{k,j}}{\sum_{n \in N} X_{n,j}}, \tag{31}
$$

where $X_{n,j}$ denotes the aggregate trade value from location n to location j. Taking the ratio of (18) between a counterfactual and the factual, I have changes in price indices

$$
\hat{P}_j = \left[\sum_{k \in N} \gamma_{k,j} \left(\frac{\hat{w}_k \hat{t}_{k,j}}{\hat{z}_k} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \quad \text{for } j \in N. \tag{32}
$$

For any pair of locations $(k, j) \in N \times N$, define location k's share in location j's exports, $\alpha_{j,k}$, by

$$
\alpha_{j,k} = \frac{X_{j,k}}{\sum_{n \in N} X_{j,n}}. \tag{33}
$$

Taking the ratio of (19) between a counterfactual and the factual, I have changes in employment

$$
\begin{aligned}
\hat{e}_j &= \frac{1}{\hat{w}_j} \sum_{k \in N} \alpha_{j,k} \left(\frac{\hat{w}_j \hat{t}_{j,k}}{\hat{z}_j \hat{P}_k} \right)^{1-\sigma} \hat{X}_k \ \text{ for } j \in N_{NUS} \\
\hat{e}_j \hat{L}_j &= \frac{1}{\hat{w}_j} \sum_{k \in N} \alpha_{j,k} \left(\frac{\hat{w}_j \hat{t}_{j,k}}{\hat{z}_j \hat{P}_k} \right)^{1-\sigma} \hat{X}_k \ \text{ for } j \in N_{US}.
\end{aligned} \tag{34}
$$

Taking the ratio of (20) between a counterfactual and the factual, I obtain changes in aggregate profits

$$
\hat{\pi}_j = \sum_{k \in N} \alpha_{j,k} \left(\frac{\hat{w}_j \hat{t}_{j,k}}{\hat{z}_j \hat{P}_k} \right)^{1-\sigma} \hat{X}_k \ \text{ for } j \in N. \tag{35}
$$

Let $\mu_j = \frac{L_j}{L_{US}}$ for any $j \in N_{US}$, that is, the share of state j in the total labor force in the US. Then taking the ratio of (24) between a counterfactual and the factual, I have

$$
\hat{L}_j = \hat{\mu}_j = \frac{\hat{\Phi}_j^{\theta}}{\sum_{k \in N_{US}} \mu_k \hat{\Phi}_k^{\theta}} \text{ for } j \in N_{US}, \tag{36}
$$

where

$$
\hat{\Phi}_j = \frac{e_j \hat{e}_j \frac{1}{\eta} \left(\frac{w_j \hat{w}_j}{\hat{P}_j} + \frac{\pi_{US} \hat{\pi}_{US}}{L_{US} P_j} \right) + (1 - e_j \hat{e}_j) \left(b_j P_j + \frac{\pi_{US} \hat{\pi}_{US}}{L_{US} P_j} \right)}{e_j \frac{1}{\eta} \left(w_j + \frac{\pi_{US}}{L_{US}} \right) + (1 - e_j) \left(b_j P_j + \frac{\pi_{US}}{L_{US}} \right)} \text{ for } j \in N_{US}. \tag{37}
$$

An equilibrium in changes is defined to be a tuple of changes in price indices $\{\hat{P}_j\}_{j \in N}$, nominal wages $\{\hat{w}_j\}_{j \in N}$, employment rates $\{\hat{e}_j\}_{j \in N}$, aggregate profits $\{\hat{\pi}_j\}_{j \in N}$, aggregate nominal incomes $\{\hat{X}_j\}_{j \in N}$ and labor forces in the US states $\{\hat{L}_j\}_{j \in N}$ that satisfies equations (28), (30), (32), (34), (35), (36) (with (37)). This is a system of $5N + N_{US}$ equations with $5n + n_{US}$ unknowns. Following Costinot and Rodriguez-Clare (2014), I refer to this system of equations as either an equilibrium in changes or hat algebra.

Taking the ratio of (25), the change in the US welfare from the factual to a counterfactual, $\hat{W}_{US}$, is

$$
\hat{W}_{US} = \left(\sum_{k \in N_{US}} \mu_k \hat{\Phi}_k^{\theta} \right)^{\frac{1}{\theta}}.
$$

Taking the ratio of (26), the change in welfare in non-US country j from the factual to a counterfactual, $\hat{W}_j$, is

$$
\hat{W}_j = \hat{\Phi}_j,
$$

where, by taking the ratio of (27) between a counterfactual and the factual, $\hat{\Phi}_j$ is

$$\hat{\Phi}_j = \frac{e_j \hat{e}_j \frac{1}{\eta}\left(\frac{w_j \hat{w}_j}{\hat{P}_j} + \frac{\pi_j \hat{\pi}_j}{L_j \hat{P}_j}\right) + (1 - e_j \hat{e}_j)\left(b_j P_j + \frac{\pi_j \hat{\pi}_j}{L_j \hat{P}_j}\right)}{e_j \frac{1}{\eta}\left(w_j + \frac{\pi_j}{L_j}\right) + (1 - e_j)\left(b_j P_j + \frac{\pi_j}{L_j}\right)}$$

for $j \in N_{NUS}$.

