DOI: 10.1111/roie.12370

WILEY

SPECIAL ISSUE PAPER

The 'China shock,' exports and U.S. employment: A global input–output analysis

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Abstract

This paper quantifies the impact on U.S. employment from imports and exports during 1995–2011, using the World Input–Output Database. We find that the growth in U.S. exports led to increased demand for 2 million jobs in manufacturing, 0.5 million in resource industries, and a remarkable 4.1 million jobs in services, totaling 6.6 million. Two-thirds of those service sectors jobs are due to the export of services themselves, whereas one-third is due to the intermediate demand from manufacturing and resource—or *merchandise*—exports, so the total labor demand gain due to merchandise exports was 3.7 million jobs. In comparison, U.S. merchandise imports from China led to reduced demand of 1.4 million jobs in manufacturing and 0.6 million in services (with small losses in resource industries), with total job losses of 2.0 million. It follows that the expansion in U.S. merchandise exports relative to imports from China over 1995–2011 created net demand for about 1.7 million jobs. Comparing the growth of U.S. merchandise exports to merchandise imports from *all* countries, we find a fall in net labor demand due to trade, but comparing the growth of *total* U.S. exports to total imports from all countries, then there is a rise in net labor demand because of the growth in service exports.

1 | INTRODUCTION

Arguably among the most significant events in international trade in recent decades has been the rapid rise in exports from China since its entry into the World Trade Organization (WTO) in 2001, or the "China shock." Even before that date China received the low, most-favored-nation tariffs associated with WTO membership by a vote of the U.S. Congress each year. But after China's accession to the WTO, the reduction in the uncertainty associated with that vote contributed importantly to the surge in exports to the United States. This argument is made by Pierce and Schott (2016) and by Handley and Limão (2017).[1] Pierce and Schott find that the surge in Chinese exports to the United States coincides with a substantial decline in U.S. manufacturing employment. Handley and Limão find that the welfare gain for consumers due to this increase in Chinese imports is of the same order of magnitude as the U.S. gain from new imported varieties in the preceding decade. These findings highlight the dual roles that Chinese imports play for the United States: on the one hand, they create import competition and labor-market dislocation; and on the other hand, they benefit U.S. consumers.[2]

The first of these roles is pursued in a series of papers by Autor, Dorn, and Hanson (2013, 2015), and with Song, 2014. They analyze the effect of rising Chinese import competition between 1990 and 2007 on local U.S. labor markets, exploiting the geographic differences in import exposure arising from initial differences in industry specialization. Rising import exposure increases unemployment, lowers labor force participation, and reduces wages in local labor markets. At the aggregate level, a conservative estimate is that the import surge accounts for one-quarter of the decline in U.S. manufacturing employment. Most recently, in joint work with Acemoglu and Price, these authors find that the import surge from China also contributes to the unusually slow employment growth in the United States following the financial crisis and the Great Recession (Acemoglu, Autor, Dorn, Hanson, & Price, 2016).

While these papers by Autor and co-authors have explored the negative impact of import competition from China on employment in the United States, some recent articles highlight the role of China as an engine of world economic growth (e.g., Vianna, 2016; IMF, 2017; World Bank, 2017). These articles speak to the second role played by China, in bringing consumer benefits as well as benefits to workers in export-oriented industries. Feenstra, Ma, and Xu (2017) have examined the positive employment effects of U.S. exports using techniques similar to those in Autor et al. (2013, 2015).[3] Depending on the estimation method, they find that employment in manufacturing industries grew by roughly the same amount due to global exports as the decline in employment due to Chinese imports. This result is perhaps not surprising given the magnitude of growth in U.S. exports as compared to total imports and imports from China. Relative to GDP, U.S. exports rose by 10 percentage points from 1995 to 2011, imports rose by 15 percentage points, and imports from China rose by 4 percentage points from a very low base, as depicted in Figure 1. So whether we focus on U.S. exports to the world or on imports from China, the magnitude of changes over this period has been large and the potential employment effects are correspondingly large.

In this paper, we quantify the employment impacts of U.S. imports and exports using a global input–output analysis.[4] Specifically, we use the World Input–Output Database (WIOD) of Timmer, Erumban, Los, Stehrer, and de Vries (2014) and Timmer, Dietzenbacher, Los, Stehrer, and de Vries (2015). In Section 2, we follow the method of Los, Timmer, and de Vries (2015, 2016), which focuses on the demand side of the labor market, to quantify the positive impact from U.S. exports on employment. We find that the growth in exports led to demand for 2 million jobs in manufacturing, 0.5 million in resource industries, and a remarkable 4.1 million jobs in services over 1995–2011, totaling 6.6 million. Two-thirds of those service-sectors jobs are due to the export of services themselves, whereas one-third is due to the intermediate demand from the manufacturing and resource—or what we call

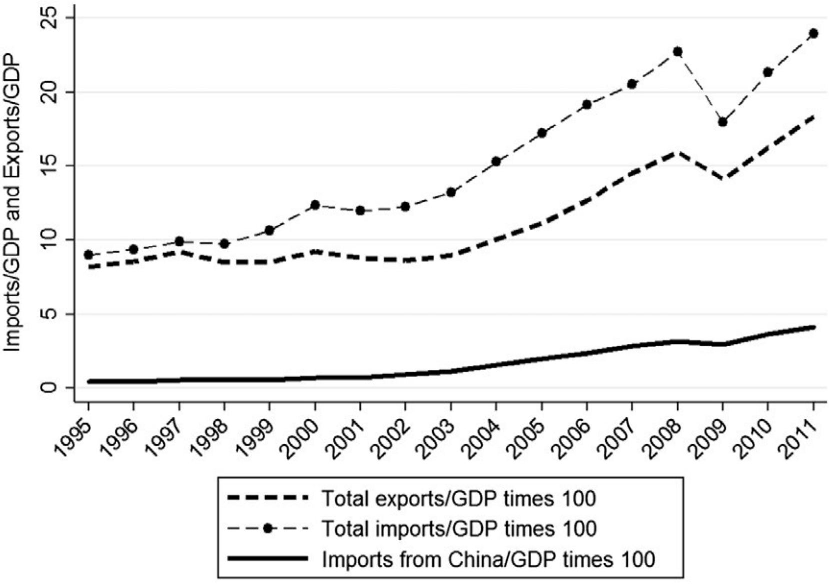

FIGURE 1 Import and export shares in the United States. *Notes*. The figure shows the U.S. aggregate export value, the U.S. aggregate import value, and the U.S. import value from China as a share of U.S. GDP. The data on exports and imports are from the WIOD Input–Output Table where both final goods and intermediate goods are included

merchandise—exports, so the total demand gains from merchandise exports are 3.7 million jobs, with 1.9 million in manufacturing, 0.45 million in natural resource industries, and 1.3 million in services.

In Section 3, we consider U.S. imports from China. In that case, we must specify the added U.S. production that would occur if imports from China had not grown, and we consider several possible assumptions along these lines. Our preferred estimates give reduced demand due to U.S. imports from China of 1.4 million jobs in manufacturing, and another 1 million in services (with small losses in resource industries), over 1995–2011. One-half of those job losses in services are due to increased U.S. service imports, with the other half due to intermediate demand from merchandise exports, so the total demand reduction due to merchandise (mainly manufacturing) imports are 2.0 million jobs. The import estimates are very close to those from Acemoglu et al. (2016), who find about 1.0 million jobs lost directly in manufacturing and another 1.0 million jobs lost throughout the economy through input–output linkages, during the slightly shorter period 1999–2011. It follows that the expansion in U.S. merchandise exports relative to imports from China over 1995–2011 led to net demand for about 1.7 million jobs. Extending our analysis to compare the growth of U.S. merchandise exports to merchandise imports from *all* countries in Section 4, we find a fall in net labor demand due to trade, but comparing the growth of *total* U.S. exports to total imports from all countries, there is a rise in net labor demand because of the growth in service exports.

There are two limitations of the global input–output analysis. First, as we have already indicated, the employment effects are calculated from the *demand side* of the labor market, without consideration of how the labor market will clear. This limitation could be addressed by incorporating the global input–output tables into a computable model with frictional labor market clearing (e.g., Caliendo, Dvorkin, & Parro, 2015), but we do not attempt that here. Second, the changes in exports or imports that are held fixed to compute their impact on employment are the *actual* changes in these trade flows, and not the *exogenous* portion of these changes that result from a specific cause. Autor et al. (2013, 2015), for example, use Chinese exports to eight other countries to instrument for Chinese exports to the United States. In Section 5, we pursue a similar approach of predicting the change in U.S. merchandise imports from China and total exports that are due to exogenous factors, including tariff changes and demand shifts. We find that nearly two-thirds of the employment impacts are explained by these factors. Conclusions are given in Section 6 and additional material is gathered in the Supporting information.

2 | U.S. EXPORTS AND EMPLOYMENT

2.1 | Structure of the global input–output table

We consider an N-country and S-sector case to match with the WIOD input–output table, which has $N = 41$ countries, including the rest of the world, and $S = 35$ sectors. Let $x^{(i,r),(j,s)}$ denote the value of intermediate goods produced in sector r of country i and used by sector s of country j. Final-good flows are also described in a similar manner: $d^{(i,r),j}$ indicates the value of final goods produced in sector r of country i and demanded in country j. The gross value of output of sector r of country i, $y^{i,r}$, is computed as the sum of sales for intermediate and final use over all purchasing sectors and countries:

$$y^{i,r} = \sum_s \sum_j x^{(i,r),(j,s)} + \sum_j d^{(i,r),j}. \tag{1}$$

By dividing the intermediate-good flows by the gross output in the destination sector of the destination country, we find the input–output coefficients:

$$a^{(i,r),(j,s)} \equiv x^{(i,r),(j,s)} / y^{j,s},$$

which are arranged in the matrix,

$$A \equiv \begin{bmatrix} a^{(1,1),(1,1)} & a^{(1,1),(1,2)} & \dots & a^{(1,1),(N,S)} \\ a^{(1,2),(1,1)} & a^{(1,2),(1,2)} & \dots & a^{(1,2),(N,S)} \\ \vdots & \vdots & \ddots & \vdots \\ a^{(2,1),(1,1)} & a^{(2,1),(1,2)} & & \\ \vdots & \vdots & \ddots & \vdots \\ a^{(N,S),(1,1)} & a^{(N,S),(1,2)} & \dots & a^{(N,S),(N,S)} \end{bmatrix}$$

with N countries and S sectors, the global input–output matrix $\mathbf{A}$ is $(N \times S) \times (N \times S)$, and it extends the Leontief (1936) matrix to include international linkages between countries.

Denote the final demand of country j buying from country i with the $S \times 1$ vector $\mathbf{d}^{i,j}$,

$$\underbrace{\mathbf{d}^{i,j}}_{S\times 1} \equiv \begin{bmatrix} d^{(i,1),j} \\ d^{(i,2),j} \\ \vdots \\ d^{(i,S),j} \end{bmatrix} \text{ and } \underbrace{\mathbf{D}}_{(N\times S)\times 1} \equiv \begin{bmatrix} \sum_k \mathbf{d}^{1,k} \\ \sum_k \mathbf{d}^{2,k} \\ \vdots \\ \sum_k \mathbf{d}^{N,k} \end{bmatrix}$$

where $\mathbf{D}$ is the $(N \times S) \times 1$ stacked vector of final demands over all countries. Likewise we denote the gross output from country i as the $S \times 1$ vector $\mathbf{y}^i$, and we stack these in the $(N \times S) \times 1$ vector $\mathbf{Y}$. Then Equation (1) is written alternatively as

$$\mathbf{Y} = (\mathbf{I} - \mathbf{A})^{-1} \mathbf{D},$$

where $\mathbf{I}$ denotes an identity matrix. The inverse $(\mathbf{I}-\mathbf{A})^{-1}$ can be expressed as the geometric series $(\mathbf{I}-\mathbf{A})^{-1}\mathbf{D}=\sum_{n=0}^{\infty}\mathbf{A}^n\mathbf{D}$. The first term $\mathbf{D}$ is the direct output absorbed as final goods, the second term $\mathbf{AD}$ is the intermediate goods used to produce those final goods, including imported intermediate goods, and the third term $\mathbf{A}^2\mathbf{D}$ includes the additional intermediate goods employed to produce the first round of intermediate goods $\mathbf{AD}$, and so on.

