Incorporating Industry-Specific Wages and Unemployment into the GTAP Model: U.S.-EU Trade Liberalization Scenarios

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Abstract

This paper applies a new GTAP Labor model (GTAP-LAB) developed by Peterson (2019) to analyze U.S.-EU trade liberalization scenarios. The paper finds that when job search frictions and unemployment are incorporated into the GTAP model, the model predicts changes in wages at the sectoral level. Simulated effects of a unilateral tariff elimination by the EU on U.S. exports of food and agricultural products show that while U.S. food and agricultural workers gain in wages, U.S. metals industry workers suffer from a wage decline. Simulated effects of U.S.-EU bilateral tariff removals show wage gains for U.S. workers in different industries, with the highest gains for U.S. food and agricultural workers, where the extent of the EU tariff liberalization is the biggest. The full U.S.-EU bilateral tariff removal scenario also leads to U.S. worker reallocation across industries, with the largest increase in employment in the services sectors, mainly due to an increase in overall household income, and a decline in U.S. employment in extraction, metals and other manufacturing industries. Finally, sensitivity analysis shows that the simulated effects are sensitive to the labor substitution elasticities used between existing and matched labor — the higher frictions to labor reallocation, the bigger the effect on sectoral wages. The wage results could be different not only in magnitude, but also in signs when using different labor substitution elasticities in the GTAP-LAB model.

1. Introduction

Computable General Equilibrium (CGE) models are used to evaluate the impact of a trade policy shock on the overall economy, such as the effects of import tariffs and trade agreements on the economy (Shobande, Uddin, and Ashogbon, 2021). One distinguishing feature of most modern, large-scale CGE models is their granularity— CGE models can represent many sectors of the economy and incorporate an input-output structure to capture upstream and downstream effects. For instance, the standard GTAP model has 141 regions and 65 sectors, which allows the model to capture economy-wide as well as detailed sectoral-level effects as a result of changes in trade policies (Corong et al., 2017 and Aguiar et al., 2019).

However, standard CGE models are limited in their capacity of analyzing labor market outcomes because they assume full employment. This assumption is restrictive because it does not reflect labor market frictions. Recent developments in the CGE literature have tried to address this issue. For example, Pant and Warr (2016) incorporated a wage curve, which portrays the relationship between wage and unemployment, into a dynamic GTAP model. The wage curve reflects an inverse relationship between the changes in real wage rate and the change in unemployment rate, and therefore allows the unemployment rate to be determined endogenously in the model. Another strand of research analyzes changes in wages and unemployment through incorporating a matching function into the modeling framework, which is a mechanism that relates job seekers to vacancies and introduces labor market frictions that result in incomplete matching. For instance, Peterson (2019) incorporates a matching function into the GTAP model to account for more realistic labor market features.

The end goal of our research is to develop a dynamic inter-sectoral CGE model to estimate changes in wages, employment and unemployment at the sectoral level due to changes in trade policies. This paper is the first step of our research. The paper applies the GTAP-LAB model, a static CGE model developed by Peterson (2019) to study hypothetical U.S.-EU trade liberalization scenarios, to illustrate the labor market and unemployment mechanisms in the model. The paper is organized as follows: Section 2 provides a literature review on the recent model developments that address labor market frictions and unemployment in a CGE modeling framework. Section 2 also provides a detailed explanation of the theoretical framework of the GTAP-LAB model. Section 3 introduces a stylized simulation of the EU unilaterally eliminating its tariffs and tariff-rate quotas (TRQs) on U.S. food and agricultural exports to the EU, and compares the simulation results using the standard GTAP model and the GTAP-LAB model. Section 4 compares the results of an experiment of a full bilateral tariff and TRQ elimination between the United States and the EU under the standard GTAP model and the GTAP-LAB model. Section 5 presents a sensitivity analysis with different values of labor substitution elasticities between the existing and matched labor to highlight how simulation results change under the GTAP-LAB model with these alternative values. Section 6 concludes the paper.

2. Literature Review and the Theoretical Framework of the GTAP-LAB Model

The literature review is divided into two parts. The first part discusses recent work which incorporates certain wage mechanisms, job search frictions and unemployment into the CGE modeling framework. The second part introduces the theoretical framework of the Peterson (2019) model as well as the next steps of our research.

Trade, Wages and Unemployment in CGE models

Literature that considers labor market frictions and unemployment in CGE modeling is scarce. The results of standard CGE models usually show that trade liberalization increases GDP and labor demand, with real wages adjusting to clear the labor market (Boeters and Savard 2013). Some studies include certain labor market features in a CGE model by incorporating wage rigidities and/or representing unemployment through a wage curve (Dixon, Rimmer and Tran, 2019, 2020; Pant and Warr 2016; Latorre and Yonezawa 2020).

For example, Pant and Warr (2016) developed a recursive dynamic labor augmenting technical progress model as an extension of the standard GTAP model. The authors represent the labor relationships in the economy by a wage curve, which is derived from the empirical literature and reflects an inverse relationship between the wage rate and the unemployment rate. Pant and Warr argue that given the observed persistence and prevalence of unemployment in some sectors and across the world, the assumption of exogenously determined labor supply is hard to maintain. Therefore, they move away from the assumption of full employment in their model and introduce flexibility in the labor supply function. The wage equation in their paper assumes that the labor employment depends on the size of the elasticity of factor substitution and the cost share of labor. The labor market is based on the fundamental assumption that "workers are conscientious but fear unemployment". Therefore, workers tend to supply additional hours of labor for "free" when there is higher unemployment in the market. However, firms are unwilling to hire them. Firms maximize profits at a positive unemployment rate. The authors show that the wage curve represents the cost-minimizing supply of efforts at a wide range of possible hourly wage rates. The authors conduct sensitivity analysis assuming a wide range of parameters.

Another similar example of incorporating a wage mechanism into a GTAP model can be found in Dixon, Rimmer, and Tran (2019, 2020). The authors build a recursive dynamic GTAP model (the GTAP-MVH model) which incorporates the sticky wage mechanism, i.e., real wages are sticky in the short run and flexible in the long run[1]. Therefore, policy shocks that lead to

[1] This framework is a feature of models developed by Dixon and Rimmer dating back to ORANI, MONASH and USAGE. See discussion in Dixon and Rimmer (2002, 2008). In Dixon, Rimmer and Tran (2019, 2020), real wages are sticky both ways. Meanwhile, some recent empirical labor literature suggests that nominal wages are sticky downward (see Rodriguez-Clare, 2020). The degree of downward stickiness of real wages is therefore a function of the prevailing inflation rate. In Rodriguez-Clare (2020), the fundamental assumption for the Downward Nominal Wage Rigidity (DNWR) is keeping the world nominal GDP in dollars constant, and the parameter of inflation is therefore kept constant overtime (Rodriguez-Clare et al, 2020, Pg. 12).

welfare gains for the whole economy would generate short-run gains in aggregate employment and long-run gains in real wages.