3 Taking the Model to Data

This section details data source and how parameters and factual values in the hat algebra are assigned from the data. I consider two counterfactuals, that is, the 5% increase in China's productivity and the 5% decrease in China-US trade costs. I do not have to assign productivity, amenity and trade costs to compute these counterfactuals because the hat algebra cancels them out. However, some parameter values and the factual equilibrium values remain to be assigned. Specifically, I need to assign the values of the disutility from making an effort η for (28) and (37), the probabilities that firms detect shirking $\{q_j\}_{j\in N}$ for (28), the factual aggregate profits in non-US countries $\{\pi_j\}_{j\in N_{NUS}}$ and in the US π_{US} for (28), (30) and (37), the factual employment rates $\{e_j\}_{j\in N}$ for (30) and (37), the factual nominal wages $\{w_j\}_{j\in N}$ for (30) and (37), the elasticity of substitution σ for (32), (34) and (35), location k's share in location j's imports $\{\gamma_{k,j}\}_{(k,j)\in N\times N}$ for (32), location k's share in location j's exports $\{\alpha_{j,k}\}_{(j,k)\in N\times N}$ for (34) and (35), the factual nominal unemployment benefits $\{b_j P_j\}_{j\in N}$ for (28), (30) and (37) and the shares of state j's labor force in the US $\{\mu_j\}_{j\in N_{US}}$ for (36).

Following Broda and Weinstein (2006), I opt to set the elasticity of substitution $\sigma = 4$.[7]

I collect trade values among 30 non-US countries and the 50 US states as of 2012.[8] The trade values among the 80 locations constitute the 80×80 matrix whose (j,k) element is the trade value from location j to location k, $X_{j,k}$. Trade values between non-US countries come from the United Nations comtrade database. Trade values between the US states and the non-US countries come from the US Census Bureau USA trade online. Trade values between the US states are from the commodity flow survey that is uploaded on the US Census Bureau American Fact Finder. Merging the three data yields the trade value matrix of the 30 non-US countries and the 50 US states. A problem is that 288 values out of

[7] The mean of the point estimates for the elasticities of substitution for US imports across SITC-3 industries is 4, as in pp. 568, Table IV of Broda and Weinstein (2006). The elasticity of substitution varies across SITC-3 industries from 1.2 of thermionic cold cathode to 22.1 of crude oil.

[8] At the time of writing this paper (November, 2019), the most recent data of the US inter-state trade values is of 2012.

$50 \times 50 = 2500$ are missing in the US inter-state trade data. Suppose that the trade value from US state k to US state j as of 2012, $X_{k,j}^{2012}$, is missing. Then if I have the trade value from k to j as of 2007, say $X_{k,j}^{2007}$, I fill the missing value $X_{k,j}^{2012}$ with

$$X_{k,j}^{2007} \times g_{US}^{2007,2012},$$

where $g_{US}^{2007,2012} = 1.12$ is the growth rate of the US nominal GDP from 2007 to 2012. This procedure fills 194 missing values out of 288. I set zeros for the remaining 94 missing trade values among the US states, which are 3.8% of all the 2500 inter-state trade values. Some of international trade values and trade values between non-US countries and US states are zeros in the data sources, and I set zeros for missing values in them. After all, I have 129 zero values in the 80×80 whole trade value matrix, thus 2% of the trade values are zeros in my data.

Once I obtain trade values between any pair of locations, I can compute $\{\gamma_{j,k}\}_{(j,k)\in N\times N}$ and $\{\alpha_{j,k}\}_{(j,k)\in N\times N}$ following the definitions (31) and (33) respectively. Moreover, for any $j \in N$, equation (20) implies

$$\pi_j = \frac{1}{\sigma}\sum_{k\in N} X_{j,k}.$$

Therefore with the parameter value $\sigma = 4$, I back out aggregate profits in locations from the trade values.

Factual levels of nominal wages $\{w_j\}_{j\in N}$, labor forces $\{L_j\}_{j\in N}$ and employment rates $\{e_j\}_{j\in N}$ are directly taken from data. The nominal wages of all the non-US countries but China come from OECD's data of average annual wages as of 2012. The average nominal wages of the OECD countries are measured in national currency units such as euros for EU and yens for Japan, and I translate them in terms of the US dollars with the nominal exchange rates in 2012. The nominal wage in China as of 2012 is taken from China Labour Statistical Yearbook 2016. Again I translate it in terms of the US dollars with the nominal exchange rate. For the nominal wages for the US states, I use the data of average annual pays from Bureau of Labor Statistics Quarterly Census of Employment and Wages.

Labor forces in the non-US countries come from the World Bank. Labor forces in the US states are taken from US Bureau of Labor Statistics Local Area Unemployment Statistics by the US Census Bureau. For any location j, the employment rate e_j satisfies $e_j = 1 - u_j$, where u_j denotes the unemployment rate. Therefore it is sufficient to have unemployment rates to assign the factual employment rates to the hat algebra. I obtain the unemployment rates in the non-US countries except China at the World Bank Open Data, where the data, in turn, is from the ILOSTAT database of International Labour Organization (ILO). The unemployment rate in China as of 2012 is taken from China Labour Statistical Yearbook

2016.[9] The unemployment rates of the US states come from the US Bureau of Labor Statistics Expanded State Employment Status Demographic Data.

The data of unemployment benefits in 2012 come from three sources. First, the data of the unemployment benefits in the non-US countries except China come from OECD.Stat Net Replacement Rates in unemployment. The website provides the percentages that an unemployed person can receive from unemployment insurance relative to her previous wage that she received before unemployment. This data is provided for a variety of countries, wage levels and periods of unemployment. For example, I can obtain how much an unemployed single person receives from unemployment insurance if she has been unemployed for 1 year and had received the national average wage before unemployment. I use the value of insurance payment for this profile (single, unemployed for 1 year, previous in-work earnings of the national average wage) to assign the values of unemployment benefits for non-US countries except China. Second, I assume that unemployed people receive 20% of the wage in China, based on the description in Qian (2014), because I cannot find the data of unemployment benefits of China in sources from the government or public organizations. He says "Benefits, which could be valid for as long as 104 weeks, can account up to about 20% of average wage," thus assuming that anyone unemployed receives 20% of the average wage admittedly overstates the unemployment benefits in China. Third, the data of the unemployment benefits in the US states come from UI Replacement Rates Report by the US Department of Labor, Employment and Training Administration. The webpage presents the replacement rate which is defined by the weighted average of

$$\frac{\text{the weekly benefit amounts (WBA)}}{\text{the claimants' normal hourly wage times 40 hours}}.$$ [10]

The replacement rate is the weighted average rather than the simple average across unemployed people because each unemployed person has a different spell of unemployment. The weights are lengths of unemployment spells. I multiply the average nominal wage of a US state by the replacement rate to compute the level of the nominal unemployment benefit in the US state.