The $(N\times S)\times 1$ vector of employment in each country and sector is obtained by multiplying the gross outputs by the ratio of employment to gross output in each sector, denoted by $\lambda^{i,s}$, with the $(N\times S)\times(N\times S)$ diagonal matrix $\mathbf{\Lambda}$, to obtain:

$$\mathbf{L}\equiv\mathbf{\Lambda}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{D}. \tag{2}$$

We shall use the global input–output table provided by WIOD (Timmer et al., 2014, 2015), which differs by year, so we henceforth add the subscript t to all variables. It is worth stressing that (2) holds identically in WIOD in all years, meaning that labor demands (on the right) equal supplies (on the left). In our calculations we will be investigating changes in demand, but without imposing labor-market clearing.

2.2 | Quantifying the employment effect of export expansion

In this section we employ the technique proposed by Los et al. (2015) to quantify the employment effect of the growth in U.S. exports to the world.[5] Since the first year of the WIOD is 1995, as the baseline the employment effect of export expansion is computed as:

$$\tilde{\mathbf{L}}^{EX1}_{1995,t}\equiv\mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t-\mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\tilde{\mathbf{D}}^{EX}_{1995,t}, \tag{3}$$

where $\tilde{\mathbf{D}}^{EX}_{1995,t}$ is the hypothetical final-demand matrix defined as follows:

$$\underbrace{\tilde{\mathbf{D}}^{EX}_{1995,t}}_{(N\times S)\times 1}\equiv\begin{bmatrix}\sum_k \mathbf{d}_t^{1,k}\\ \sum_k \mathbf{d}_t^{2,k}\\ \vdots\\ \mathbf{d}_t^{US,US}+\sum_{k\neq US}\mathbf{d}_{1995}^{US,k}\\ \vdots\\ \sum_k \mathbf{d}_t^{N,k}\end{bmatrix}.$$

From this definition, exports from the United States to the rest of the world are kept at the 1995 level ($\sum_{k\neq US}\mathbf{d}_{1995}^{US,k}$), while the U.S. domestic purchases from the U.S. final-good producers ($\mathbf{d}_t^{US,US}$) and trade in other countries are allowed to change over time.

The first term on the right of (3) measures the actual employment, while the latter term is the employment in a hypothetical world where U.S. exports stayed the same at the 1995 level. The gap between the two is interpreted as the employment effect of export expansion. A positive number means job creation while a negative number implies job destruction. Although this measure takes final-good exports in the final-demand matrix $\mathbf{D}_t$ into consideration, it does not take intermediate-good exports in the global input–output matrix $\mathbf{A}_t$ into account. The next measure also includes changes in the exports of intermediate goods:

$$\tilde{\mathbf{L}}^{EX2}_{1995,t} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\tilde{\mathbf{A}}^{EX}_{1995,t})^{-1}\tilde{\mathbf{D}}^{EX}_{1995,t},$$

where,

$$\underbrace{\tilde{\mathbf{A}}^{EX}_{1995,t}}_{(N\times S)\times(N\times S)} \equiv \begin{bmatrix} \mathbf{A}^{1,1}_t & \mathbf{A}^{1,2}_t & \dots & \mathbf{A}^{1,US}_t & \dots & \mathbf{A}^{1,N}_t \\ \mathbf{A}^{2,1}_t & \mathbf{A}^{2,2}_t & \dots & \mathbf{A}^{2,US}_t & \dots & \mathbf{A}^{2,N}_t \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \tilde{\mathbf{A}}^{US,1}_{1995,t} & \tilde{\mathbf{A}}^{US,2}_{1995,t} & \dots & \mathbf{A}^{US,US}_t & \dots & \tilde{\mathbf{A}}^{US,N}_{1995,t} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}^{N,1}_t & \mathbf{A}^{N,2}_t & \dots & \mathbf{A}^{N,US}_t & \dots & \mathbf{A}^{N,N}_t \end{bmatrix}$$

denotes the global input–output matrix in which each of the elements in the matrix is a $S\times S$ sub-matrix describing intermediate-good flows from one country to another:

$$\underbrace{\mathbf{A}^{i,j}_t}_{S\times S} \equiv \begin{bmatrix} a^{(i,1),(j,1)} & a^{(i,1),(j,2)} & \dots & a^{(i,1),(j,S)} \\ a^{(i,2),(j,1)} & a^{(i,2),(j,2)} & \dots & a^{(i,2),(j,S)} \\ \vdots & \vdots & \ddots & \vdots \\ a^{(i,S),(j,1)} & a^{(i,S),(j,2)} & \dots & a^{(i,S),(j,S)} \end{bmatrix}.$$

This is a matrix of Leontief coefficients $a^{(i,r),(j,s)}$ denoting the intermediate-good flows from sector r of country i to sector s of country j in year t. However, for the U.S. sub-matrices, $\{\tilde{\mathbf{A}}^{US,k}_{1995,t}\}_{k\neq US}$, the intermediate-good flows from 1995 are employed to find the coefficients, $\tilde{a}^{(US,r),(j,s)}_{1995,t} \equiv x^{(US,r),(j,s)}_{1995}/y^{j,s}_t$.

$\tilde{\mathbf{L}}^{EX1}_{1995,t}$ and $\tilde{\mathbf{L}}^{EX2}_{1995,t}$ are both stacked $(N\times S)\times 1$ vectors of the employment effects over all sectors and countries, and in either case we are particularly interested in the $S\times 1$ sub-vector for the United States. Using the sectors available in WIOD, we aggregate the U.S. employment effects into the natural-resource sector (i.e., agricultural and mining, WIOD sectors 1–3), manufacturing (sectors 4–16), and services (sectors 17–35), as follows:[6]

$$\tilde{\mathbf{L}}^{EX,US}_{1995,t}(\text{Resource}) \equiv \sum_{s=1}^{3} \tilde{\mathbf{L}}^{EX,US}_{1995,t}(s),$$

$$\tilde{\mathbf{L}}^{EX,US}_{1995,t}(\text{Manufacturing}) \equiv \sum_{s=4}^{16} \tilde{\mathbf{L}}^{EX,US}_{1995,t}(s), \tag{4}$$

$$\tilde{\mathbf{L}}^{EX,US}_{1995,t}(\text{Services}) \equiv \sum_{s=17}^{35} \tilde{\mathbf{L}}^{EX,US}_{1995,t}(s).$$

The overall employment effect in the U.S. economy is

$$\tilde{\mathbf{L}}^{EX,US}_{1995,t}(\text{All sectors}) \equiv \sum_{s=1}^{35} \tilde{\mathbf{L}}^{EX,US}_{1995,t}(s). \tag{5}$$

The same aggregation as that in Equations (4) to (5) is applied to the rest of the employment effect measures presented in this paper.

The results from estimating the employment effect of export expansion are shown in Table 1. Exports of final goods added demand for 760,000 manufacturing jobs over 1995–2011, which is 4.5 percent of total manufacturing employment in 1995. By taking intermediate exports into account, the employment effect of export expansion becomes even greater—export expansion added demand for 2.0 million manufacturing jobs, and another 0.5 million jobs in resource industries. These estimates are somewhat larger than found for another 16-year period by Feenstra et al. (2017, note 9), who find gains in manufacturing jobs of 1.91 million due to rising U.S. exports over 1991–2011. Still, considering that our input–output analysis is based purely on the demand side, whereas Feenstra et al. use equilibrium changes in employment, and that we have not yet attempted to isolate exogenous changes in exports, there is surprising similarity between the two sets of estimates. The extent of demand creation due to U.S. exports is the greatest for the service sector, where final-good exports added 0.9 million jobs while intermediate exports added another 3.2 million—4.1 million jobs in total.

These total estimates for the three sectors are carried over into column (1) of Table 2. There we separate the direct-plus-indirect effects of manufacturing and resource exports—or what we call *merchandise* exports—from the direct-plus-indirect effect of service exports. We see that for the merchandise sectors, nearly the entire added labor demand is due to the exports of these industries themselves. But for the service sectors, comparing decomposed numbers of Table 2, we find that *one-third* of the job gains arise indirectly due to manufacturing and resource exports, whereas *two-thirds* of these job gains are explained by exports of final or intermediate services themselves. Our focus in this paper shall be on

TABLE 1 Employment effect of U.S. exports, 1995–2011 (million workers)

	Through final good exports only	Through final good and intermediate exports	Employment in 1995
Manufacturing	0.76 (4.5%)	1.99 (11.9%)	16.8
Resource	0.17 (3.3%)	0.46 (8.9%)	5.2
Services	0.92 (0.8%)	4.11 (3.7%)	112.0
All sectors	1.85 (1.4%)	6.57 (4.9%)	134.0

Notes. Numbers without parentheses are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. Numbers in parentheses are the ratio of the employment effect to the total employment in the benchmark year 1995. The 35 WIOD sectors are aggregated into three broad sectors: the natural resource sector (sectors 1–3), the manufacturing sector (sectors 4–16), and the service sector (sectors 17–35), and the last row reports the sum of employment effects in all 35 sectors.

TABLE 2 Employment effect of U.S. merchandise versus service exports, 1995–2011 (million workers)

		Decomposition	
	The impact of final good and intermediate exports from *all* sectors	**The impact of final good and intermediate exports from *merchandise* sectors**	**The impact of final good and intermediate exports from *service* sectors**
Manufacturing	1.99	1.94	0.053
Resource	0.46	0.45	0.015
Services	4.11	1.34	2.78
All sectors	6.57	3.73	2.85

Notes. Numbers reported are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. See notes to Table 1 for the sector definitions.

the exports of manufacturing and resource industries, including its intermediate demand for service jobs. We see that U.S. exports led to increased demand of about 1.9 million manufacturing jobs, 0.45 resource industry jobs and 1.3 service sector jobs, or 3.7 million jobs in total during 1995–2011. These results show that U.S. labor demand has grown substantially from export opportunities.

3 | QUANTIFYING THE EMPLOYMENT EFFECT OF IMPORTS FROM CHINA

In order to quantify the employment effect of export expansion, in the previous section we replaced current export values with the one from benchmark year, 1995. Quantifying the employment effect of import competition from China is not as simple, however, as it is for export expansion. We will show that simply replacing the current China import values with the values from 1995 leads to a misleading estimate. In order to understand this result, we first consider a simple two-country, one-sector world, and solve for the employment effects analytically using expansions based on Johnson and Noguera (2012).

3.1 | Two-country, one-sector case

Suppose that there are two countries, the United States and China, indicated by superscripts *US* and *C*, respectively. Each country is comprised of only one sector. The employment effect of import competition from China is estimated as the gap between the actual employment and the one in a hypothetical world where U.S. imports from China are fixed at the 1995 level:

$$\begin{pmatrix} \tilde{L}^{IM,C}_{1995,t} \\ \tilde{L}^{IM,US}_{1995,t} \end{pmatrix} = \begin{pmatrix} \lambda^C_t & 0 \\ 0 & \lambda^{US}_t \end{pmatrix} \left[\mathbf{I} - \begin{pmatrix} a^{C,C}_t & a^{C,US}_t \\ a^{US,C}_t & a^{US,US}_t \end{pmatrix} \right]^{-1} \begin{pmatrix} d^{C,C}_t + d^{C,US}_t \\ d^{US,US}_t + d^{US,C}_t \end{pmatrix} - \begin{pmatrix} \lambda^C_t & 0 \\ 0 & \lambda^{US}_t \end{pmatrix} \left[\mathbf{I} - \begin{pmatrix} a^{C,C}_t & a^{C,US}_t \\ a^{US,C}_t & a^{US,US}_t \end{pmatrix} \right]^{-1} \begin{pmatrix} d^{C,C}_t + d^{C,US}_{1995} \\ d^{US,US}_t + d^{US,C}_t \end{pmatrix},$$

where λ^i_t is the employment-to-gross output ratio for country $i = US, C$ in year t; $a^{i,j}_t$ denotes the input–output coefficient describing intermediate-good flows from country i to country j in year t; and $d^{i,j}_t$ denotes the corresponding final-good flows.