It is difficult to implement a wage representation in GTAP that is consistent with the microeconomic fundamentals of the GTAP model. For instance, the wage curve incorporated by Pant and Warr (2016) was initially developed by Blanchflower and Oswald (1995), which is empirically estimated using the historical wage and unemployment data. Therefore, when the wage curve is incorporated into the GTAP model framework, it is likely that both equilibrium and disequilibrium(cyclical) unemployment are incorporated.

Theoretical Framework of the GTAP-LAB Model

The most relevant CGE model for our purposes was developed by Peterson (2019). The key feature of the GTAP-LAB model developed by Peterson (2019) is that it incorporates a job search and matching function into the GTAP Model. The economic rationale behind the matching function is that unemployed individuals need to go onto the job market looking for jobs, and conversely, employers also need to go to the job market searching for an individual to fill a job vacancy. Therefore, the number of individuals who got "matched" into job vacancies will be dependent upon the total unemployment rate in the economy, as well as the matching efficiency and recruiting effort.

In the GTAP-LAB model, the labor endowment data (for both unskilled and skilled labor) are divided into different labor categories: *existing* labor, *matched* labor, *recruiters*, and *unmatched* labor. *Existing* labor refers to employed workers who carry on with their current jobs and don't switch industries. Since they don't switch industries, *existing* labor is sector-specific (that is, immobile) in the GTAP-LAB model. *Matched* labor are the new hires in each sector. *Unmatched* labor is the labor pool that includes all the unemployed individuals who are in the job market and the matched labor is drawn from this pool.[2] *Recruiters* are the workers who match those who are looking for a job with job vacancies.

The matching function which Peterson (2019, pg. 75) incorporates into the GTAP-LAB model is as followed:

$$m_j = \mu_j(1-\bar{n})^{\gamma_j} R_j \left(\sum_k R_k\right)^{-\gamma_j}$$

where:

- m_j is the number of matches in sector j,
- R_j is the units of recruiter labor used in sector j,
- $(1-\bar{n})$ is the unemployment rate,

[2] In the GTAP-LAB model, *Unmatched Labor* equals to *Matched Labor* plus *Unemployed Labor*. At the beginning of the period, there are unmatched workers, some of whom get matched to job vacancies and the remaining are unemployed.

- k is the index across all sectors, and
- μ_j and γ_j are matching efficiency and matching elasticity parameters.

The matching function incorporated in Peterson (2019) comes from the work of Hafstead and Williams (2018), which incorporates the matching function in a two-sector dynamic general equilibrium model. Meanwhile, Hafstead and Williams (2018) builds their model based on a matching model developed by Shimer (2010). Shimer (2010) presents a forward-looking dynamic matching model for analyzing equilibrium unemployment where the measure of unemployment and recruiters are both endogenous (Shimer 2010, pg. 21-22). Firms choose the sequence of allocating workers between production and recruiting to maximize the profit of the firms, while the households choose the consumption and employment combinations that maximizes consumers surplus (See Shimer 2010, pg. 21-23). The model is able to reach a steady state equilibrium where all variables including consumption, employment, wages, etc. all converge to their equilibrium values (Shimer 2010, pg.24 - pg.33).

Some literature on the search and matching framework starts with developing a dynamic model but in some circumstances are able to determine a static equilibria (see Shimer 2010, Michaillat 2012). In Michaillat (2012), the author develops a dynamic search and matching model which includes both rationing and frictional unemployment, but indicates that the equilibrium in a static environment could well approximate the equilibrium in a stochastic environment when in the model, technology $a_t = a$[3], for two reasons 1) technology is very persistent, 2) the labor market rapidly converges to an equilibrium in which inflows to and outflows from employment are balanced (Hall 2005b; Shimer 2012). The author demonstrates that the equilibrium outcomes in the static environment "delivers the same qualitative predictions as the study of a stochastic environment" (see p. 1727).

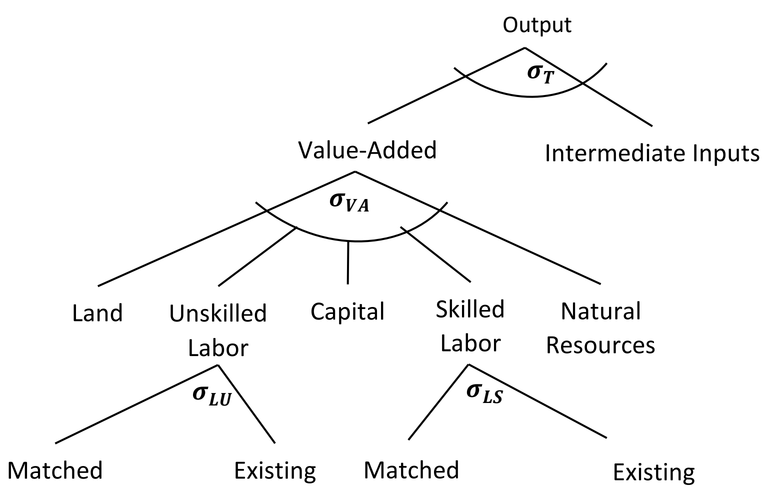
One issue with the Peterson (2019) paper is that the author didn't justify the inclusion of the matching function, which is derived from a forward-looking dynamic model framework, in his paper. In order to improve the consistency of the labor module in Peterson (2019) with the theoretical underpinnings of the GTAP model, it will be desirable to incorporate a matching mechanism into GTAP which is originally developed to describe a static equilibrium of the labor market. One alternative is to incorporate the matching mechanism developed in Hall (1979) into GTAP. In Hall (1979), the matching function is static, and the job-finding rate is dependent only upon the number of job seekers on the market, and the number of vacancies available (see Hall 1979, p. 156). This will be the next step of our research, which we plan to: 1) update the data within the GTAP-LAB model from 2011 to 2017; 2) improve the consistency of the labor module with the theoretical underpinnings of the GTAP model; 3) expand the types of U.S. labor within the model by disaggregating U.S. labor by skill level, education, and gender; and 4) develop a dynamic framework to represent changes in sectoral wages, employment and unemployment overtime. Our end goal is to build a CGE model with labor market features that

[3] In the standard GTAP and GTAP-Recursive Dynamic (RD) framework, the total factor productivity (which is the technology a_t) is exogeneous, and if a modeler backs out the value of total factor productivity in GTAP-RD, it should (theoretically) reflects the change in total factor productivity in the real world, which is considered as persistent.

is compatible with labor economics theories but also have the country and sectoral-level detail that will make it suitable for USITC's statutory work analysis.