The values of η, the disutility from making an effort, and $\{q_j\}_{j \in N}$, the probabilities that firms detect shirking, have not been assigned yet. Following Davis and Harrigan (2011), I set $\eta = 1.0001$, which is admittedly arbitrary. This means that making an effort reduces utility by 0.01% relative to shirking, if consumption and amenity are held fixed. Then,

[9] In the data of the World Bank-ILO, the unemployment rate of China in 2012 is 4.6%. In the China Labour Statistical Yearbook 2016, it is 4.1%. I use the value of 4.1%.

[10] This replacement rate is defined to be the "replacement ratio 1" at the webpage, because another definition for the replacement rate is also presented.

rewriting (12), $\eta = 1.0001$ and the factual values that I have assigned together determine the values of $\{q_j\}_{j \in N}$ by

$$q_j = \frac{(\eta - 1)\left(\frac{\pi_j}{L_j} + w_j\right)}{\eta(w_j - b_j P_j)} \text{ for } j \in N_{NUS},$$
$$q_j = \frac{(\eta - 1)\left(\frac{\pi_{US}}{L_{US}} + w_j\right)}{\eta(w_j - b_j P_j)} \text{ for } j \in N_{US}. \tag{38}$$

Now the hat algebra (28), (30), (32), (34), (35) and (36) (with (37)) is equipped with all the parameters and the factual values to compute counterfactuals.

4 Counterfactuals

Based on the model in Section 2 and the data and the parameter values in Section 3, I compute two counterfactuals. Subsection 4.1 presents the counterfactual of the 5% increase in China's productivity. Subsection 4.2 presents the counterfactual of the 5% decrease in China-US trade costs.

4.1 5% Increase in China's Productivity

I consider the 5% exogenous increase in China's productivity. That is, $\hat{z}_{CHN} = 1.05$ and $\hat{z}_j = 1$ for any $j \in N \setminus \{CHN\}$, where CHN stands for China.

Figure 1 represents the % changes in real wages in the US states. Real wages increase in all the states. State with dark blue have a large increase in real wages, and states with light blue have a small increase in real wages. I observe gradation from the heartland with light blue to the west coast with dark blue. California has the largest increase of 0.11% in the real wage, and Louisiana has the smallest increase of 0.02% in the real wage.

Figure 2 represents the % changes in real profits in the US states. That is, $\left\{\frac{\hat{\pi}_j}{\hat{P}_j}\right\}_{j \in N_{US}}$ are expressed in % changes. Real profits increase only in California and Tennessee. Real profits decrease in the other 48 states. States with dark blue have an increase or a small decrease in real profits, and states with light blue have a large decrease in real profits. I observe gradation from the heartland with light blue to the west coast with dark blue. California has the largest increase of 0.20% in real profits, and Wyoming has the largest decrease of 0.30% in real profits.

Figure 3 represents the percentage point changes in unemployment in the US states. Unemployment increases in all the states. States with dark blue have a large increase in unemployment, and states with light blue have a small increase in unemployment. I observe gradation from the heartland with dark blue to the west coast with light blue, except Oregon. This is in line with the finding of Bloom et al. (2019) that employment in the US has shifted from the heartland to the coasts in response to China's economic emergence. Alaska has the smallest increase of 0.05 percentage points in unemployment, and Iowa has the largest increase of 0.23 percentage points in unemployment. The model predicts that California has the third smallest increase of 0.08 percentage points in unemployment, whereas Caliendo et al. (2019) claims that California had the largest decline in employment in response to the China shock. This is perhaps because I have only one sector in the model, whereas Caliendo et al. (2019) have multiple sectors. They argue that California faced the severest competition with China because both California and China are specialized in electronics and computers. My model does not capture sectoral specialization of places.

Figure 4 represents the % changes in labor forces in the US states. Labor forces increase in only 8 states, and labor forces decrease in the other 42 states. State with dark blue have an increase or a small decrease in labor forces, and state with light blue have a large decrease in labor forces. I observe gradation from the heartland with light blue to the west coast with dark blue. California has the largest increase of 0.18% in the labor force, and South Dakota has the largest decrease of 0.10% in the labor force.

Table 1 reports the % changes in real wages, the % changes in real profits, the percentage point changes in unemployment, and the % changes in welfare in non-US countries, and the % change in the US welfare. Real wages increase in all the non-US countries. Real profits increase in China, and do not substantially change in Czech Republic and South Korea. Real profits decrease in the other 27 non-US countries. Unemployment decreases only in China. Unemployment increases in the other 29 non-US countries. Welfare increases only in China, Czech Republic and South Korea. Welfare decreases in the other 27 non-US countries. The model predicts a country's welfare loss from another country's productivity improvement, which is different from the predictions by Eaton and Kortum (2002), Anderson and van Wincoop (2003) and Melitz (2003).

I have shown the counterfactual outcomes of the 5% increase in China's productivity under the assumption that $\eta = 1.0001$. Table 2 compares the welfare changes in China and the US for three values of η, $\eta = 1.0001, 1.01, 1.05$. Recall that for each value of η, equation (38) yields different values of $\{q_j\}_{j \in N}$ to rationalize no-shirking wages in the factual equilibrium. Any other parameter is the same across $\eta = 1.0001, 1.01, 1.05$. As η increases from 1.0001 to 1.05, the absolute values of the welfare changes decrease. The 5% increase in China's productivity decreases China's unemployment, thus more people are employed in China. The larger η is, the less attractive working and making an effort is. Therefore, the welfare increase from the larger employment in China is dampened for a large value of η. The 5% increase in China's productivity increases the US unemployment, thus less people are employed in the US. The welfare decrease from the smaller employment in the US is numbed for a large value of η.