Solving for the U.S. employment effect $\tilde{L}^{IM,US}_{1995,t}$ due to fixed imports, we obtain:

$$\begin{aligned} \tilde{L}^{IM,US}_{1995,t} &= \underbrace{\lambda^{US}_t \mu^{US}_t \left[\left(d^{US,US}_t + d^{US,C}_t\right) + \frac{a^{US,C}_t}{1 - a^{C,C}_t} \left(d^{C,US}_t + d^{C,C}_t\right) \right]}_{\text{Actual employment}} \\ &\quad - \underbrace{\lambda^{US}_t \mu^{US}_t \left[\left(d^{US,US}_t + d^{US,C}_t\right) + \frac{a^{US,C}_t}{1 - a^{C,C}_t} \left(d^{C,US}_{1995} + d^{C,C}_t\right) \right]}_{\text{Hypothetical employment}} \\ &= \lambda^{US}_t \mu^{US}_t \frac{a^{US,C}_t}{1 - a^{C,C}_t} \left(d^{C,US}_t - d^{C,US}_{1995}\right) > 0, \end{aligned}$$

where $\mu_t^{US} \equiv \left(1 - a_t^{US,US} - \frac{a_t^{US,C} a_t^{C,US}}{1-a_t^{C,C}}\right) \geq 1$ is an intermediate-good multiplier that describes the total amount of gross output from the United States required to produce one unit of U.S. net output. Because imports from China to the United States increased over time since 1995, we know that $d_t^{C,US} > d_{1995}^{C,US}$ for $t > 1995$. It follows that $\tilde{L}_{1995,t}^{IM,US} > 0$, meaning that the employment effect of imports from China becomes positive. In order to understand why this is the case, we look at the first term of the above equation carefully.

The U.S. employment which appears as the first bracketed term above has two components. The first, $\lambda_t^{US}\mu_t^{US}\left(d_t^{US,US} + d_t^{US,C}\right)$, is the total number of workers employed in the United States to produce final goods absorbed at home, $d_t^{US,US}$, and exported to China, $d_t^{US,C}$. The second component, $\lambda_t^{US}\mu_t^{US}\frac{a_t^{US,C}}{1-a_t^{C,C}}\left(d_t^{C,US} + d_t^{C,C}\right)$, is the total number of workers employed in the United States to produce goods in China. In order to consume final goods of $d_t^{C,C}$ and export final goods of $d_t^{C,US}$, Chinese producers need to produce $(1-a_t^{C,C})^{-1}(d_t^{C,US} + d_t^{C,C})$ units of output, which requires $a_t^{US,C}(1-a_t^{C,C})^{-1}(d_t^{C,US} + d_t^{C,C})$ units of U.S. output as intermediates. In the second bracketed term above, we hypothetically hold fixed U.S. imports from China at their 1995 level. But then we find that the computed U.S. employment level is *less than* the actual employment level, because the United States loses intermediate demand from China. As a result, the gap between the actual and hypothetical employment, $\tilde{L}_{1995,t}^{IM,US}$, becomes positive, meaning that U.S. imports from China have a positive employment-creation effect.

This counter-intuitive result occurs because we have not taken into account the impact of fixed U.S. imports from China on U.S. domestic production $d_t^{US,US}$ (and intermediate use $a_t^{US,US}$). In a hypothetical world where U.S. imports from China are fixed at their 1995 level, we would expect that U.S. domestic production should be higher than otherwise in order to meet domestic demand. Denote the hypothetical U.S. domestic final-good production, when imports from China are fixed, as $\tilde{d}_{1995,t}^{US,US}$, which we expect is greater than $d_t^{US,US}$. With this adjusted U.S. domestic final-good production, the employment effect of China is now estimated as:

$$\begin{pmatrix} \tilde{L}_{1995,t}^{IM,C} \\ \tilde{L}_{1995,t}^{IM,US} \end{pmatrix} = \underbrace{\begin{pmatrix} \lambda_t^C & 0 \\ 0 & \lambda_t^{US} \end{pmatrix}\left[\mathbf{I} - \begin{pmatrix} a_t^{C,C} & a_t^{C,US} \\ a_t^{US,C} & a_t^{US,US} \end{pmatrix}\right]^{-1}\begin{pmatrix} d_t^{C,C} + d_t^{C,US} \\ d_t^{US,US} + d_t^{US,C} \end{pmatrix}}_{\text{Actual employment}}$$
$$- \underbrace{\begin{pmatrix} \lambda_t^C & 0 \\ 0 & \lambda_t^{US} \end{pmatrix}\left[\mathbf{I} - \begin{pmatrix} a_t^{C,C} & a_t^{C,US} \\ a_t^{US,C} & a_t^{US,US} \end{pmatrix}\right]^{-1}\begin{pmatrix} d_t^{C,C} + d_{1995}^{C,US} \\ \tilde{d}_{1995,t}^{US,US} + d_t^{US,C} \end{pmatrix}}_{\text{Hypothetical employment}}.$$

The U.S. employment effect from Chinese imports is now calculated as

$$\tilde{L}_{1995,t}^{IM,US} = \underbrace{\lambda_t^{US}\mu_t^{US}\left(d_t^{US,US} - \tilde{d}_{1995,t}^{US,US}\right)}_{(-)} + \underbrace{\lambda_t^{US}\mu_t^{US}\frac{a_t^{US,C}}{1-a_t^{C,C}}\left(d_t^{C,US} - d_{1995}^{C,US}\right)}_{(+)},$$

which is negative if the job loss through reduced U.S. domestic production (the first term) exceeds the job gain through China's intermediate good demand (the second term).

This simple two-country and one-sector example shows that simply replacing imports from China to the United States with the one from the benchmark year does not lead to a reasonable result, because U.S. domestic production also needs to be adjusted. In Appendix B in the Supporting information we confirm that this counter-intuitive result holds quantitatively in the multi-country, multi-sector WIOD model. In the following section, we consider the general case and propose ways to find hypothetical U.S. domestic production when imports from China stay at the benchmark year level.

3.2 | *N*-country and *S*-sector case

The employment effect of U.S. imports from China is estimated in the general *N*-country and *S*-sector case as follows:

$$\tilde{\mathbf{L}}^{IM1}_{1995,t} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\tilde{\mathbf{D}}^{IM}_{1995,t}, \tag{6}$$

where,

$$\underbrace{\mathbf{D}_t}_{(N\times S)\times 1} \equiv \begin{bmatrix} \sum_k \mathbf{d}_t^{1,k} \\ \sum_k \mathbf{d}_t^{2,k} \\ \vdots \\ \sum_k \mathbf{d}_t^{C,k} \\ \vdots \\ \sum_k \mathbf{d}_t^{US,k} \\ \vdots \\ \sum_k \mathbf{d}_t^{N,k} \end{bmatrix} \text{ and } \underbrace{\tilde{\mathbf{D}}^{IM}_{1995,t}}_{(N\times S)\times 1} \equiv \begin{bmatrix} \sum_k \mathbf{d}_t^{1,k} \\ \sum_k \mathbf{d}_t^{2,k} \\ \vdots \\ \mathbf{d}_{1995}^{C,US} + \sum_{k\neq US} \mathbf{d}_t^{C,k} \\ \vdots \\ \tilde{\mathbf{d}}_{1995,t}^{US,US} + \sum_{k\neq US} \mathbf{d}_t^{US,k} \\ \vdots \\ \sum_k \mathbf{d}_t^{N,k} \end{bmatrix}.$$

The first term in Equation (6), $\mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t$, is the actual employment effect due to the total demand (equivalent to the total employment) while the second term, $\mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\tilde{\mathbf{D}}^{IM}_{1995,t}$, is the employment effect of the total demand in a hypothetical world where increases in imports from China since 1995 are replaced with increases in U.S. domestic demand for goods from U.S. domestic producers. The hypothetical U.S. demand for home final-good producers in sector s in year t, $\tilde{d}^{(US,s),US}_{1995,t}$, is calculated using the following three functional forms:

Functional form #1: $\tilde{d}^{(US,s),US}_{1995,t} \equiv d_t^{(US,s),US} + (d_t^{(C,s),US} - d_{1995}^{(C,s),US})$

Functional form #2: $$\tilde{d}^{(US,s),US}_{1995,t} \equiv \underbrace{\frac{d_{1995}^{(US,s),US}}{\sum_{k=1}^{N} d_{1995}^{(k,s),US}}}_{\text{Hypothetical share of U.S. producers}} \times \underbrace{\sum_{k=1}^{N} d_t^{(k,s),US}}_{\text{Total U.S. final good demand}}$$

Functional form #3: $$\tilde{d}^{(US,s),US}_{1995,t} \equiv \underbrace{\frac{d_t^{(US,s),US}}{d_{1995}^{(C,s),US} + \sum_{k\neq C}^{N} d_t^{(k,s),US}}}_{\text{Hypothetical share of U.S. producers}} \times \underbrace{\sum_{k=1}^{N} d_t^{(k,s),US}}_{\text{Total U.S. final good demand}}$$

Functional form #1 assumes that imports from China exactly replace U.S. domestic production. With Chinese imports held fixed at their 1995 level, then U.S. production increases commensurate with the growth that would have occurred in Chinese imports. Functional form #2 assumes that U.S. domestic production increases proportionately to the actual increase in the total U.S. final demand, assuming that U.S. market share in the U.S. domestic market is constant at the 1995 level, $d_{1995}^{(US,s),US} / \sum_{k=1}^{N} d_{1995}^{(k,s),US}$. This case actually accounts for changing imports from *all* countries, since it holds imports from all countries constant in the denominator of the hypothetical share term. We will see that this functional form gives the greatest employment impact. In functional form #3, we hold only imports from China constant in the share term, so we are allowing those imports to crowd out not just U.S. production but also imports from other countries, proportional to their market shares.

Measure (6) quantifies the employment effect of final-goods imports from China, with adjustment to U.S. production of final goods. It does not take into account, however, possible adjustments to the imports of intermediate goods. To incorporate these adjustments, we use a second measure of the employment effect:

$$\tilde{\mathbf{L}}_{1995,t}^{IM2} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\tilde{\mathbf{A}}_{1995,t}^{IM})^{-1}\tilde{\mathbf{D}}_{1995,t}^{IM}, \tag{7}$$

where $\tilde{\mathbf{A}}_{1995,t}^{IM}$ is an $(N \times S) \times (N \times S)$ global input–output matrix representing a hypothetical situation in which imports from China to the United States are kept at the 1995 level:

$$\underbrace{\tilde{\mathbf{A}}_{1995,t}^{IM}}_{(N\times S)\times(N\times S)} \equiv \begin{bmatrix} \mathbf{A}_t^{1,1} & \mathbf{A}_t^{1,2} & \dots & \mathbf{A}_t^{1,US} & \dots & \mathbf{A}_t^{1,N} \\ \mathbf{A}_t^{2,1} & \mathbf{A}_t^{2,2} & \dots & \mathbf{A}_t^{2,US} & \dots & \mathbf{A}_t^{2,N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}_t^{C,1} & \mathbf{A}_t^{C,2} & \dots & \tilde{\mathbf{A}}_{1995,t}^{C,US} & \dots & \mathbf{A}_t^{C,N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}_t^{US,1} & \mathbf{A}_t^{US,2} & \dots & \tilde{\mathbf{A}}_{1995}^{US,US} & \dots & \mathbf{A}_t^{US,N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}_t^{N,1} & \mathbf{A}_t^{N,2} & \dots & \mathbf{A}_t^{N,US} & \dots & \mathbf{A}_t^{N,N} \end{bmatrix},$$

Each element in this matrix is an $S \times S$ Leontief matrix. The matrix for intermediate flows from China to the United States is $\tilde{\mathbf{A}}_{1995,t}^{C,US}$, with elements $\tilde{a}_{1995,t}^{(C,r),(US,s)}$, describing the intermediate imports from China fixed at their 1995 level:

$$\tilde{a}_{1995,t}^{(C,r),(US,s)} \equiv x_{1995}^{(C,r),(US,s)} / y_t^{US,s}. \tag{8}$$

Correspondingly, the matrix for intermediate flows within the United States is $\tilde{\mathbf{A}}_{1995}^{US,US}$, with elements that describe intermediate flows from sector r to sector s when demand has shifted towards U.S. producers:

$$\tilde{a}_{1995,t}^{(US,r),(US,s)} \equiv \tilde{x}_{1995}^{(US,r),(US,s)} / y_t^{US,s}.$$