This paper is the first step of our research, which we focus on analyzing how labor market results in a static GTAP-LAB model are different from the results of the standard GTAP model. The four different labor categories in GTAP-LAB are calibrated in the GTAP-LAB model baseline using the job turnover data and unemployment data from the U.S. Bureau of Labor Statistics. Meanwhile, the model also incorporates the economic rationale that existing labor and matched labor (new hires) are imperfect substitutes, as the newly hired matched labor is usually less experienced and therefore assumed to be less productive than the existing labor (see Schema 1 - the production structure in the GTAP-LAB model).

In Schema 1, σ_{LU} and σ_{LS} are the labor substitution elasticities between the existing and matched labor, for both unskilled and skilled labor by sector. In the standard version of the GTAP-LAB model, the value of the substitution elasticity is assumed to be 2.5 between existing and matched labor for all sectors for both labor types (Peterson 2019, pg. 92). Section 5 presents the results of a sensitivity analysis, where we show how the results change when assuming different values of the elasticity of substitution.



Schema 1: Production structure in the GTAP-LAB model

Source: Peterson (2019, pg. 77).
Notes: σ_T is the elasticity of substitution between intermediate inputs and value added, σ_{VA} is the elasticity of substitution between production factors.

As discussed above, existing labor is sector-specific in the GTAP-LAB model. Meanwhile, matched labor could move across sectors as they are searching for jobs. This immobile labor assumption for existing labor deviates from the assumption in the standard GTAP model which assumes that all workers could move freely across industries. In the GTAP-LAB model, for the unemployed individuals, there is a "matching cost" throughout the job search process as reflected in the matching function, and therefore it takes additional effort for unemployed individuals to find a job when there is a policy change that leads to workers moving across sectors. This immobile labor assumption is aligned with the empirical literature, including Artuç, Chaudhuri, and McLaren (2010); Autor, Dorn, Song, and Hanson (2014); Autor, Dorn, and Hanson (2016); Dix-Carneiro (2014); Dix-Carneiro and Kovak (2019). Therefore, it captures more realistic effects of changes in wages and employment. The next two sections present simulation results of two illustrative simulations: the first one is a unilateral tariff (including TRQ) elimination of the EU on U.S. exports of food and agricultural products, and the second one is a full bilateral tariff (including TRQ) elimination between the United States and the EU.

3. Unilateral Tariff Elimination of the EU on U.S. Exports of Food and Agricultural Products

This section discusses simulation results of a stylized simulation: a unilateral tariff (including TRQ) elimination of the EU on U.S. exports of food and agricultural products. We compare the simulation results under the standard GTAP model and the GTAP-LAB model.

We use version 9A of the GTAP database with a base year of 2011 (Aguiar et al. 2016). The 140 regions in the version 9A of the GTAP database is aggregated into three regions, namely, the U.S., the EU and the rest of the world; the 57 sectors are aggregated into 6 sectors: food and agriculture, extraction industries, metals (ferrous and nonferrous), manufacturing, trade and transportation, and other services. We maintain the traditional distinction of labor types in the GTAP Dataset — the unskilled and skilled labor. Apart from the parameters discussed in the previous section, all the other common parameters in both the standard GTAP and the GTAP-LAB model are set to their default values.

The policy shock in this scenario is a decline in the power of EU tariff rate[4] on food and agriculture imports from the United States of 7.7 percent. The percentage of the tariff decline was calculated as follows, let t_1 be the 2011 EU tariff rate on imports of food and agricultural products from the United States, and the EU tariff rate after the unilateral tariff liberalization is set as t_0 (with t_0 equals to zero). The change in the power of tariff rate is $\Delta T = \frac{t_0 - t_1}{1 + t_1} * 100$.

Comparison of Results between Standard GTAP and GTAP-LAB Models

When EU unilaterally eliminates its import duties on imports of food and agricultural products from the United States, U.S. food and agricultural exports to the EU becomes cheaper, causing EU consumers to substitute domestic food and agricultural products for imports from the United States. The increase in demand from the EU drives up U.S. production, leading to an increase in U.S. output and market prices of food and agricultural products (Figures 1, 2 and 3). Meanwhile, resources are pulled away from other sectors into the U.S. food and agricultural

[4] The power of tariff T = 1+t, with t being the EU tariff rate on imports of food and agricultural products from the United States.

sector, causing the output of some other U.S. industries, including extraction, metals, and other manufacturing sectors, to fall (Figure 3).

Wage Effects

- ***Standard GTAP***: When it comes to the labor market effects, the increase in output in the U.S. food and agricultural sector drives up its demand for labor. However, such an increase is largely offset by the reduction in output and therefore a decline in labor demand in the U.S. extraction, metals and other manufacturing sectors. In the standard GTAP model, with fixed national labor supply and free flow of labor across sectors, the slight increase in national labor demand leads to a slight increase in the wage rate — taking unskilled labor as an example, the U.S. wage rate for unskilled labor increases by 0.06 percent for all sectors in this simulation (Figure 1).
- ***GTAP-LAB:*** By incorporating the job search frictions and unemployment into the GTAP framework, the GTAP-LAB model generates quite different labor market results in terms of wages as well as total employment of labor. Because "existing" labor is sector-specific and it is an imperfect substitute of "matched" labor in the GTAP-LAB model, the wage rate for existing labor moves in the same direction as sectoral output. Taking the simulation results of unskilled labor as an example, the expansion of production in the U.S. food and agricultural sector and the resulting increase in demand for unskilled labor increases wages of existing labor (unskilled) in the U.S. food and agricultural sector by 0.57 percent. As a result, the overall wage[5] paid by the U.S. food and agricultural sector to unskilled labor, which includes both existing and matched labor, increases by 0.42 percent, compared to the 0.06 percent increase in the standard GTAP model (Figure 1). Given that U.S. exports of food and agricultural products to the EU only accounts for 1.01 percent of total U.S. output of food and agricultural products in 2011[6], the elimination of EU tariff on U.S. exports of food and agricultural products generate a notable effect on changes in wages of U.S. food and agricultural sector workers under the GTAP-LAB model.