4.2 5% Decrease in China-US Trade Costs

I consider the 5% exogenous decrease in China-US trade costs. That is, $\hat{t}_{j,CHN} = 0.95$ for any $j \in N_{US}$ and $\hat{t}_{CHN,j} = 0.95$ for any $j \in N_{US}$.

Figure 5 represents the % changes in real wages in the US states. Real wages increase in all the US states. States with dark blue have a large increase in real wages, and states with light blue have a small increase in real wages. I observe gradation from the heartland with light blue to the west coast with dark blue. California has the largest increase of 0.19% in the real wage, and Wyoming has the smallest increase of 0.04% in the real wage.

Figure 6 represents the % changes in real profits in the US states. Real profits increase in 30 US states, and they decrease in the other 20 US states. States with dark blue have an increase in real profits, and states with light blue have a decrease in real profits. I observe gradation from the heartland with light blue to the west coast with dark blue. Alaska has the largest increase of 2.2% in real profits, and South Dakota has the largest decrease of 0.33% in real profits.

Figure 7 represents the percentage point changes in unemployment in the US states. Unemployment increases in 11 US states, and unemployment decreases in the other 39 US states. States with dark blue have an increase in unemployment, and states with light blue have a decrease in unemployment. I observe gradation from the heartland with dark blue to the west coast with light blue. Alaska has the largest decrease of 1.33 percentage points in unemployment, and South Dakota has the largest increase of 0.14 percentage points in unemployment.

Figure 8 represents the % changes in labor forces in the US states. Labor forces increase in 12 US states, and labor forces decrease in the other 38 US states. States with dark blue have an increase in labor forces, and states with light blue have a decrease in labor forces. Alaska has the largest increase of 0.65% in the labor force, and South Dakota has the largest decrease of 0.24% in the labor force.

Table 3 reports the % changes in real wages, the % changes in real profits, the percentage point changes in unemployment, and the % changes in welfare in non-US countries, and the % change in the US welfare. Real wages increase in 14 non-US countries, and they decrease in the other 16 non-US countries. Real profits increase only in China, and they decrease in the other 29 non-US countries. Unemployment decreases only in China, and unemployment increases in the other 29 non-US countries. Welfare increases only in China and the US, and welfare decreases in the other 29 countries. This is analogous to a classical theory about free trade agreements (FTA) (Bhagwati, 1993). If two countries sign an FTA, it is beneficial to the signatories and harmful to the third countries, because a signatory discriminates against goods from the third countries relative to goods from the other signatory. Similarly, if trade costs only between China and the US decrease, these two countries gain and the other countries lose, because China and the US's goods become more attractive to each other relative to goods from the other countries.

I have discussed the counterfactual outcomes of the 5% decrease in China-US trade costs under the assumption that $\eta = 1.0001$. Table 4 compares the welfare changes in China and the US for three values of η, $\eta = 1.0001, 1.01, 1.05$. For each value of η, equation 38 implies different $\{q_j\}_{j \in N}$. Any other parameter is the same across $\eta = 1.0001, 1.01, 1.05$. As η increases from 1.0001 to 1.05, the magnitudes of the welfare increases decrease. The 5% decrease in China-US trade costs decrease unemployment in both China and the US. The larger η is, the smaller the welfare increase from the larger employment is, because working and making an effort are not very attractive for a large value of η.

5 Conclusion

I have developed a many-region model that equilibrates involuntary unemployment. I have integrated the efficiency-wage model of Shapiro and Stiglitz (1984) into a quantitative general equilibrium model of international trade and spatial economy. I have computed the counterfactuals of the 5% increase in China's productivity and the 5% decrease in China-US trade costs. In both the counterfactuals, the model has predicted a geographic pattern where US states in the heartland have relatively more negative labor market effects than US states in the west coast.

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Figure 1: % Changes in Real Wages in the US States in Response to 5% Increase in China's Productivity

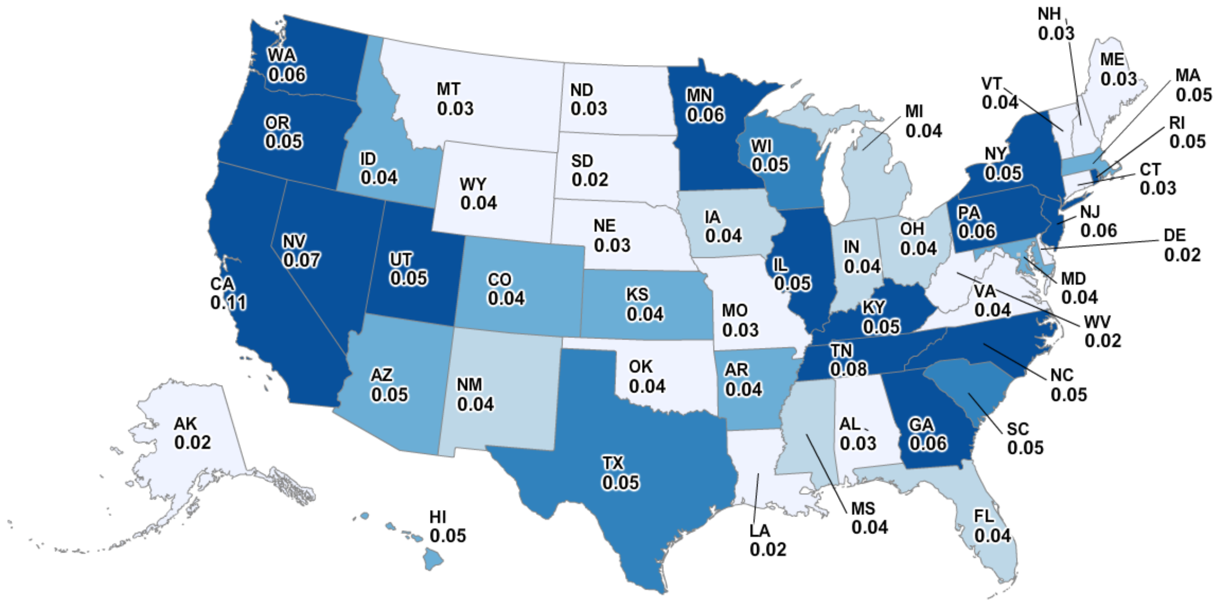

Figure 2: % Changes in Real Profits in the US States in Response to 5% Increase in China's Productivity