The values of intermediate goods $\tilde{x}_{1995}^{(US,r),(US,s)}$ are calculated using the same three functional forms as used for final goods:

Functional form #1: $\tilde{x}_{1995,t}^{(US,r),(US,s)} \equiv x_t^{(US,r),(US,s)} + (x_t^{(C,r),(US,s)} - x_{1995}^{(C,r),(US,s)})$

Functional form #2: $$\tilde{x}_{1995,t}^{(US,r),(US,s)} \equiv \underbrace{\frac{x_{1995}^{(US,r),(US,s)}}{\sum_{k=1}^{N} x_{1995}^{(k,r),(US,s)}}}_{\text{Hypothetical share of U.S. producers}} \times \underbrace{\sum_{k=1}^{N} x_t^{(k,r),(US,s)}}_{\text{Total U.S. final good demand}}$$

Functional form #3: $$\tilde{x}_{1995,t}^{(US,r),(US,s)} \equiv \underbrace{\frac{x_t^{(US,r),(US,s)}}{x_{1995}^{(C,r),(US,s)} + \sum_{k \neq C}^{N} x_t^{(k,r),(US,s)}}}_{\text{Hypothetical share of U.S. producers}} \times \underbrace{\sum_{k=1}^{N} x_t^{(k,r),(US,s)}}_{\text{Total U.S. final good demand}}$$

Table 3 summarizes the employment effect of imports from China estimated by adjusting U.S. domestic production using the three functional forms above. Panels A through C show the results from using functional forms #1 through #3, respectively. Panel A shows that final-good imports from China led to reduced labor demand of 0.8 million jobs in manufacturing, 40,000 jobs in resource industries, and 350,000 service sector jobs, or 1.2 million jobs in total. Together with intermediate-goods imports from China, reduced U.S. labor demand was 1.4 million, 60,000, and 960,000 in the manufacturing, resource, and the service sectors, respectively, or 2.4 million jobs in total.

Panel B reports the result from using functional form #2. It predicts a greater negative employment impact in the manufacturing and resource sectors. Final-good and intermediate imports from China reduced demand for manufacturing jobs by 2.9 million and resource jobs by 0.5 million. Together with 2.5 million service sector jobs lost, the overall job losses were 5.9 million. Functional form #3 leads to the smallest demand reduction as shown in Panel C. Imports of final goods and intermediate goods from China led to 0.7 million job losses in manufacturing, 40,000 job losses in resource industries, and another 0.7 million job losses in services, for overall reduced demand of 1.4 million jobs.

Our results are evidently sensitive to the assumed functional form for implied U.S. domestic production increases. In the next section, we utilize actual data to relate the market share of U.S. domestic producers to imports from China in a regression framework and propose a fourth estimate of the employment effect of these imports.

3.3 | Estimating U.S. producers' domestic market share

Rather than assuming a particular relationship between imports from China and the U.S. producers' market share, we shall estimate the share as:

$$\frac{d_t^{(US,s),US}}{\sum_{k=1}^{N} d_t^{(k,s),US}} = \alpha_0^s + \alpha_1 \frac{d_t^{(C,s),US}}{\sum_{k=1}^{N} d_t^{(k,s),US}} + u_t^s. \quad (9)$$

TABLE 3 Employment effect of imports from China while adjusting U.S. production, 1995–2011 (million workers)

	Through final good imports only	Through final good and intermediate good imports
Panel A: Functional form #1		
Manufacturing	–0.80	–1.37
Resource	–0.040	–0.060
Services	–0.35	–0.96
All sectors	–1.18	–2.39
Panel B: Functional form #2		
Manufacturing	–1.16	–2.85
Resource	–0.16	–0.52
Services	–0.71	–2.50
All sectors	–2.03	–5.86
Panel C: Functional form #3		
Manufacturing	–0.37	–0.70
Resource	–0.027	–0.041
Services	–0.21	–0.69
All sectors	–0.60	–1.44

Notes. Numbers reported are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. See notes to Table 1 for the sector definitions.

The dependent variable is the home market share in the U.S. domestic final-good market, $\frac{d_t^{(C,s),US}}{\sum_{k=1}^N d_t^{(k,s),US}}$ is the market share of China in the U.S. final-good market, α_0^s denotes sector fixed effects; and α_1 is the pass-through parameter from China's market share to U.S. producers' market share.

After estimating the relationship between the U.S. market share and imports from China, we compute a hypothetical domestic share by considering the situation in which imports from China are fixed at the 1995 level:[6]

$$\widehat{dshare}_{1995,t}^{(US,s)US} \equiv \hat{\alpha}_0^s + \hat{\alpha}_1 \frac{d_{1995}^{(C,s),US}}{d_{1995}^{(C,s),US} + \sum_{k \neq C}^N d_t^{(k,s),US}} + \hat{u}_t^s. \tag{10}$$

Using this estimated U.S. share and the actual total U.S. final-good demand, $\sum_{k=1}^{N} d_t^{(k,s),US}$, we compute hypothetical U.S. domestic production as:

$$\hat{d}_{1995,t}^{(US,s),US} \equiv \widehat{dshare}_{1995,t}^{(US,s)US} \sum_{k=1}^{N} d_t^{(k,s),US}. \tag{11}$$

Similarly, in order to find a relationship between home producers' market share in the U.S. domestic intermediate-good market and intermediate imports from China, we estimate:

$$\frac{x_t^{(US,r),(US,s)}}{\sum_{k=1}^N d_t^{(k,r),(US,s)}} = \alpha_0^{r,s} + \alpha_1^s \frac{x_t^{(C,r),(US,s)}}{\sum_{k=1}^N x_t^{(k,r),(US,s)}} + u_t^{r,s}. \tag{12}$$

In these equations we estimate 34 separate regressions, one for each importing sector s.[7]

The results from these market-share regressions are shown in Table 4. With OLS, the pass-through coefficient $\hat{\alpha}_1$ is estimated quite tightly at -1.1 for final goods, so that an increase in the Chinese market share displaces the U.S. market share by nearly the same amount. For intermediate goods, the pass-through coefficient varies over a wider range around -1. The market-share equation is also estimated with a dynamic panel IV model in order to deal with possible endogeneity. This could arise from the facts that (1) both the dependent and independent variables incorporate total U.S. demand; (2) the domestic market share of U.S. producers might be mechanically related with the Chinese market share there; and (3) the existence of measurement errors. To overcome these issues, we employ lagged dependent variables (lag 1 and lag 2), using the first difference of the independent variable as instruments. The results are reported in Table 4, showing that IV estimation implies slightly lower pass-through parameters. This suggests that OLS estimates have upward bias due to reverse causality and some other reasons.

Given these estimates, the predicted intermediate sales of U.S. producers, $\tilde{x}_{1995,t}^{(US,r),(US,s)}$, is computed like in (10) and (11):

$$\widehat{xshare}_{1995,t}^{(US,r),(US,s)} \equiv \hat{\alpha}_0^{r,s} + \hat{\alpha}_1^{s} \frac{x_{1995}^{(C,r),(US,s)}}{x_{1995}^{(C,r),(US,s)} + \sum_{k \neq C}^{N} x_t^{(k,r),(US,s)}} + \hat{u}_t^{r,s}, \tag{13}$$

$$\hat{x}_{1995,t}^{(US,r),(US,s)} \equiv \widehat{xshare}_{1995,t}^{(US,r),(US,s)} \sum_{k=1}^{N} x_t^{(k,r),(US,s)}. \tag{14}$$

We then compute the predicted job losses due to U.S. imports from China. Focusing first on the imports of final goods, the calculation in (6) is modified as:

$$\hat{\mathbf{L}}_{1995,t}^{IM1} \equiv \mathbf{\Lambda}_t (\mathbf{I} - \mathbf{A}_t)^{-1} \mathbf{D}_t - \mathbf{\Lambda}_t (\mathbf{I} - \mathbf{A}_t)^{-1} \hat{\mathbf{D}}_{1995,t}^{IM},$$

where,

$$\underbrace{\hat{\mathbf{D}}_{1995,t}^{IM}}_{(N \times S) \times 1} \equiv \begin{bmatrix} \sum_k \mathbf{d}_t^{1,k} \\ \sum_k \mathbf{d}_t^{2,k} \\ \vdots \\ \mathbf{d}_{1995}^{C,US} + \sum_{k \neq US} \mathbf{d}_t^{C,k} \\ \vdots \\ \hat{\mathbf{d}}_{1995,t}^{US,US} + \sum_{k \neq US} \mathbf{d}_t^{US,k} \\ \vdots \\ \sum_k \mathbf{d}_t^{N,k} \end{bmatrix}.$$

That is, the estimated domestic sales of U.S. goods, $\hat{\mathbf{d}}_{1995,t}^{US,US}$, is used from (11). Likewise, when extending the analysis to include the imports of intermediate goods from China, (7) is replaced by:

TABLE 4 Estimation result from the U.S. domestic market share regression, dep. var. = U.S. producers' market share in the U.S. domestic market

		OLS				IV		
		"Pass-through" parameters				"Pass-through" parameters		
		Coefficient	SE	Obs.	R^2	Coefficient	SE	Obs.
(0)	Final goods	−1.103***	(0.276)	595	0.56	−1.077	(6.506)	525
(1)	Agriculture, hunting, forestry, and fishing	−0.967	(0.607)	593	0.37	−1.564	(4.844)	523
(2)	Mining and quarrying	−2.512***	(0.367)	579	0.40	−1.719	(12.07)	510
(3)	Food, beverages and tobacco	−0.924**	(0.434)	595	0.42	−0.490	(18.82)	525
(4)	Textiles	−1.251***	(0.229)	584	0.57	−1.098	(6.068)	512
(5)	Leather and footwear	−0.882***	(0.156)	514	0.45	−0.646	(9.778)	448
(6)	Wood and cork	−1.162***	(0.148)	561	0.68	−0.803	(1.830)	495
(7)	Pulp, paper, printing and publishing	−0.961***	(0.316)	595	0.36	−0.841	(2.395)	525
(8)	Coke, refined petroleum and nuclear fuel	−0.969**	(0.469)	562	0.06	−1.730	(25.83)	488
(9)	Chemicals	−0.622	(0.491)	595	0.21	−0.270	(7.402)	525
(10)	Rubber and plastics	−1.445***	(0.207)	595	0.22	−1.131	(30.08)	525
(11)	Other non-metallic mineral	−1.102***	(0.107)	571	0.72	−1.022	(1.953)	495
(12)	Basic metals and fabricated metals	−0.150	(0.113)	595	0.05	−0.060	(0.595)	525
(13)	Machinery, nec	−0.961**	(0.360)	595	0.23	−0.264	(1.375)	525
(14)	Electrical and optical equipment	−0.783**	(0.351)	595	0.31	−0.371	(3.493)	525
(15)	Transport equipment	−0.778**	(0.364)	595	0.26	−0.756	(13.61)	525
(16)	Manufacturing nec; recycling	−1.104**	(0.468)	581	0.28	−1.234	(17.98)	509
(17)	Electricity, gas and water supply	−2.044***	(0.359)	571	0.11	−1.852	(143.7)	498
(18)	Construction	−1.278***	(0.316)	595	0.33	−0.720	(7.158)	525
(19)	Sale, maintenance and repair of motor vehicles	−0.649**	(0.264)	579	0.10	−0.581	(2.608)	509
(20)	Wholesale trade and commission trade	−2.266***	(0.297)	595	0.73	−1.999	(13.40)	525
(21)	Retail trade, except of motor vehicles	−1.583***	(0.170)	595	0.40	−1.080	(4.148)	525
(22)	Hotels and restaurants	−1.411***	(0.367)	595	0.32	−1.120	(19.44)	525
(23)	Inland transport	−1.517***	(0.127)	580	0.41	−1.011	(6.510)	510
(24)	Water transport	−1.282***	(0.136)	525	0.05	−1.049	(13.55)	454
(25)	Air transport	−0.767	(0.899)	556	0.02	−0.977	(20.25)	488