  Moreover, this immobile labor assumption in the GTAP-LAB model deviates from the costless switching assumption in the standard GTAP model, and therefore is able to predict changes in wages at the sectoral level: the small reduction in output in the U.S. metals and other manufacturing sectors results in a decline in wages of existing labor in these two sectors — again taking unskilled labor as an example, wages of existing labor in the U.S. metals and other manufacturing sectors decline by 0.10 percent and 0.005

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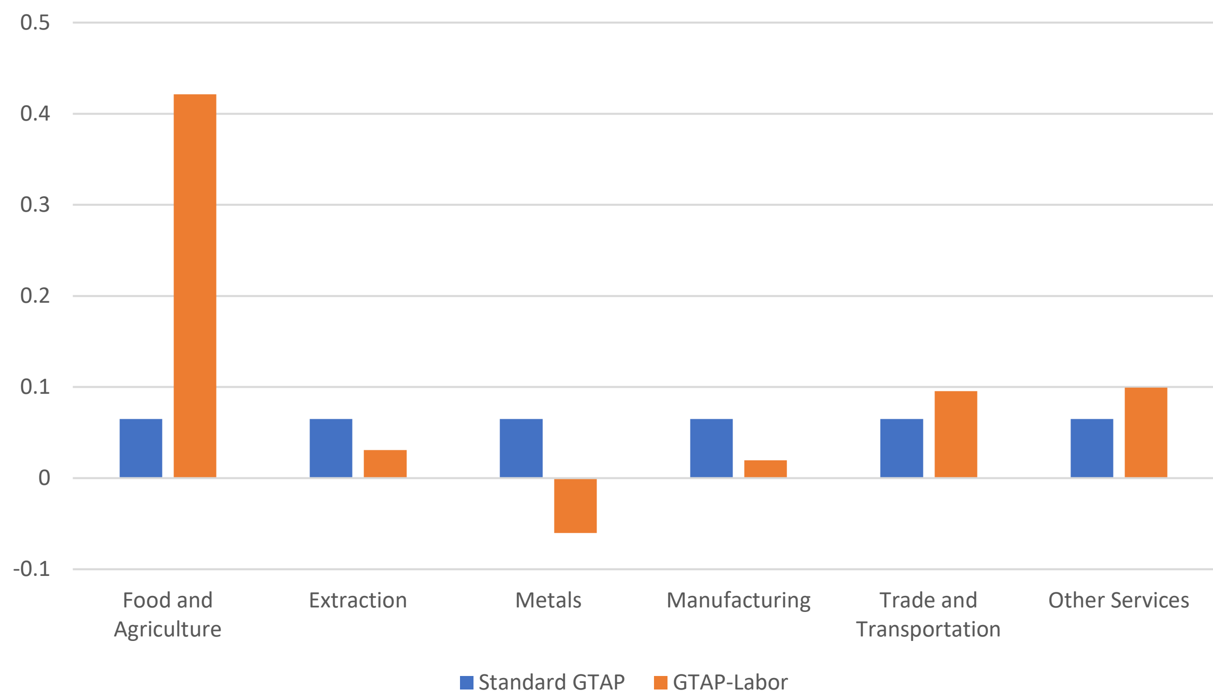
[5] The overall wage is the composite wage of the existing labor and the matched labor (new hires into the food and agricultural sector).

[6] According to the 2011 baseline statistics of the standard GTAP model and the GTAP-LAB model, total U.S. output of food and agricultural products equal to 1291 billion dollars, while U.S. exports of food and agricultural products to the EU is 13 billon dollars. Therefore, the share is calculated as the value of U.S. exports of food and agricultural products divided by total U.S. output of food and agricultural products.

percent respectively. The overall wage paid by the U.S. metals sector to unskilled labor declines by 0.06 percent, while the overall wage paid by the U.S. other manufacturing sector to unskilled labor increases by 0.02 percent, as compared to the sectoral-wide 0.06 percent increase in wage rate in the standard GTAP model (Figure 1).

Figure 1: Simulated removal of EU tariff on U.S. food and agricultural exports: Effects on U.S. sectoral wages for unskilled labor, in percent



Effects on Market Prices, Output and Trade

The larger increase in labor cost in the U.S. food and agricultural sector in the GTAP-LAB model results in a larger increase in the market price of U.S. food and agricultural products — a 0.20 percent price increase as compared to a 0.10 percent increase in the standard GTAP model (see figure 2 below). The larger price increase leads to a smaller output increase of 0.41 percent in the GTAP-LAB model, compared with a 0.54 percent increase in output in the standard GTAP model (see figure 3 below). The larger market price increase projected under the GTAP-LAB model also has a small impact on the trade side, as it causes a slightly smaller increase in the quantity of U.S. exports of food and agricultural products to the EU — exports of U.S. food and agricultural products to the EU increases by 46.4 percent under the GTAP-LAB framework, as compared to a 47.3 percent increase in the standard GTAP model.

Figure 2: Simulated removal of EU tariff on U.S. food and agricultural exports: Effects on U.S. market prices by sector, in percent