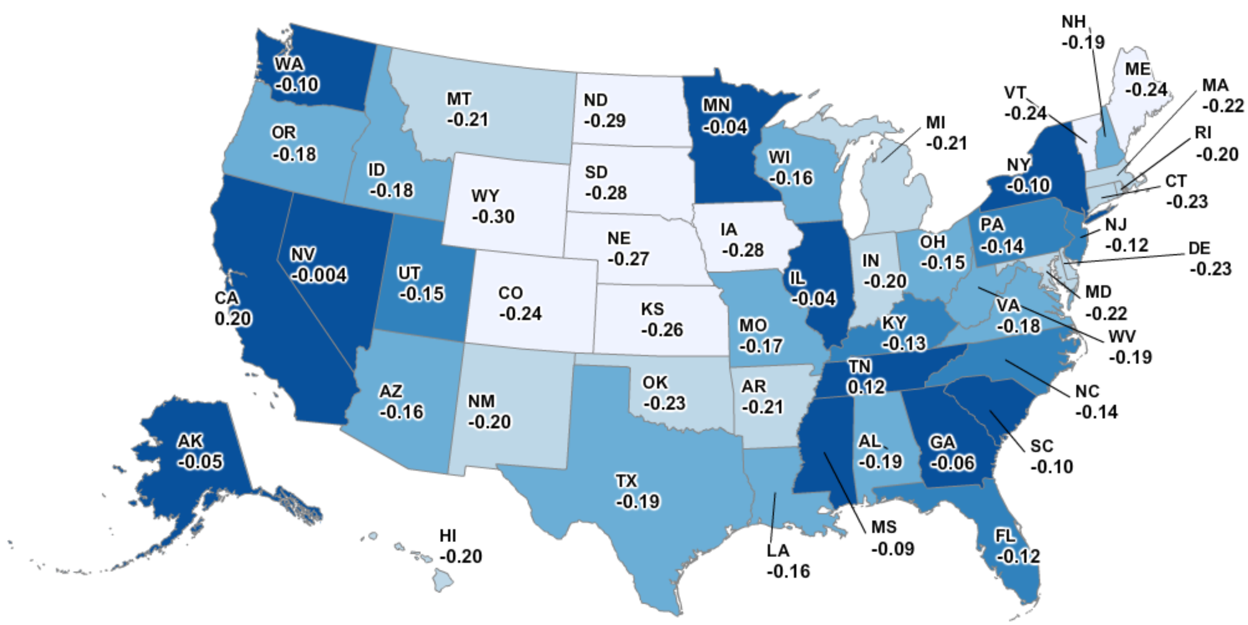

Figure 3: Percentage Point Changes in Unemployment in the US States in Response to 5% Increase in China's Productivity

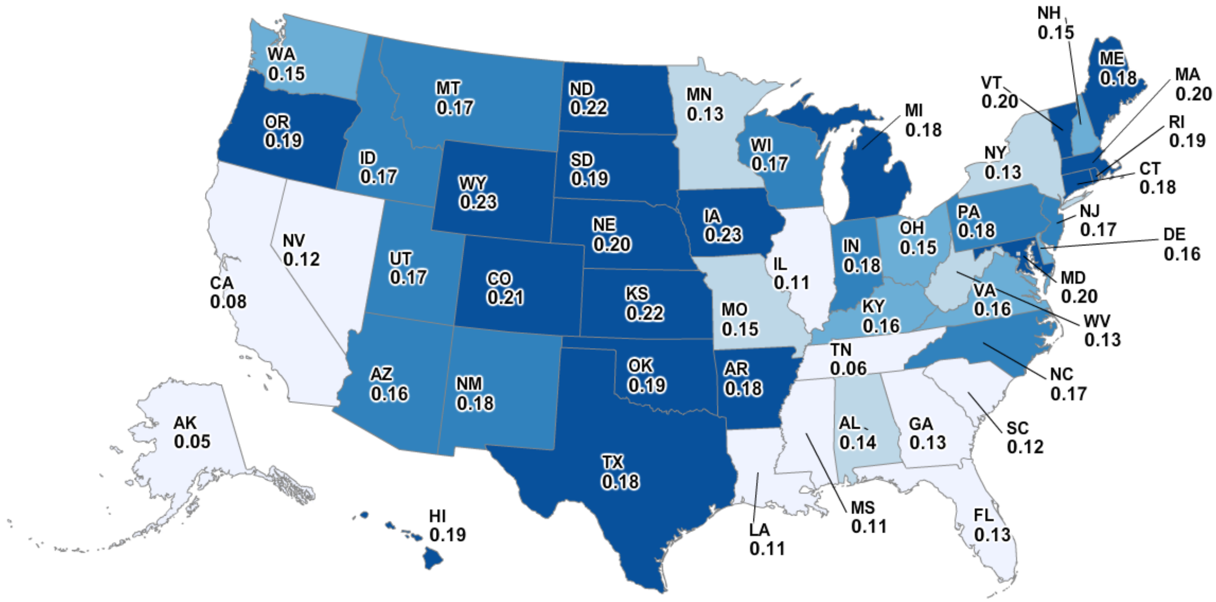

Figure 4: % Changes in Labor Forces in the US States in Response to 5% Increase in China's Productivity