		OLS				IV		
		"Pass-through" parameters				"Pass-through" parameters		
		Coefficient	SE	Obs.	R^2	Coefficient	SE	Obs.
(26)	Supporting and auxiliary transport activities	−1.306***	(0.143)	560	0.30	−1.200	(7.146)	492
(27)	Post and telecommunications	−1.739***	(0.316)	595	0.62	−1.359	(2.401)	525
(28)	Fiscal intermediation	−0.496*	(0.275)	594	0.13	−0.682	(14.23)	522
(29)	Real estate activities	−0.516***	(0.110)	594	0.26	−0.924	(4.098)	522
(30)	Renting and other business activities	−1.378***	(0.150)	595	0.59	−1.235	(9.838)	525
(31)	Public admin and defense, and social security	−1.266**	(0.515)	595	0.40	−1.157	(3.090)	525
(32)	Education	−2.586***	(0.446)	582	0.78	−1.993	(5.642)	511
(33)	Health and social work	−1.405***	(0.378)	595	0.35	−1.093	(15.68)	525
(34)	Other community, social and personal services	−1.895***	(0.274)	595	0.49	−1.412	(10.57)	525

Notes. All OLS regressions include a constant term and sector fixed effects. All IV regressions include a constant term, lagged dependent variable. Sector fixed effects are controlled for by taking first differences. The first stage regression includes lagged dependent variable (lag 1 and lag 2), the first difference of Chinese market share. Row (0) reports the result from estimating Equation (9). Rows (1)–(34) show the result from estimating Equation (12) for each of importing sectors in the United States. Robust standard errors are in parentheses. The sample period is from 1995 to 2011. The market share regression for WIOD sector 35: "Private households with employed persons" is not estimated because there are no imports from China. ***, **, and * indicate statistical significance at 1%, 5%, and 10% level, respectively.

$$\hat{\mathbf{L}}^{IM2}_{1995,t} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\hat{\mathbf{A}}^{IM}_{1995,t})^{-1}\hat{\mathbf{D}}^{IM}_{1995,t},$$

where,

$$\underbrace{\tilde{\mathbf{A}}^{IM}_{1995,t}}_{(N\times S)\times(N\times S)} \equiv \begin{bmatrix} \mathbf{A}_t^{1,1} & \mathbf{A}_t^{1,2} & \dots & \mathbf{A}_t^{1,US} & \dots & \mathbf{A}_t^{1,N} \\ \mathbf{A}_t^{2,1} & \mathbf{A}_t^{2,2} & \dots & \mathbf{A}_t^{2,US} & \dots & \mathbf{A}_t^{2,N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}_t^{C,1} & \mathbf{A}_t^{C,2} & \dots & \tilde{\mathbf{A}}_{1995,t}^{C,US} & \dots & \mathbf{A}_t^{C,N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}_t^{US,1} & \mathbf{A}_t^{US,2} & \dots & \tilde{\mathbf{A}}_{1995}^{US,US} & \dots & \mathbf{A}_t^{US,N} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}_t^{N,1} & \mathbf{A}_t^{N,2} & \dots & \mathbf{A}_t^{N,US} & \dots & \mathbf{A}_t^{N,N} \end{bmatrix},$$

The input–output coefficients for China's sales to the United States, $\hat{\mathbf{A}}^{US,US}_{1995,t}$, are still calculated by holding Chinese imports fixed at their 1995 levels, as in (8). But the input–output coefficients for the United States are computed using the predicted U.S. sales,

$$\hat{a}_{1995,t}^{(US,r),(US,s)} \equiv \hat{x}_{1995}^{(US,r),(US,s)} / y_t^{US,s}.$$

The results from using predicted U.S. final and intermediate sales based on the OLS estimates are shown in Table 5. In the first column, we report the estimated reduction in labor demand from all final-good and intermediate imports from China. These declines include 1.4 million in manufacturing, 55,000 in resource industries, and 1.1 million in services, for a total of 2.6 million. Within the job losses in services, about 560,000 are due to input–output linkages with merchandise imports and the other 500,000 are due to competition from direct service imports. The results based on the IV estimates are summarized in Table 6. Because the IV estimation leads to slightly smaller pass-through parameters, the implied negative employment effect of Chinese imports is somewhat smaller than the one from Table 5. It shows that there are 1.25 million manufacturing job losses, 50,000 in natural resource sectors, and 900,000 in services, totaling 2.19 million. Among the job losses in services, 470,000 are due to the spillover effects through input–output linkages between manufacturing and services. Therefore, combined with the manufacturing job losses of 1.25 million, 1.72 million job cuts are due to manufacturing import penetration from China in the United States.

Focusing on the merchandise sector and its intermediate-demand effects through services, column (2) shows overall job losses of 1.8 to 2.0 million, based on IV and OLS estimates, respectively. This

TABLE 5 Employment effect of U.S. merchandise versus service imports from China, while estimating U.S. production, OLS, 1995–2011 (million workers)

	The impact of final good and intermediate imports from *all* sectors	Decomposition	
		The impact of final good and intermediate imports from *merchandise* sectors	The impact of final good and intermediate imports from *service* sectors
Manufacturing	−1.44	−1.43	−0.006
Resource	−0.055	−0.053	−0.002
Services	−1.06	−0.56	−0.50
All sectors	−2.56	−2.04	−0.51

Notes. Numbers reported are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. See notes to Table 1 for the sector definitions.

TABLE 6 Employment effect of U.S. merchandise versus service imports from China, while estimating U.S. production, IV, 1995–2011 (million workers)

	The impact of final good and intermediate imports from *all* sectors	Decomposition	
		The impact of final good and intermediate imports from *merchandise* sectors	The impact of final good and intermediate imports from *service* sectors
Manufacturing	−1.25	−1.24	−0.006
Resource	−0.05	−0.05	−0.002
Services	−0.90	−0.47	−0.43
All sectors	−2.19	−1.76	−0.43

Notes. Numbers reported are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. See notes to Table 1 for the sector definitions.

estimate is very close to Acemoglu et al. (2016), who find that import competition from China led to about 1.0 million job losses in manufacturing and another 1.0 million job losses through input–output linkages with the rest of the economy, during the slightly shorter period 1999–2011.

4 | NET EMPLOYMENT EFFECTS

We now compare more carefully the positive impact of U.S. exports on labor demand to the negative effect from imports, reporting the *net* impact on jobs. Table 7 summarizes our results for U.S. total exports and imports from China over 1995–2011. Panel A provides the net employment effect from trade in the merchandise sectors, including their indirect effect on services, while panel B provides the net effects from trade in all sectors. For merchandise exports and imports from China, we have found added demand of 3.7 million jobs and reduced demand of 2.0 million jobs, respectively, giving a net gain of 1.7 million jobs. That number is the final entry in the third column of panel A, which uses the estimates from our OLS market-share regressions. Alternatively, for trade in all sectors, we obtain a much larger net gain of 4.0 million jobs, the final entry in panel B, and that is because of the growth in U.S. service exports. The last column is based on our IV market-share regressions and shows that merchandise trade led to 1.97 million net job gains and trade in all sectors added 4.38 million net job creation.

In Table 7, we also include the net employment estimates obtained while using differing assumptions on the response of U.S. production to imports from China. Functional form #1 assumes that Chinese imports displace U.S. production dollar-for-dollar, and it gives results similar to the market-share regressions, that is, net job gains of 1.8 million and 4.2 million for merchandise trade and total trade, respectively. Somewhat larger estimates of net gains are obtained from functional form #3. We do not report in Table 7 the results for functional form #2 because, as we have already noted, that specification allows for U.S. production to respond to the imports of *all* countries.

In Table 8, we extend our earlier analysis to report results for U.S. total exports net of imports from *all* countries over 1995–2011.[8] For merchandise trade, we obtain a net reduction in labor demand.

TABLE 7 Net employment effects of U.S. total exports and U.S. imports *from China*, 1995–2011 (million workers)

	Functional form #1	Functional form #3	Market share regression, OLS	Market share regression, IV
Panel A: Trade in merchandise sectors				
Manufacturing	0.58	1.24	0.50	0.70
Resource	0.39	0.41	0.40	0.40
Services	0.80	1.03	0.78	0.87
All Sectors	1.77	2.68	1.68	1.97
Panel B: Trade in all sectors				
Manufacturing	0.63	1.29	0.55	0.75
Resource	0.40	0.42	0.41	0.42
Services	3.15	3.42	3.05	3.22
All sectors	4.18	5.13	4.01	4.38

Notes. Numbers reported are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. See notes to Table 1 for the sector definitions.

TABLE 8 Net employment effects of U.S. total exports and U.S. *total imports*, 1995–2011 (million workers)

	Functional form #1	Functional form #2	Functional form #3
Panel A: Trade in merchandise sectors			
Manufacturing	−1.67	−0.90	−0.11
Resource	−0.55	−0.06	−0.25
Services	−1.04	−0.37	−0.11
All sectors	−3.25	−1.32	−0.48
Panel B: Trade in all sectors			
Manufacturing	−1.64	−0.86	−0.08
Resource	−0.55	−0.05	−0.25
Services	−0.05	1.62	1.03
All sectors	−2.24	0.71	0.70

Notes. Numbers reported are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. See notes to Table 1 for the sector definitions.

That is, for the three functional forms for the possible displacement of U.S. production, we obtain net job losses ranging from −3.3 to −0.5 million at the bottom of panel A.[9] We are not able to implement the market-share regressions in this case because, for some trading partners, that regression is too unstable. Thus, we simply conclude that there is a negative net impact on U.S. labor demand from merchandise trade, without being more precise about its magnitude. When we take into account trade in *all* sectors, however, in panel B, the net impact on labor demand becomes a positive 0.7 million jobs for functional forms #2 and #3, though it is still negative for functional form #1. We find the dollar-for-dollar displacement of U.S. producers, assumed in functional form #1, to be rather implausible and so we have more confidence in the results from the other two specifications. In these cases, the positive net impact of trade on labor demand is explained by the growth in U.S. service exports.[10]

5 | DECOMPOSING THE EMPLOYMENT EFFECTS

5.1 | Decomposing the employment effect of export expansion

A limitation of our above analysis is that *all* the changes in U.S. exports or import from China, and the associated changes in final goods or intermediates sold within the United States, are used to compute the employment impacts. It would be preferable to isolate the portion of such changes that could be viewed as exogenous to the United States, as Autor et al. (2013, 2015) do when they use Chinese exports to eight other advanced countries to instrument for Chinese exports to the United States. In this section we investigate the principal contributors leading to changes in trade flows, focusing on U.S. exports in this section and imports in the next.

As in Feenstra et al. (2017), we start with a simple CES specification[11]:

$$\frac{d_t^{(US,s),j}}{d_t^{(i,s),j}} = \left(\frac{\tau_t^{(US,s),j}}{\tau_t^{(i,s),j}}\right)^{1-\sigma}, \tag{15}$$

where $d_t^{(i,s),j}$ is the final-good flows from sector s of country i to country j, and $\tau_t^{(i,s),j}$ is one plus the *ad valorem* tariff rate imposed by country j on sector s products from country i. Multiplying the above equation by $d_t^{(i,s),j}$ and averaging over the $N-1$ countries $i \neq US$ yields:

$$d_t^{(US,s),j} = \frac{(\tau_t^{(US,s),j})^{1-\sigma}}{N-1}\left(\sum_{k\neq US} d_t^{(k,s),j}\right)\sum_{i\neq US}\frac{d_t^{(i,s),j}}{\sum_{k\neq US} d_t^{(k,s),j}}(\tau_t^{(i,s),j})^{\sigma-1}, \tag{16}$$

where we have multiplied and divided by $\sum_{k\neq US} d_t^{(k,s),j}$ for convenience. Taking logs of this equation, we estimate:

$$\ln d_t^{(US,s),j} = \beta_0^{(US,s),j} + \beta_1 \ln\tau_t^{(US,s),j} + \beta_2 \ln MultiD_t^{(US,s),j} + \beta_3 \ln Multi\tau_t^{(US,s),j} + \varepsilon_t^{(US,s),j}, \tag{17}$$

where $\beta_0^{(US,s),j}$ is a destination-country and source-sector fixed effect and the variable $MultiD_t^{(US,s),j}$ is a "multilateral demand" term defined as,

$$MultiD_t^{(US,s),j} \equiv \sum_{k\neq US} d_t^{(k,s),j}, \tag{18}$$

which is the sum of final-good flows from all countries besides the United States to country j. The final variable, $Multi\tau_t^{(US,s),j}$ denotes the "multilateral tariffs" applied by country j to trading partners other than the United States:

$$Multi\tau_t^{(US,s),j} \equiv \sum_{i\neq US}\frac{d_t^{(i,s),j}(\tau_t^{(i,s),j})^{\sigma-1}}{\sum_{k\neq US} d_t^{(k,s),j}}, \tag{19}$$

where σ is the elasticity of substitution.[12] Comparing log-linearized (16) and (17) we see that the monopolistic competition model implies that $\beta_1 = -(\sigma-1)$, and $\beta_2 = \beta_3 = 1$.