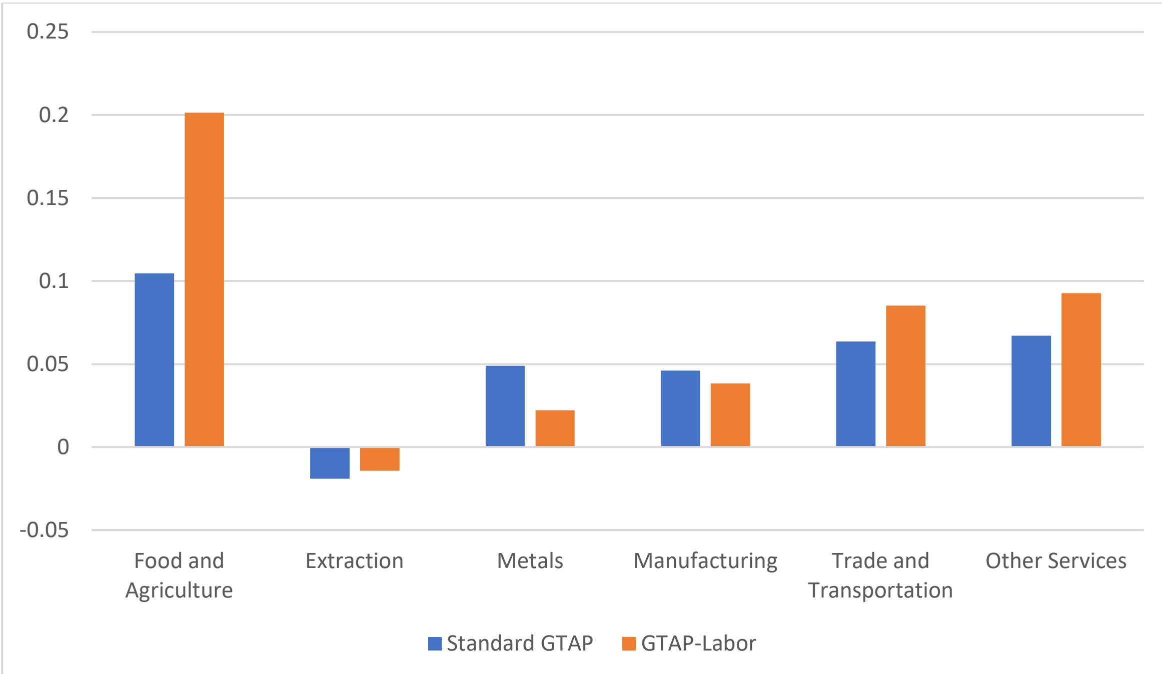
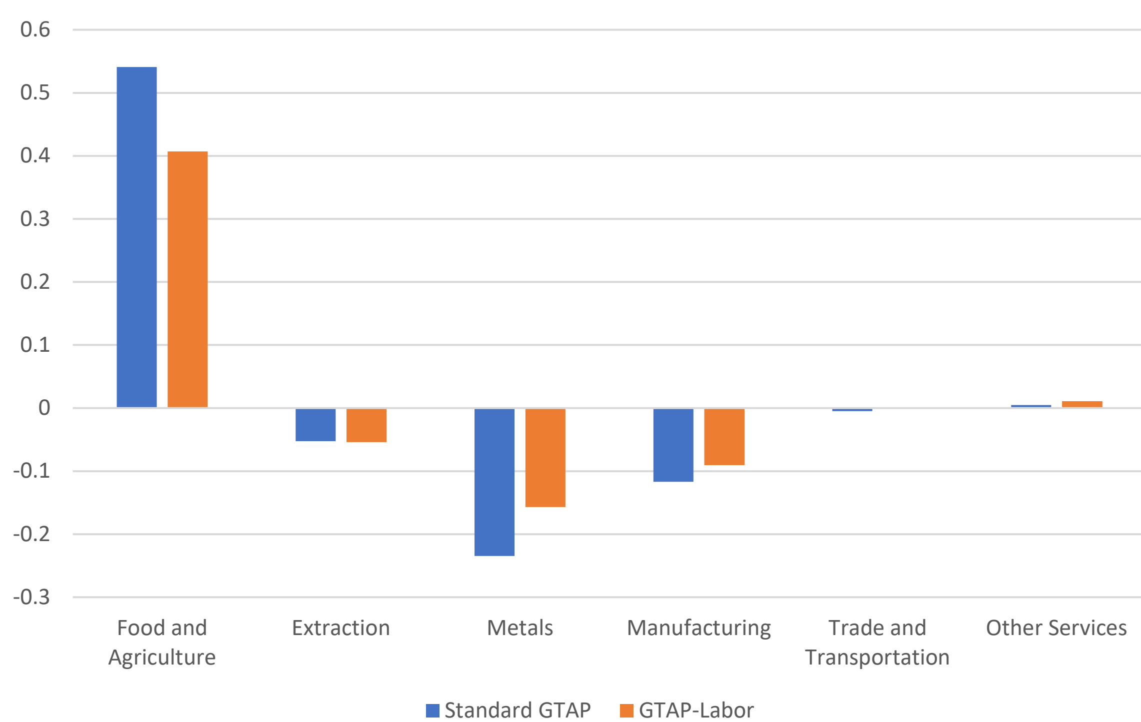


Figure 3: Simulated removal of EU tariff on U.S. food and agricultural exports: Effects on U.S. output by sector, in percent



Employment Effects

Since existing labor is sector-specific in the GTAP-LAB model, changes in sectoral employment is predominately due to the changes in the level of matched labor, that is, the number of new hires/matches made in each sector. The simulation result indicates that quantity of matched labor in the U.S. food and agricultural sector increases by 1.20 percent for unskilled labor and 1.19 percent for skilled labor as a result of the unilateral tariff elimination of EU agricultural tariff on U.S. food and agricultural exports. Table 1 presents the change in employment in the United States as a result of the unilateral tariff elimination of EU on U.S. food and agricultural exports, as measured by the change in the number of workers in each sector.[7]

- **Employment in the Food and Agriculture Sector:** As can be seen from table 1 below, the production increase in the U.S. food and agricultural sector results in an increasing demand for labor. With an upward sloping labor supply curve in the GTAP-LAB model, employment of unskilled and skilled labor in the U.S. food and agricultural sector both increases. Overall, employment in the U.S. food and agricultural sector is expected to increase by 4103 numbers of workers.
- **Employment in Services and Manufacturing Sectors:** As will be discussed in more details in the next section, increases in factor prices and overall employment leads to an increase in U.S. household income. Since services sector is mainly a non-traded sector with higher income elasticity of demand compared to agricultural and manufacturing sectors, employment in the trade and transportation as well as other services sector also increase. Given the relative size of the trade and transportation and other services sector in the U.S. economy, the increase in employment in these two sectors are relatively big in absolute value terms — employment in the U.S. trade and transportation sector increases by 1181 numbers of workers while employment in the other services sector expands by 8643 numbers of workers. Such an increase is partially offset by a decline in employment in the extraction, metals and other manufacturing sectors.
- **Overall Change in Employment and Unemployment:** As a result, overall employment in the United States increases by 5714 numbers of workers, and unemployment in the United States declines by 0.04 percent for unskilled labor, and by 0.13 percent for skilled labor in the GTAP-LAB model.

[7] The simulation results in the GTAP-LAB model shows the percent change in the quantity of unskilled and skilled labor in each sector as a result of the unilateral tariff elimination. The authors calculate the percent change in the quantity of total labor in each sector by taking the weighted average of the percent changes for unskilled and skilled labor. The authors then collect the number of workers in the food and agriculture, extraction, metals, other manufacturing, trade and transportation and other services sector in 2011 from the U.S. Bureau of Labor Statistics (BLS). The change in employment, measured by the change in the number of workers, is calculated by multiplying the percent change in the quantity of labor by the number of workers in each sector.

Table 1: Change in Employment, measured by Change in the Number of Workers

Food and Agriculture	*Extraction*	*Metals*	*Manufacturing*	*Trade and Transportation*	*Other Services*	*Total*
4103	-896	-19	-7298	1181	8643	5714

Effects on Welfare and Household Income

Due to the output increase in the U.S. food and agricultural sector, the increase in the U.S. demand for matched and recruitment labor causes the wage rate for matched unskilled and skilled labor to increase both by 0.09 percent. The composite wage rate, across all sectors and for both the existing and matched labor, increases by 0.09 percent for unskilled labor and 0.10 percent for skilled labor. The capital rental rate and the land price increase by 0.11 percent and 1.02 percent, respectively. With the increases in factor prices (except for natural resources) and more labor employed, U.S. household income increases by 0.1080 percent in the GTAP-LAB model, compared to the 0.0753 percent increase in the standard GTAP model. The increase in the household income leads to an increase in total utility of 0.0257 percent in the GTAP-LAB model, compared to 0.0136 percent in the standard GTAP model. With a larger increase in total utility in the GTAP-LAB model, U.S. welfare increases by $3.5 billion in the GTAP-LAB model, as compared to $1.8 billion in the standard GTAP model.