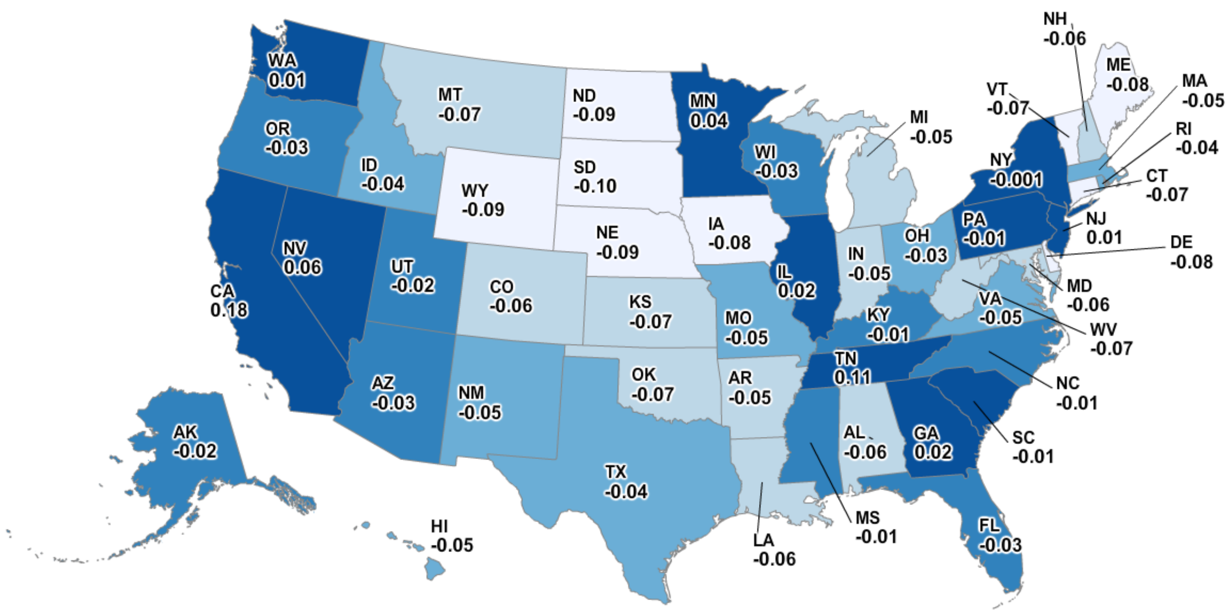

Figure 5: % Changes in Real Wages in the US States in Response to 5% Decreases in China-US Trade Costs

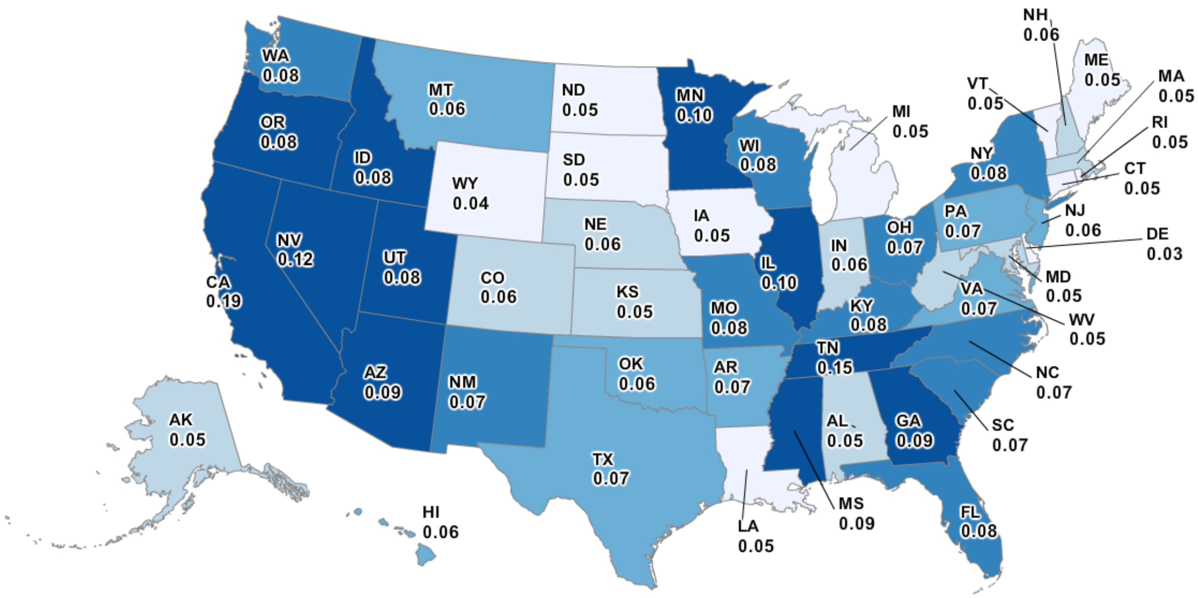

Figure 6: % Changes in Real Profits in the US States in Response to 5% Decreases in China-US Trade Costs