We treat the variables in (18) and (19) as exogenous to the error term in (17), and use these variables to predict the trade flows due to each of these instruments. Specifically, after estimating (17), we compute the hypothetical final-good exports from the United States to the rest of the world when the tariff rates imposed on U.S. exporters remain at the 1995 level as:

$$\ln \hat{d}_t^{(US,s),j}|_{\tau=\tau_{1995}} = \hat{\beta}_0^{(US,s),j} + \hat{\beta}_1 \ln\tau_{1995}^{(US,s),j} + \hat{\beta}_2 \ln MultiD_t^{(US,s),j} + \hat{\beta}_3 \ln Multi\tau_t^{(US,s),j} + \hat{\varepsilon}_t^{(US,s),j}. \tag{20}$$

Note that the tariff variable used to calculate this predicted demand is replaced with its 1995 value, $\tau_{1995}^{(US,s),j}$, and we include the estimated residual in (20) so that we will be able to determine what amount of the employment effects is due to this unexplained portion.[13] We also compute hypothetical final-good flows when the multilateral final-demand term remains at the 1995 level, $\ln \hat{d}_t^{(US,s),j}|_{MultiD=MultiD_{1995}}$, and when the multilateral tariff term remains fixed at the 1995 level, $\ln \hat{d}_t^{(US,s),j}|_{Multi\tau=Multi\tau_{1995}}$. Hereafter, the procedure to find the employment effect due to changes in tariffs will be discussed, and a similar procedure is used to compute the employment effects through changes in multilateral final demand and the multilateral tariff term.

The employment effect of export expansion through changes in tariffs imposed on U.S. exporters is estimated as:

$$\hat{\mathbf{L}}_{1995,t}^{EX1,\tau} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\hat{\mathbf{D}}_{1995,t}^{EX,\tau} \tag{21}$$

where,

$$\underbrace{\hat{\mathbf{D}}^{EX,\tau}_{1995,t}}_{(N\times S)\times 1} \equiv \begin{bmatrix} \sum_k \mathbf{d}^{1,k}_t \\ \sum_k \mathbf{d}^{2,k}_t \\ \vdots \\ \mathbf{d}^{US,US}_t + \sum_{k\neq US} (\hat{\mathbf{d}}^{US,k}_{1995,t})^\tau \\ \vdots \\ \sum_k \mathbf{d}^{N,k}_t \end{bmatrix} \text{ with } \underbrace{(\hat{\mathbf{d}}^{US,j}_{1995,t})^\tau}_{S\times 1} \equiv \begin{bmatrix} (\hat{d}^{(US,1),j}_t)|_{\tau=\tau_{1995}} \\ (\hat{d}^{(US,2),j}_t)|_{\tau=\tau_{1995}} \\ \vdots \\ (\hat{d}^{(US,S),j}_t)|_{\tau=\tau_{1995}} \end{bmatrix}.$$

In this procedure, U.S. exports to the rest of the world $\{\mathbf{d}^{US,j}_t\}_{j\neq US}$ are replaced with the estimated U.S. exports, $\{(\hat{\mathbf{d}}^{US,j}_{1995})^\tau\}_{j\neq US}$, with the tariffs imposed by trading partners held fixed at their 1995 level. The employment effect due to the multilateral final demand term, $\hat{\mathbf{L}}^{EX1,MultiD}_{1995,t}$, and due to the multilateral tariff term, $\hat{\mathbf{L}}^{EX1,Multi\tau}_{1995,t}$, are estimated by taking similar steps.

As in the previous sections, we also provide the counterpart in which we take intermediate trade into account. First of all, in order to find the determinants of intermediate-good flows from the United States to the rest of the world, we estimate the same regression as in (17), but allow for different regression coefficients for the intermediate goods. Then we take the predicted values of the traded intermediates, holding tariffs fixed at their 1995 level, to obtain $\ln \hat{x}^{(US,s),(j,r)}_t|_{\tau=\tau_{1995}}$, and $\ln \hat{x}^{(US,s),(j,r)}_t|_{MultiD=MultiD_{1995}}$ and $\ln \hat{x}^{(US,s),(j,r)}_t|_{Multi\tau=Multi\tau_{1995}}$, holding fixed multilateral demand and the multilateral tariff, respectively.

The employment effect of export expansion through changes in tariffs imposed on U.S. exporters is estimated as:

$$\hat{\mathbf{L}}^{EX1,\tau}_{1995,t} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\hat{\mathbf{A}}^{EX,\tau}_{1995,t})^{-1}\hat{\mathbf{D}}^{EX,\tau}_{1995,t},$$

where,

$$\underbrace{\hat{\mathbf{A}}^{IM,\tau}_{1995,t}}_{(N\times S)\times(N\times S)} \equiv \begin{bmatrix} \mathbf{A}^{1,1}_t & \mathbf{A}^{1,2}_t & \dots & \mathbf{A}^{1,US}_t & \dots & \mathbf{A}^{1,N}_t \\ \mathbf{A}^{2,1}_t & \mathbf{A}^{2,2}_t & \dots & \mathbf{A}^{2,US}_t & \dots & \mathbf{A}^{2,N}_t \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ (\hat{\mathbf{A}}^{US,1}_{1995})^\tau & (\hat{\mathbf{A}}^{US,2}_{1995})^\tau & \dots & \mathbf{A}^{US,US}_t & \dots & (\hat{\mathbf{A}}^{US,N}_{1995})^\tau \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ \mathbf{A}^{N,1}_t & \mathbf{A}^{N,2}_t & \dots & \mathbf{A}^{N,US}_t & \dots & \mathbf{A}^{N,N}_t \end{bmatrix}$$

denotes the global input–output matrix with $(\hat{\mathbf{A}}^{(US,r),(j,s)}_{1995,t})^\tau$ denoting the intermediate-good flows from sector r of the United States to sector s of country j. The elements of this matrix are obtained by dividing the estimated intermediate flows by gross output in sector s of country j:

$$(\hat{a}^{(US,r),(j,s)}_{1995,t})^\tau \equiv \hat{x}^{(US,r),(j,s)}_{1995,t}|_{\tau=\tau_{1995}}/y^{j,s}_t,$$

where $\hat{x}^{(US,r),(j,s)}_{1995,t}|_{\tau=\tau_{1995}}$ is computed analogously to final goods as shown in (20). The employment effects of export expansion through a change in the multilateral demand term, $\hat{\mathbf{L}}^{EX2,MultiD}_{1995,t}$, and through a change in the multilateral tariff term $\hat{\mathbf{L}}^{EX2,Multi\tau}_{1995,t}$, are found using $\hat{x}^{(US,r),(j,s)}_{1995,t}|_{MultiD=MultiD_{1995}}$

TABLE 9 Predicting trade flows

Exporter(s) Importer(s)	United States All other countries		All other countries United States	
	ln(Final good flows)	ln(Intermediate good flows)	ln(Final good flows)	ln(Intermediate good flows)
	(1)	(2)	(3)	(4)
ln(1+Tariff)	−1.16*** (0.42)	−2.90*** (0.18)	−2.79* (1.46)	−2.87*** (0.31)
ln(Multilateral Final Demand)	0.55*** (0.032)	0.47*** (0.010)	0.87*** (0.07)	0.55*** (0.02)
ln(Multilateral Tariff)	0.93*** (0.22)	1.28*** (0.10)	0.57 (1.18)	1.20*** (0.43)
Uncertainty×1{1995–2001}			−0.42*** (0.13)	−0.64*** (0.03)
Multi. Uncert.×1{1995–2001}			1.96** (0.94)	3.06*** (0.14)
Cross Sectional Fixed Effect	Yes	Yes	Yes	Yes
R^2	0.218	0.206	0.252	0.253
# of obs.	8,252	134,197	8,309	149,512
# of cross sectional obs.	515	10,057	527	10,922
Observations are characterized by…				
Exporting countries			Yes	Yes
Exporting sectors		Yes	Yes	Yes
Importing countries	Yes	Yes		
Importing sectors	Yes	Yes		Yes

Notes. The table reports the regression result predicting U.S. exports (columns 1 and 2) and U.S. imports (columns 3 and 4). Columns 3 and 4 include year fixed effects after 2001 in order to identify the uncertainty measure by capturing year-to-year macroeconomic shocks common to all exporters to the U.S. Robust standard errors, clustered at the cross sectional unit level, are in parentheses. ***, **, and * indicate statistical significance at 1%, 5%, and 10% level, respectively. The data on trade flows come from the WIOD. The data on tariffs come from Caliendo et al. (2016). The sample includes 37 countries out of 40 WIOD countries where Belgium and Luxenberg are dropped due to missing tariff observations. The sample period is 1995-2011.

and $\hat{x}_{1995,t}^{(US,r),(j,s)}|_{Multi\tau=Multi\tau_{1995}}$, respectively. Before presenting the export results, we describe the more complex procedure for U.S. imports.

5.2 | Decomposing the employment effect of import competition from China

Previous literature has found that there was policy uncertainty prior to China's accession to the WTO in 2001, which had a negative effect on Chinese firm entry into the U.S. export market (Handley & Limão, 2017; Pierce & Scott, 2016). Accordingly, we shall introduce variables taking this policy uncertainty into account. In addition to the three components in the decomposition exercise for U.S. exports, we introduce two additional components: (1) the policy uncertainty measured by the difference between the column 2 tariff rate $\tau_{Col2}^{(C,s),US}$ and the MFN tariff rate $\tau_{MFN}^{(C,s),US}$, times the probability ρ that the United States reverts to the column 2 rate; and (2) a "multilateral uncertainty" term, which incorporates the uncertainty in China's tariff faced in the U.S. market when calculating the exports of *other* countries to that destination.

The starting point for our estimating equations is a simple CES equation for the relative exports of China and another country i to the United States in sector s:

$$\frac{d_t^{(US,s),j}}{d_t^{(i,s),j}}=\left(\frac{\rho\tau_{Col2}^{(C,s),US}+(1-\rho)\tau_{MFN}^{(C,s),US}}{\tau_t^{(i,s),j}}\right)^{1-\sigma}, \tag{22}$$

where ρ is the probability of reverting to the column 2 rate; and $\sigma>1$ is the elasticity of substitution. Notice that unlike (15), in the numerator of (22) we are using an *expected tariff* that applies *before* China joins the WTO, since afterwards the MFN rate $\tau_{MFN}^{(C,s),US}$ is guaranteed.[14]

Using similar steps to that used for the U.S. export equation, we show in Appendix D in the Supporting information that the presence of tariff uncertainty before China's entry to the WTO leads to a system of two estimating equations for final goods, which extend those derived in the previous section:

$$\begin{aligned}\ln d_t^{(C,s),US}=&\beta_0^{(C,s),US}+\beta_1\ln\tau_t^{(C,s),US}+\beta_2\ln MultiD_t^{(C,s),US}+\beta_3\ln Multi\tau_t^{(C,s),US}\\&+\beta_4\underbrace{\left(\frac{\tau_{Col2,t}^{(C,s),US}-\tau_{MFN}^{(C,s),US}}{\tau_{MFN}^{(C,s),US}}\right)}_{\text{Tariff Uncertainty}}\times\mathbf{1}\{1995-2000\}+\varepsilon_t^{(C,s),j}\end{aligned} \tag{23}$$

for trade flows from China to the United States, and

$$\begin{aligned}\ln d_t^{(i,s),US}=&\beta_0^{(i,s),US}+\beta_1\ln\tau_t^{(i,s),US}+\beta_2\ln MultiD_t^{(i,s),US}+\beta_3\ln Multi\tau_t^{(i,s),US}\\&+\beta_5\ln MulUncert_t^{(i,s),US}\times\mathbf{1}\{1995-2000\}+\varepsilon_t^{(i,s),j}\end{aligned} \tag{24}$$

for trade flows from a country $i \neq C$ to the same market.