Table 2: Change in Welfare and Household Income

	Standard GTAP	**GTAP-LAB**
(percent change)		
Household Income	0.0753	0.1080
Total Utility	0.0136	0.0257
(in million dollars)		
Welfare Change (measured in EV)	1,849	3,494

4: Full Tariff Liberalization between the United States and the EU

In this section, we compare the simulation results of a full bilateral tariff liberalization between the United States and the EU, using both the standard GTAP model and the GTAP-LAB Model. The tariff (including TRQ) shock is applied to all traded commodities except the services sectors. We assemble information about U.S. and EU tariffs (including TRQs) using the 2011 GTAP baseline statistics. According to the 2011 baseline statistics (used both by the standard GTAP and the GTAP-LAB Model), EU imposes, on average, a higher import duty on U.S. exports to the EU compared to the import duty U.S. imposes on EU exports to the United States. Table 3 details the tariff eliminations of the EU tariff on U.S. exports to the EU, as well as the U.S. tariff on EU exports to the United States, measured in the percentage change in the power of tariff rates.

Table 3: Change in the Power of Tariff Rates (in percent) –

Policy Shock put into the Model

	EU tariff on U.S. exports	U.S. tariff on EU exports
Food ang Agriculture	-7.7	-2.4
Extraction	-0.3	-0.1
Metals	-1.7	-0.9
Other Manufacturing	-1.8	-1.2

Wage and Output Effects

Since the extent of tariff elimination in the EU on U.S. exports is greater than the tariff elimination in the U.S. on EU exports, it increases the competitiveness of U.S. exports to the EU of agriculture and manufacturing products.

- **Wage Effects using Standard GTAP:** As can be seen from Figure 4 below, under the standard GTAP model, since national labor supply is fixed, and that labor is freely mobile across sectors, the removal of U.S. and EU bilateral tariffs and TRQs results in an increase in the U.S. national wage rate of 0.34 percent.
- **Wage and Output Effects using GTAP-LAB:** By contrast, under the GTAP-LAB framework, changes in wage rates vary across sectors and closely correlates with the change in the output level by sector (see Figure 4 and Figure 5 below). As can be seen in Figure 5 below, since the extent of tariff elimination from the EU on U.S. exports is highest in the agricultural sector, output increase (in percent) is highest in the U.S. agricultural sector — output in the U.S. agricultural sector increase by 0.17 percent under the GTAP-LAB model. The increase in output results in an increase in labor demand in the U.S. food and agricultural sector, which results in an increase in the overall wage rate (composite wage rate of existing and matched labor) for unskilled labor in the U.S. food and agricultural sector by 0.49 percent, as compared to 0.34 percent under the standard GTAP model. Meanwhile, under the GTAP-LAB model, output declines in the U.S. extraction, metals and other manufacturing sector, by 0.17 percent, 0.16 percent and 0.04 percent, respectively. The decline in output in the U.S. extraction, metals and other manufacturing sector is driven mainly by the resource reallocation between sectors, as well as the U.S. tariff elimination on EU exports, which results in an increase in EU exports of such products to the United States. Figure 5 also shows that there is a positive correlation between the change in sectoral wage for unskilled labor and the change in output under the GTAP-LAB model— the larger the decline in sectoral output, the smaller the increase in sectoral wage. Sectoral overall wage for unskilled labor increases by 0.15 percent for U.S. extraction industry, 0.21

percent for the U.S. metals industry, and 0.33 percent for the U.S. other manufacturing industry, which are all lower than the 0.34 percent increase in wage in the standard GTAP model. The correlation between the wage change and the output change under the GTAP-LAB model is very high, with an R2 equaling to 0.97.

Figure 4: Simulated removal of US-EU bilateral AVEs: Effects on U.S. sectoral wages for unskilled labor, in percent

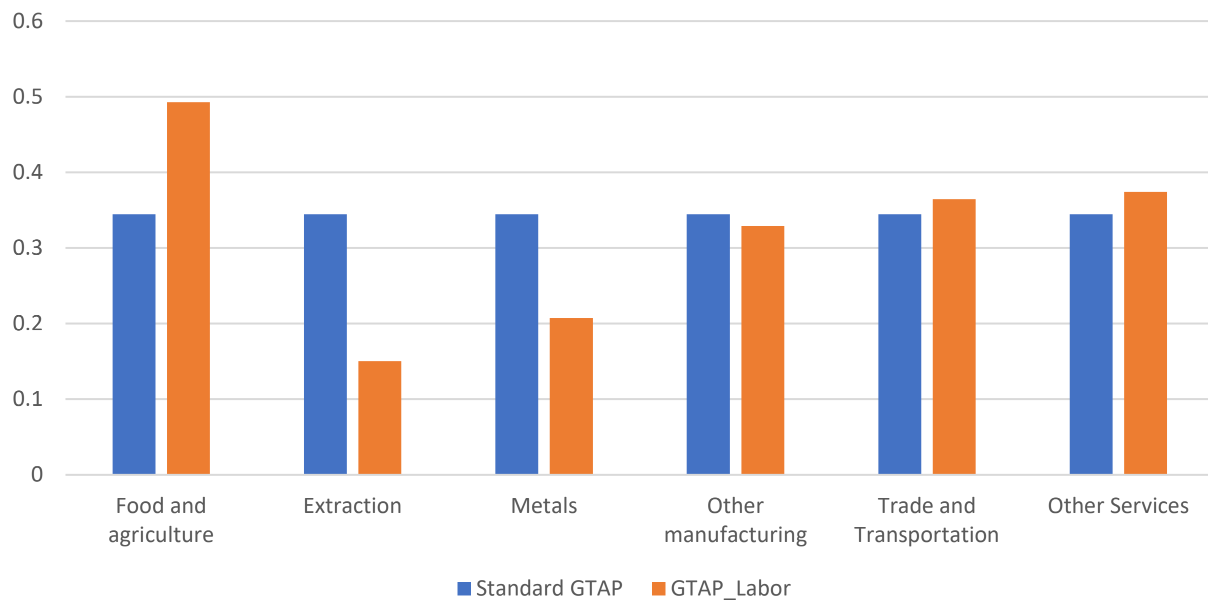
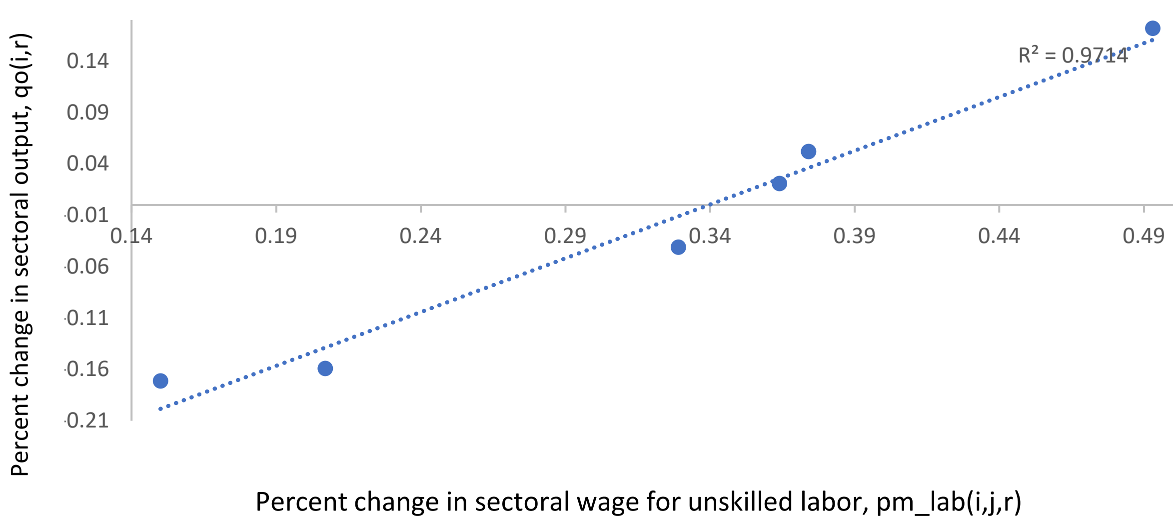