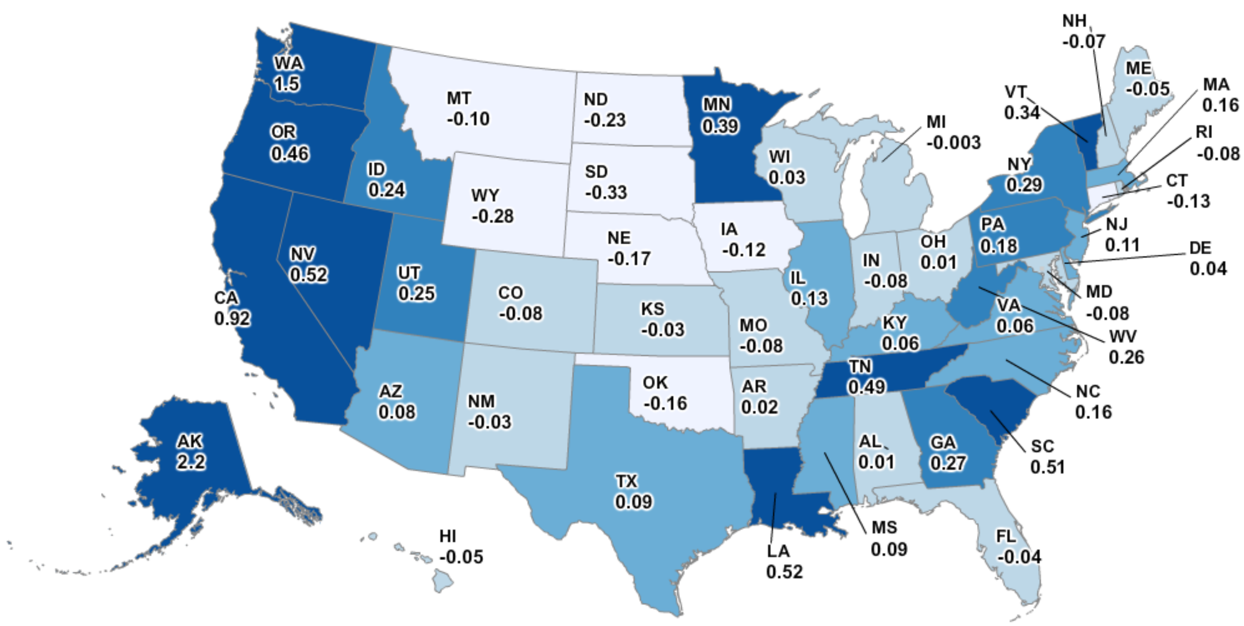

Figure 7: Percentage Point Changes in Unemployment in the US States in Response to 5% Decreases in China-US Trade Costs

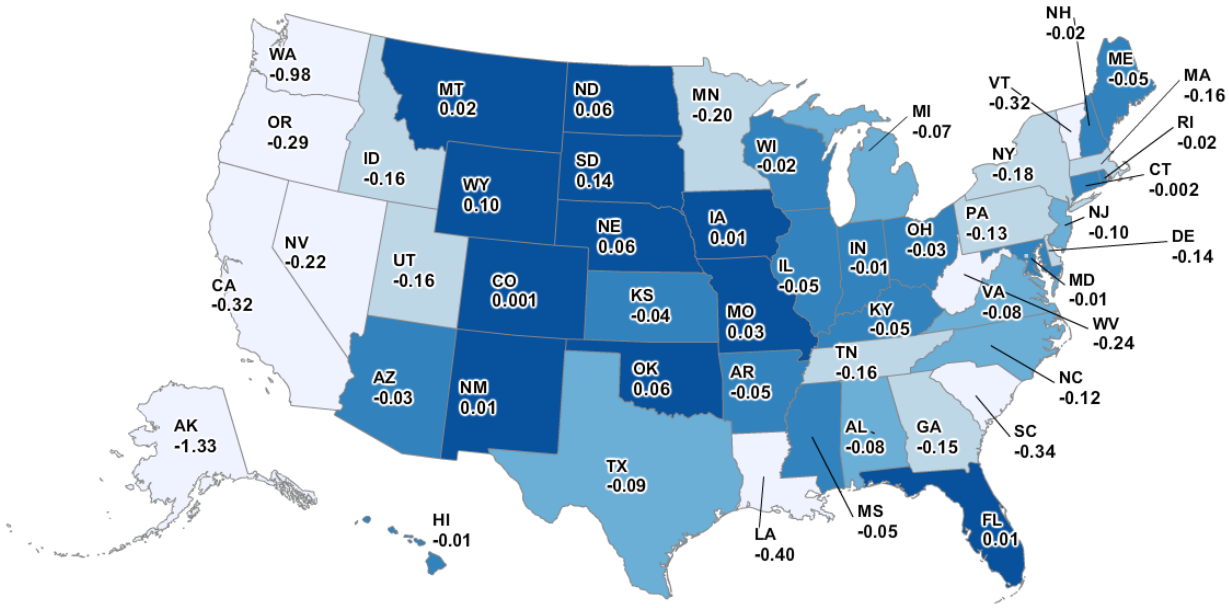

Figure 8: % Changes in Labor Forces in the US States in Response to 5% Decreases in China-US Trade Costs