The terms $MultiD_t^{(C,s),US}$ and $Multi\tau_t^{(i,s),US}$ are the multilateral demand and multilateral tariff terms defined in (18) and (19), respectively. The new variables in the above equations are, first, the term $\left(\tau_{Col2,t}^{(C,s),US}-\tau_{MFN}^{(C,s),US}\right)/\tau_{MFN}^{(C,s),US}$ in (23), which measures the percentage gap between the column 2 and MFN rates. Second, there is a multilateral uncertainty term in (24):[15]

$$MulUncert_t^{(i,s),US}\equiv 1+\frac{\rho d^{(C,s),US}}{\sum_{k\neq i}d^{(i,s),US}\tau^{i,US}}(\tau_{Col2,t}^{(C,s),US}-\tau_{MFN}^{(C,s),US}), \tag{25}$$

which measures the added exports from countries besides China who do not face this tariff uncertainty. Because the uncertainty was present until 2001, when China joined the WTO, these uncertainty variables are interacted with the dummy variable $\mathbf{1}\{1995-2000\}$, which equals unity between 1995 and 2000. The regression coefficients satisfy $\beta_1=-(\sigma-1)$, $\beta_2=\beta_3=\beta_5=1$, and $\beta_4=-\rho(\sigma-1)$ from which it follows that ρ is estimated as the ratio β_4/β_1.

The hypothetical final-good flows from China to the United States when tariff levels remain at 1995 values are found by plugging $\tau_{MFN}^{(C,s),j}$ into the regression result from (23):

$$\begin{aligned}\ln\hat{d}_t^{(C,s),US}|_{\tau=\tau_{1995}}=&\hat{\beta}_0^{(C,s),US}+\hat{\beta}_1\ln\tau_{MFN,1995}^{(C,s),US}+\hat{\beta}_2\ln MultiD_t^{(C,s),US}+\hat{\beta}_3\ln Multi\tau_t^{(C,s),US}\\&+\hat{\beta}_4\left(\frac{\tau_{Col2,t}^{(C,s),US}-\tau_{MFN}^{(C,s),US}}{\tau_{MFN}^{(C,s),US}}\right)\times\mathbf{1}\{1995-2000\}+\hat{\varepsilon}_t^{(C,s),j}.\end{aligned} \tag{26}$$

TABLE 10 Explaining the employment effect of merchandise exports, 1995–2011 (million workers)

		Decomposition			
		Tariff cuts	Multilateral final demand	Multilateral tariff	Residuals
	The overall effect of exports	The effect through a reduction of tariffs imposed by trading partners on the United States	The effect through an increase in multilateral demand term	The effect through a decrease of the multilateral tariff term	The unexplained part
	(1)	(2)	(3)	(4)	(5)
Panel A: Through final good exports only					
Manufacturing	0.753	0.065 [8.7%]	0.454 [60.3%]	−0.019 [−2.5%]	0.253 [33.6%]
Resource	0.169	0.016 [9.3%]	0.080 [47.1%]	−0.005 [−2.9%]	0.079 [46.6%]
Services	0.517	0.040 [7.7%]	0.287 [55.5%]	−0.012 [−2.4%]	0.203 [39.2%]
All sectors	1.440	0.121 [8.4%]	0.821 [57.0%]	−0.036 [−2.5%]	0.535 [37.1%]
Panel B: Through final good and intermediate exports					
Manufacturing	1.937	0.293 [15.2%]	1.063 [54.9%]	−0.062 [−3.2%]	0.643 [33.2%]
Resource	0.449	0.092 [20.4%]	0.187 [41.7%]	−0.006 [−1.4%]	0.177 [39.4%]
Services	1.339	0.185 [13.8%]	0.670 [50.0%]	−0.032 [−2.4%]	0.516 [38.5%]
All sectors	3.725	0.570 [15.3%]	1.920 [51.5%]	−0.101 [−2.7%]	1.336 [35.9%]

Notes. Numbers without brackets are the employment effect measured in million workers. Positive numbers mean increased labor demand while negative numbers indicate reduced labor demand. Numbers in square brackets are the ratio of each component of the employment effect to the overall employment effect. See notes to Table 1 for the sector definitions.

The hypothetical imports from China when each of the other factors were fixed at 1995 levels, $\ln \hat{d}_t^{(C,s),US}|_{MultiD=MultiD_{1995}}$, $\ln \hat{d}_t^{(C,s),US}|_{Multi\tau=Multi\tau_{1995}}$, and $\ln \hat{d}_t^{(C,s),US}|_{Uncert=Uncert_{1995}}$ are found by replacing each of the variables with the one from 1995, and likewise for U.S. imports from China of intermediate goods.

With these regression results, we then calculate the employment effect of U.S. imports from China. For example, the employment effect when tariff levels are fixed at their 1995 level is:

$$\hat{\mathbf{L}}_{1995,t}^{IM1,\tau} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\hat{\mathbf{D}}_{1995,t}^{IM,\tau}$$

where,

$$\underbrace{\hat{\mathbf{D}}_{1995,t}^{IM,\tau}}_{(N\times S)\times 1} \equiv \begin{bmatrix} \sum_k \mathbf{d}_t^{1,k} \\ \sum_k \mathbf{d}_t^{2,k} \\ \vdots \\ (\hat{\mathbf{d}}_t^{C,US})^{\tau_{1995}} + \sum_{k\neq US} \mathbf{d}_t^{C,k} \\ \vdots \\ (\hat{\mathbf{d}}_t^{US,US})^{\tau_{1995}} + \sum_{k\neq US} \mathbf{d}_t^{US,k} \\ \vdots \\ \sum_k \mathbf{d}_t^{N,k} \end{bmatrix}$$

TABLE 11 Explaining the employment effect of merchandise imports from China, IV, 1995–2011 (million workers)

		Decomposition				
		Tariff cuts	Multilateral final demand	Multilateral tariffs	Policy uncertainty	Residuals
	The overall effect of imports	The effect through a reduction of U.S. tariffs on China	The effect through an increase in multilateral demand term	The effect through a decrease of multilateral tariff term	The effect through a reduction of tariff "gap" uncertainty	The unexplained part
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Through final good imports only						
Manufacturing	−0.761	−0.027 [3.5%]	0.013 [−1.7%]	0.018 [−2.3%]	−0.374 [49.2%]	−0.391 [51.4%]
Resource	−0.037	0.003 [−9.5%]	−0.008 [21.4%]	0.002 [−6.0%]	−0.018 [49.4%]	−0.016 [44.6%]
Services	−0.272	0.008 [−2.8%]	−0.017 [6.3%]	0.024 [−8.7%]	−0.128 [47.1%]	−0.158 [58.1%]
All sectors	−1.069	−0.015 [1.4%]	−0.012 [1.1%]	0.044 [−4.1%]	−0.521 [48.7%]	−0.565 [52.9%]
Panel B: Through final good and intermediate imports						
Manufacturing	−1.239	−0.034 [2.8%]	−0.020 [1.6%]	0.036 [−2.9%]	−0.636 [51.3%]	−0.584 [47.1%]
Resource	−0.047	0.005 [−9.7%]	−0.009 [19.4%]	0.004 [−8.4%]	−0.027 [58.0%]	−0.019 [40.7%]
Services	−0.470	0.019 [−4.0%]	−0.031 [6.5%]	0.047 [−10.0%]	−0.232 [49.3%]	−0.274 [58.2%]
All sectors	−1.756	−0.011 [0.6%]	−0.060 [3.4%]	0.087 [−5.0%]	−0.895 [51.0%]	−0.876 [49.9%]

Notes. Numbers without brackets are the employment effect measured in million workers. A positive number means increased labor demand while a negative number indicates reduced labor demand. Numbers in square brackets are the ratio of each component of the employment effect to the overall employment effect. Residuals include year-to-year macroeconomic shocks captured in year fixed effects after 2001, which are included in order to identify the policy uncertainty effect. See notes to Table 1 for the sector definitions.

is the hypothetical final-demand vector when U.S. tariffs were fixed. Elements of $(\hat{\mathbf{d}}_t^{C,US})^{\tau_{1995}}$ are obtained from (26), and the corresponding estimates of $(\hat{\mathbf{d}}_t^{US,US})^{\tau_{1995}}$ are obtained by using $(\hat{\mathbf{d}}_t^{C,US})^{\tau_{1995}}$ in (10) and (11). The effect through multilateral final demand $\hat{\mathbf{L}}_{1995,t}^{IM1,MultiD}$, the multilateral tariff $\hat{\mathbf{L}}_{1995,t}^{IM1,Multi\tau}$, and the uncertainty measure $\hat{\mathbf{L}}_{1995,t}^{IM1,Uncert}$ are estimated by taking similar steps.

The employment effect of imports of final *and* intermediate goods from China through a change in U.S. tariffs imposed is estimated as:

$$\hat{\mathbf{L}}_{1995,t}^{IM2,\tau} \equiv \mathbf{\Lambda}_t(\mathbf{I}-\mathbf{A}_t)^{-1}\mathbf{D}_t - \mathbf{\Lambda}_t(\mathbf{I}-\hat{\mathbf{A}}_{1995,t}^{IM,\tau})^{-1}\hat{\mathbf{D}}_{1995,t}^{IM,\tau},$$

where the elements of $\hat{\mathbf{A}}_{1995,t}^{IM,\tau}$ for China's sales to the United States use the prediction analogous to that in (26). However, for intermediates, we obtain:

$$(\hat{a}_{1995,t}^{(C,r),(US,s)})^{IM,\tau} = \hat{x}_t^{(C,s),(US,r)}\big|_{\tau=\tau_{1995}} / y_t^{US,s}.$$

Then the input–output coefficients for the United States are computed using the predicted value of Chinese sales $\hat{x}_t^{(C,s),(US,r)}\big|_{\tau=\tau_{1995}}$ within the market share regressions (13) and (14). The same computation procedure applies to the effect through the multilateral final demand $\hat{\mathbf{L}}_{1995,t}^{IM2,MultiD}$, the multilateral tariff $\hat{\mathbf{L}}_{1995,t}^{IM2,Multi\tau}$, and the uncertainty measure $\hat{\mathbf{L}}_{1995,t}^{IM2,Uncert}$.

5.3 | Trade flow regression results

The trade flow regressions are estimated over industries in the merchandise sector.[16] The first two columns in Table 9 report the estimates of (17) for U.S. exports, while the last two columns estimate (23) and (24) for U.S. imports. Odd-numbered columns use the log of bilateral final-good flows as the dependent variable, while even-numbered columns use the log of bilateral intermediate flows. All coefficients have the expected signs: the log of tariffs has negative signs, meaning that tariff cuts have contributed to increasing U.S. exports as well as U.S. imports. The multilateral final-demand term has positive signs, indicating that increases in final demand of trading partners raise U.S. exports and higher final U.S. demand also works to increase that country's imports. The multilateral tariff term has the expected positive sign, so a reduction of tariffs imposed by other countries on their trading partners will reduce U.S. exports.

In addition to these three variables, the uncertainty measure and the multilateral uncertainty term are introduced in predicting U.S. imports. The uncertainty measure interacted with the dummy variable, taking the value one during 1995–2000, is negative and highly significant, meaning that the United States imported less from China due to policy uncertainty before that country's WTO entry. The multilateral uncertainty term has a positive sign, implying that other countries besides China were able to export more to the U.S. market due to this policy uncertainty. China's accession to WTO in 2001 eliminated the policy uncertainty and China's exports to the United States increased, while exports from other countries fell. As discussed in the previous section, the probability of reverting from MFN to the column 2 rate is estimated as the ratio $\hat{\beta}_4/\hat{\beta}_1 = -0.42/-2.79 = 0.15$ for final goods and $-0.64/-2.87 = 0.22$ for intermediate good flows. These estimates are close to the probability of the column 2 tariff as estimated by Handley and Limão (2017).