Figure 5: Simulated Removal of US-EU bilateral AVEs: Effects of U.S. Sectoral Output and Wages for unskilled labor, in percent



Change in Employment, Household Income and Welfare

As was discussed in simulation 1, changes in sectoral employment under the GTAP-LAB model is predominately due to the changes in the level of matched labor, that is, the number of new hires/matches made in each sector. The decline in output in the U.S. extraction, metals and other manufacturing sector results in a decline in employment in these three sectors (see Table 4 below). By contrast, the output increase in the food and agriculture, trade and transportation and other services sector leads to workers moving into these sectors, and hence an increase in employment in these three sectors. The output and employment increase in the food and agricultural sector is mainly due to the relatively big tariff liberalization from the EU on U.S. food and agricultural exports.

The two services sectors, namely, trade and transportation and other services, didn't experience a tariff change. However, with an increase in factor prices and overall household income, resources move into these two services sectors which have a higher income elasticity of demand, leading to a small increase in output in these two sectors — output increases by 0.02 percent for the trade and transportation sector, and 0.05 percent for the other services sector. Given the relatively big size of the services sector as a share of the U.S. economy, the small output increase results in a relatively large increase in employment in absolute terms (see Table 4 below). Employment in the trade and transportation sector increases by 8838 numbers of workers, while employment in the other services sector increases by 42,509 numbers of workers. Total employment in the United States increases by 48,445 numbers of workers, predominately driven by the employment expansion in the services sectors as the U.S. households become richer. As a result, national unemployment rate for unskilled labor in the United States declines by 0.37 percent for unskilled labor, and 0.72 percent for skilled labor.

Table 4: Change in Employment, measured by Change in Number of Workers

Food and Agriculture	Extraction	Metals	Manufacturing	Trade and Transportation	Other Services	Total
1,855	-2,802	-18	-1,936	8,838	42,509	48,445

When it comes to the change in welfare and household income, the increase in factor prices in the United States due to the bilateral tariff liberalization leads to an increase in household income — U.S. household income increases by 0.323 percent under the standard GTAP model and 0.394 percent under the GTAP-LAB model. Meanwhile, the increase in labor employment in the United States under the GTAP-LAB model leads to a larger increase in household income and total utility under the GTAP-LAB model, compared to standard GTAP. As a result, total welfare increases by $14.6 billion under the GTAP-LAB model as opposed to $8.8 billion under the standard GTAP model. The analysis on change in wages, output, employment, welfare and household income indicates that a full bilateral tariff and TRQ liberalization between the United

States and the EU is beneficial to the whole U.S. economy, with some differential effects on wages and employment reflected under the GTAP-LAB model at the sectoral level.

Table 5: Change in Welfare and Household Income

	Standard GTAP	GTAP-LAB
(percent change)		
Household Income	0.323	0.394
Total Utility	0.065	0.107
(in million dollars)		
Welfare Change (measured in EV)	8,839	14,564

5. Sensitivity Analysis

This section provides insights on the sensitivity of the GTAP-LAB model results to applying different labor substitution elasticities between existing and matched labor. The standard version of the GTAP-LAB model uses 2.5 as the substitution elasticity for all sectors for both unskilled and skilled labor. However, there is qualitative evidence that it is more difficult for agricultural, extraction and manufacturing sector workers to reallocate to new sectors/regions, particularly for unskilled labor. Therefore, we revise the labor substitution elasticity and make them smaller for agricultural, extraction and manufacturing sector workers, to see how simulation results change. Table 6 shows the revised labor substitution elasticities we use in this sensitivity analysis.

Table 6: Substitution elasticity between Existing and Matched Labor, used in the Sensitivity Analysis

	Unskilled Labor	Skilled Labor
Food and Agriculture	0.2	0.2
Extraction	0.2	0.2
Metals	1	2.5
Other manufacturing	1	2.5
Trade and Transportation	2.5	2.5
Other services	2.5	2.5

As can be seen from figure 6 below, when running the illustrative simulation (simulation 1 in the previous section) on EU unilaterally eliminates its tariff on U.S. food and agricultural exports to the EU, overall wage rate paid to the U.S. food and agricultural sector workers increases by 0.88 percent in the GTAP-LAB model with the revised labor substitution elasticities, as compared to 0.42 percent in the standard GTAP-LAB model. Meanwhile, overall wage paid to workers in the U.S. extraction industry declines by 0.12 percent, as opposed to an 0.03 percent increase in overall wage in the U.S. extraction industry, as projected with the standard GTAP-LAB model (see figure 1 and 6).