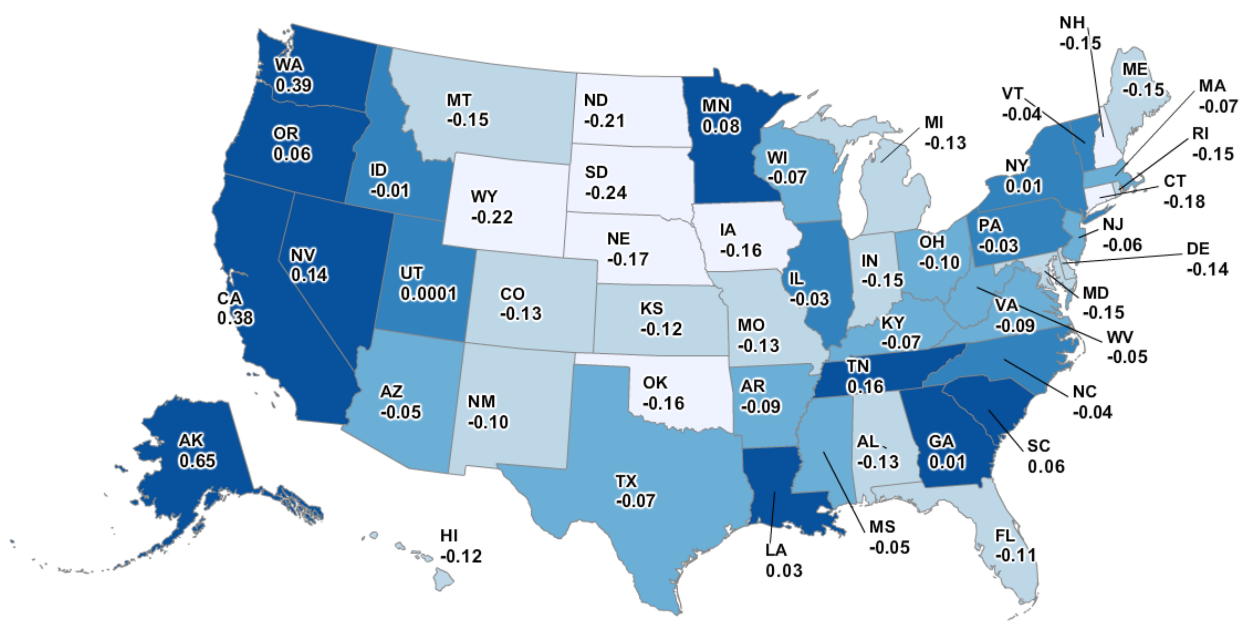

Table 1: Changes in Equilibrium Outcomes of Countries in Response to 5% Increase in China's Productivity

Country	Real Wage %	Real Profits %	Unemployment p.p.	Walfare %
Australia	0.05	-0.08	0.13	-0.06
Belgium	0.05	-0.16	0.20	-0.08
Canada	0.04	-0.09	0.12	-0.07
China	4.82	8.79	-3.64	8.21
Czech Republic	0.09	0.00	0.08	0.01
Denmark	0.05	-0.23	0.26	-0.11
Estonia	0.07	-0.06	0.11	-0.03
Finland	0.05	-0.19	0.22	-0.10
France	0.05	-0.23	0.25	-0.11
Germany	0.06	-0.16	0.20	-0.08
Greece	0.03	-0.11	0.11	-0.09
Hungary	0.03	-0.08	0.10	-0.07
Iceland	0.01	-0.15	0.15	-0.14
Ireland	0.04	-0.15	0.16	-0.09
Israel	0.04	-0.09	0.12	-0.07
Italy	0.03	-0.06	0.08	-0.06
Japan	0.06	-0.11	0.16	-0.06
Korea, South	0.10	0.01	0.08	0.02
Luxembourg	0.06	-0.40	0.43	-0.21
Netherlands	0.07	-0.11	0.17	-0.03
New Zealand	0.06	-0.08	0.13	-0.05
Norway	0.05	-0.24	0.28	-0.13
Poland	0.05	-0.10	0.14	-0.06
Portugal	0.07	-0.46	0.45	-0.16
Slovakia	0.07	-0.03	0.08	-0.02
Slovenia	0.05	-0.10	0.13	-0.07
Spain	0.05	-0.21	0.20	-0.11
Sweden	0.03	-0.18	0.19	-0.12
Switzerland	0.06	-0.30	0.34	-0.13
United Kingdom	0.04	-0.14	0.16	-0.09
United States				-0.14

Table 2: Welfare Changes of 5% Increase in China's Productivity for Three Values of η

η	1.0001	1.01	1.05
$\hat{W}_{CHN}$	8.210	8.192	8.123
$\hat{W}_{US}$	-0.139	-0.137	-0.128

Table 3: Changes in Equilibrium Outcomes of Countries in Response to 5% Decreases in China-US Trade Costs

Country	Real Wage %	Real Profits %	Unemployment p.p.	Walfare %
Australia	0.01	0.00	0.01	0.00
Belgium	0.01	-0.04	0.04	-0.02
Canada	-0.01	-0.05	0.03	-0.04
China	0.12	0.20	-0.07	0.18
Czech Republic	-0.02	-0.06	0.04	-0.05
Denmark	0.00	-0.08	0.08	-0.05
Estonia	-0.01	-0.06	0.05	-0.05
Finland	0.00	-0.06	0.06	-0.04
France	0.00	-0.07	0.06	-0.04
Germany	0.00	-0.07	0.07	-0.05
Greece	0.00	-0.02	0.02	-0.02
Hungary	0.00	-0.02	0.02	-0.02
Iceland	0.00	-0.02	0.02	-0.02
Ireland	-0.01	-0.09	0.07	-0.07
Israel	-0.02	-0.05	0.03	-0.05
Italy	0.00	-0.02	0.01	-0.02
Japan	0.00	-0.05	0.05	-0.04
Korea, South	0.01	-0.01	0.02	-0.01
Luxembourg	0.01	-0.04	0.05	-0.02
Netherlands	0.00	-0.07	0.07	-0.03
New Zealand	0.00	-0.03	0.03	-0.02
Norway	0.00	-0.07	0.07	-0.04
Poland	0.00	-0.05	0.04	-0.04
Portugal	0.01	-0.10	0.09	-0.04
Slovakia	-0.01	-0.04	0.02	-0.03
Slovenia	0.00	-0.04	0.03	-0.03
Spain	0.00	-0.06	0.05	-0.03
Sweden	0.00	-0.04	0.04	-0.03
Switzerland	0.01	-0.05	0.05	-0.02
United Kingdom	0.00	-0.04	0.04	-0.03
United States				0.43

Table 4: Welfare Changes of 5% Decrease in China-US Trade Costs for Three Values of η

η	1.0001	1.01	1.05
$\hat{W}_{CHN}$	0.184	0.183	0.182
$\hat{W}_{US}$	0.427	0.425	0.417