The predicted values from these regressions are used in order to find hypothetical trade flows in situations where these variables are kept at the 1995 levels. The regression results from columns (1) and

(2) are used to decompose the employment effect of export expansion, while the results from columns (3) and (4) are used to decompose the employment effect of imports from China.

5.4 | Results from the decomposition exercises

Table 10 reports the decomposition results for the employment effect of export expansion. Panel A takes into account only final-good exports, while panel B considers both final-good and intermediate exports. Columns (2) and (3) of Panel A show that in the manufacturing industry, 8.7 percent and 60.3 percent of the added labor demand from export expansion are due to tariff cuts by trading partners of the United States and their final demand, respectively. The multilateral tariff in column (4) explains a small negative portion (−2.5%), so in total, *two-thirds* of the added labor demand is explained by these exogenous factors. The remaining *one-third* is unexplained, as shown in column (5), and is due to the residual in the estimated export equation.

Scanning down column (5) of panel A, we see that somewhat more than one-third of the employment effect of exports is left unexplained in the natural-resource and service sectors, but in panel B, where intermediates are included, this unexplained portion is less than 40 percent. There are many other factors that could account for U.S. exports that we have not taken account of. For example, Feenstra et al. (2017) include bilateral exports of the same eight industrial countries used by Autor et al. (2013, 2015), but to explain U.S. exports rather than imports. They find that this additional instrument makes a difference. Evidently, the multilateral demand variable that we have included in the export equation does not capture the same information. More generally, the R^2 values on our trade-flow regressions in Table 9 are not high enough to expect these variables to fully account for export flows.

Table 11 reports the decomposition results for the fall in labor demand due to U.S. imports from China, based on the IV estimation result of the market-share regression.[17] The variable in the import regression that accounts for the overwhelming portion of the fall in demand is policy uncertainly associated with China's WTO accession. Specifically, eliminating the gap between the column 2 tariffs and the MFN tariffs accounts for 47 to 50 percent of the manufacturing job losses, as suggested by the results in column (5). These estimates are consistent with previous literature investigating the impact of elimination of policy uncertainty due to China's accession to WTO in 2001. For example, Pierce and Schott (2016) demonstrate that a change in U.S. policy uncertainty had a statistically significant impact on the decline of U.S. manufacturing employment. Several other studies find a sizable impact of China's WTO accession on the growth of China's exports (Crowley, Meng, & Song, 2018; Feng et al., 2017; Handley & Limão, 2017).

Our estimates of the 47 to 50 percent contribution of the reduction in policy uncertainty to the decline of manufacturing employment are greater than Handley and Limão's (2017) result that it accounts for 22 to 30 percent of Chinese exports to the United States in subsequent years. There are at least three reasons for this gap. First, our estimates explain the job losses during 1995–2011 while Handley and Limão (2017) use data from 2001–2005. As we saw in Figure 1, there is a sizable increase in Chinese exports after 2005. Therefore, this gap in the data length is partially responsible for the difference in estimates. Second, Handley and Limão's (2017) estimates are based on a general-equilibrium model, which includes a feedback from the labor market equilibrium. On the other hand, we do not attempt to close the model and only focus on a change in the demand side of the labor market. Third, we use the 35-sector data from the WIOD, while Handley and Limão (2017) use 6-digit data from the Harmonized System of bilateral imports. Thus, our estimates are based on a more aggregated macro dataset while those authors employ a micro dataset.

The direct reduction in MFN tariffs on China (see column 2) accounts for only a small effect, as does the change in multilateral tariffs (column 4). The multilateral final demand variable (column

3) explains a significant portion of the job losses only in the natural-resource sector. Overall, from column (6) we see that the unexplained portion of the job losses is higher than one-third, but less than 40 percent when intermediate goods are included in the analysis. As we argued for U.S. exports, there are many other factors that can explain the rise in merchandise imports from China that we have not included in our regressions.[18]

6 | CONCLUSIONS

This paper has examined the employment effect of U.S. exports, imports, and imports from China on the U.S. labor market by applying an input–output analysis. We find that the growth in U.S. merchandise exports over 1995–2011 led to demand for 1.9 million jobs in manufacturing, 0.45 million in resource industries, and 1.3 million jobs in services, totaling 3.7 million. In comparison, U.S. merchandise imports from China over 1995–2011 led to reduced labor demand of 1.4 million jobs in manufacturing and 0.6 million in services (with small losses in resource industries), for total job losses of 2.0 million. It follows that the expansion in U.S. merchandise exports relative to imports from China over 1995–2011 led to higher net demand of about 1.7 million jobs. Comparing the growth of U.S. merchandise exports to merchandise imports from *all* countries, we find a fall in net labor demand due to trade, but comparing the growth of *total* U.S. exports to total imports from all countries, there is a rise in net labor demand because of the growth in service exports.

It is perhaps surprising that our estimates of the job impacts of trade are not that different from existing literature, which uses industry (or commuting zone) regressions to infer the *equilibrium* impact on employment. The added demand for 1.9 million jobs in U.S. manufacturing exports that we have found is much the same as the equilibrium increase of 1.91 million jobs for a 12-year period, 1999–2011, estimated by Feenstra et al. (2017). That added demand for manufacturing jobs explains about one-half of the overall demand increase of 3.7 million jobs due to merchandise exports. The offsetting reduction in labor demand of 2.0 million jobs due to imports from China, mainly in manufactures, is very close to Acemoglu et al. (2016), who find about 1.0 million manufacturing jobs lost in equilibrium during 1999–2011, and another 1.0 million jobs lost by intermediate demand throughout the economy. Because our input–output analysis relies exclusively on the demand side of the labor market, we might have expected to get considerably larger shifts in demand that would then be offset by upward-sloping labor supply curves to obtain the (smaller) equilibrium changes. Instead, our findings that the demand shifts from the input–output analysis are similar to the equilibrium changes in employment identified by regression analysis, suggests that there are near-horizontal labor supply curves, possibly reflecting movement in and out of unemployment or labor force participation, or movement between regions. We conclude that achieving realistic labor-market clearing in a general-equilibrium model that incorporates global input–output tables, as in Caliendo et al. (2015) for example, requires a careful specification of the employment decisions and regional movement of individuals.[19]

While we have not attempted to close our model with labor-market equilibrium, we have begun to address another criticism of input–output analysis, namely, that the changes in the trade and production values as well as the input–output coefficients are all *endogenou*s since they are equilibrium values each year. That criticism is of the first order when using regressions since the coefficient estimates are biased, and it is addressed with instrumental variables. We have attempted to address the same issue here, within input–output analysis, by breaking up the total change in the endogenous trade values into exogenous portions due to various causes. In particular, we have tried to exploit changes in bilateral tariffs—including the reduction in the uncertainty on U.S. tariffs facing China after it joined the WTO—to predict changes in trade flows. We have been only partially successful in this attempt.

Using our structural equations to identify the exogenous portion of these changes, we explain nearly two-thirds of the measured employment impacts for both U.S. exports and for imports from China. It should be recognized that explaining even that amount in an input–output framework is an achievement. Caliendo et al. (2015) also use WIOD, for example, and they rely on an assumed *productivity shock* in China rather than the tariff changes to explain the surge in exports. It can be hoped that the identification of exogenous factors leading to changes in trade and associated labor demand, and their incorporation into a general-equilibrium framework, can be improved in future work.

ACKNOWLEDGMENT

The authors would like to thank Gordon H. Hanson, Richard Harris, Jeronimo Carballo, Sergey Nigai, David Weinstein, Ayumu Tanaka, Tim Baltes, Fukunari Kimura, and Hirokazu Ishise and seminar/conference participants at the Creative Perspective on International Trade and Foreign Direct Investment: A Celebration to Honor Jim Markusen, held at the University of Colorado at Boulder, University of California at Berkeley, University of Idaho, Washington State University, Kobe University, Keio University, Sophia University, Hitotsubashi University, the Summer Workshop on Economic Theory held at Otaru University of Commerce and the Spring 2018 Meetings of the Japanese Economic Association.

ENDNOTES

[1]See also the confirming empirical evidence in Feng, Li, and Swenson (2017) and a summary of debate on the impact of trade on wages in Wood (2018).

[2]Amiti, Dai, Feenstra, and Romalis (2017) argue that the consumer benefits in the United States are due more to China's reduction in its own tariffs on intermediate inputs, which led to a drop in the price of exports to the U.S., rather than the reduction in the uncertainty of tariffs in the U.S.

[3]See also Liang (2018) who studies both U.S. imports and exports. Wang, Wei, Yu, and Zhu (2018) and Shen and Silva (2018) extend the regression analysis of Autor et al. (2013, 2015) to include upstream and downstream linkages.

[4]See Feenstra and Sasahara (in press) for the impact of exports to China on employment in East Asia.

[5]The technique employed by Los et al. (2015) is called the demand-side analysis, estimating the employment level driven by final demand from foreign countries. Our approach is slightly different because we estimate the gap between the actual employment level and a counterfactual employment level when there is no increase in foreign final demand from the benchmark year, 1995. See Appendices F and G for further details.

[6]See Appendix A in the Supporting information for the list of the WIOD sectors.

[7]The predicted U.S. producers' market share from (10) is constrained to lie between zero and unity.

[8]We are unable to estimate the market share regression for $s = 35$, "Private households with employed persons" because there are no imports from China.

[9]The employment effects of imports from all countries are found by conducting the employment computation for each country besides the United States and adding them to find the overall impact.

[10]In functional form #1, we increase U.S. production dollar-for-dollar for the difference over *all* countries between their imports each year and in 1995. Similarly, for functional form #3 we hold the U.S. imports from *all* countries fixed at their 1995 value when calculating the hypothetical share of U.S. producers.

[11]See the 2.8 million service sector jobs created by those exports in Table 2.

[12]This simplified CES equation does not incorporate the range of product varieties sold by each country or differences in their costs of production. We relax these simplifying assumptions in Appendix C in the Supporting information, and show how the estimating equation in (16) is still obtained, with the range of product varieties sold by each country and differences in their costs of production incorporated into the fixed effects and the error.

[13]The estimates we obtain for β_1 are as large as -5, implying $\sigma = 6$, and we shall impose that value when constructing the multilateral tariff term in (19).

[14]Note that with the *difference* between actual and estimated final demand used in (21), including the residual in (20) ensures that only the *difference* between the 1995 and actual tariffs drives the result.

[15]Previous work finds that the uncertainty from the possibility that the United States may revert to the column 2 tariff mainly affect firms' entry into the export market (the extensive margin) rather than firms' pricing behavior (Handley & Limão, 2017). However, final-good flows $d^{i,\,US}$ include both the extensive and intensive margins, so that our specification is not far from previous analysis.

[16]The multilateral uncertainty term in (25) assumes $\sigma = 2$ for simplicity, but in Appendix D in the Supporting information we report the general term for any σ. Notice that this term also depends on ρ, which comes from the estimation of (24). Therefore, we estimate the regression equations iteratively, as described in Appendix D in the Supporting information.

[17]One reason we do not attempt to model service exports or imports is that these can reflect the headquarters' activities of multinational firms located in a third country, which are explicitly considered in Markusen (1984) and Ekholm, Forslid, and Markusen (2007). For example, U.S. firms make earnings by selling a product designed at home to the rest of the world, which are recorded in the balance of payments as U.S. exports. However, it may be that some of the earnings actually go to a multinational firm located in a third country, say Ireland. This implies that there is a possibility that a part of our estimates of the service-sector job gains include job gains that should be attributed to multinational firms located elsewhere.

[18]See Appendix E in the Supporting information for the decomposition result based on the OLS estimates. The results are very similar to the ones based on the IV estimates.

[19]As mentioned in note 2, Amiti et al. (2017) find that the growth in U.S. imports from China (and the accompanying consumer benefits in the United States) are due more to China's reduction in its own tariffs on intermediate inputs than the reduction in the uncertainty of U.S. tariffs.

[20]Dix-Carneiro and Kovak (2017) describe a general model with trade reform and regional labor-market dynamics.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Feenstra RC, Sasahara A. The 'China shock,' exports and U.S. employment: A global input–output analysis. *Rev Int Econ*. 2018;26:1053–1083. https://doi.org/10.1111/roie.12370