For simulation 2, that is, the full bilateral tariff liberalization between the United States and the EU, overall wage rate paid to U.S. food and agricultural sector workers increases by 0.71 percent in the GTAP-LAB model with revised substitution elasticities, as compared to 0.49 percent in the standard GTAP-LAB model (see figure 4 and 7). Overall wage paid to workers in the U.S. extraction industry declines by 0.36 percent in the revised GTAP-LAB model, as compared to an increase of 0.15 percent in overall wage of workers in the U.S. extraction industry projected under the standard GTAP-LAB model (see figure 4 and 7). The reason is because we use a smaller substitution elasticity between existing and matched labor for the food and agricultural and extraction industries (assumed here to be 0.2 instead of 2.5 in the standard GTAP-LAB model), which essentially increases the labor reallocation cost for agricultural and extraction sector workers. The simulation results indicate that wage changes are quite sensitive to the labor substitution elasticities used. The bigger frictions to labor reallocation across sectors, and larger the differences in sectoral wages.

Figure 6: Simulated removal of EU tariff on U.S. food and agricultural exports: Effects on U.S. sectoral wages for unskilled labor, in percent, sensitivity analysis

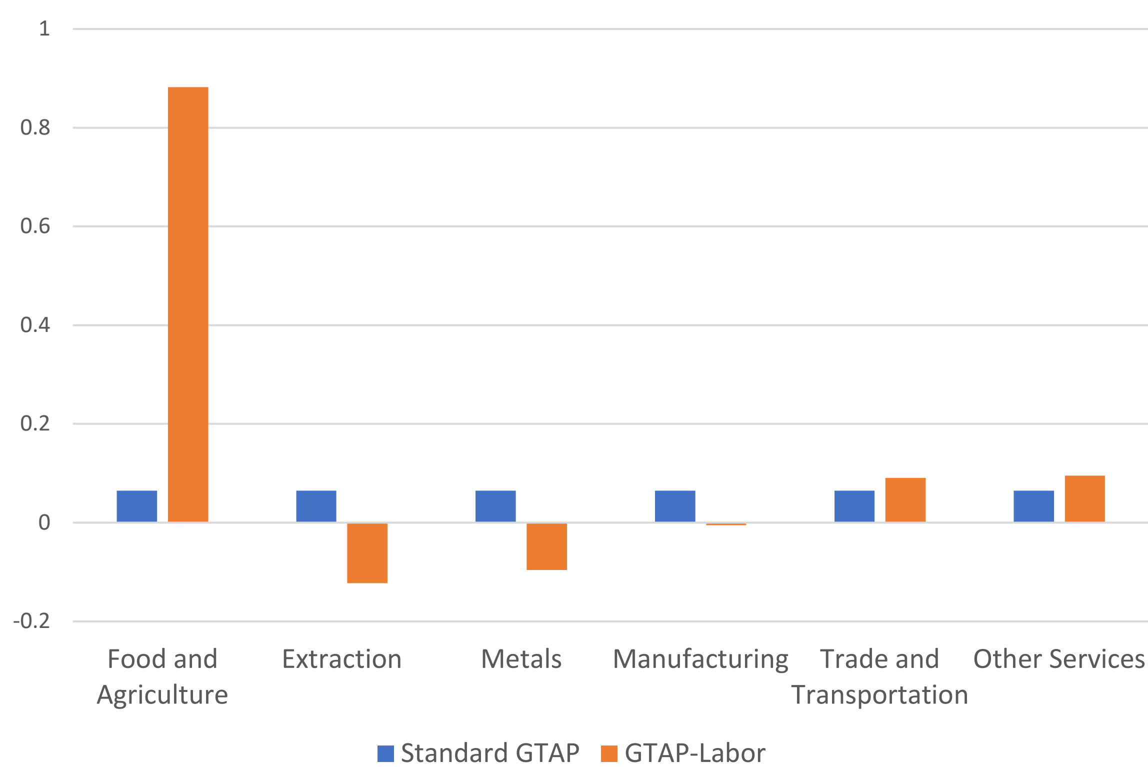
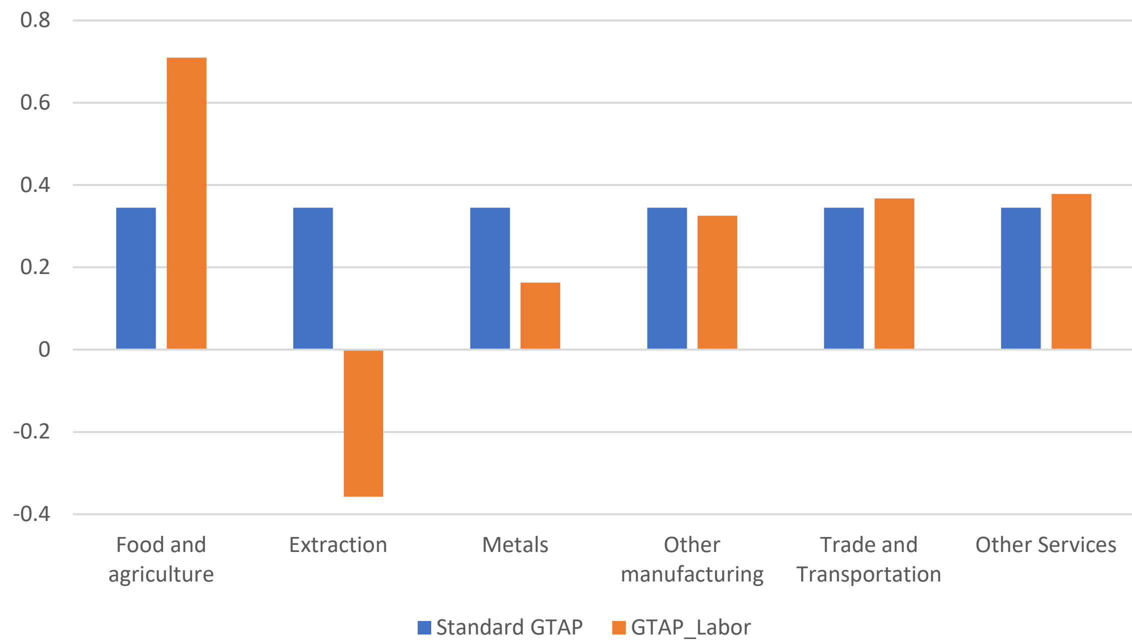


Figure 7: Simulated removal of US-EU bilateral AVEs: Effects on U.S. sectoral wages for unskilled labor, in percent, sensitivity analysis



6. Conclusions

This paper applies the GTAP-LAB model to analyze trade liberalization scenarios between the United States and the EU. When incorporating job search frictions and unemployment into the standard GTAP model, the model is able to predict changes in wages at the sectoral level.

Simulated effects suggest that a unilateral tariff elimination from the EU on U.S. exports of food and agricultural products would result in wage gains for U.S. food and agricultural sector workers, while workers in the U.S. metals industry would suffer from a wage decline. A full bilateral tariff libralization between the U.S. and EU would lead to wage gains for U.S. workers in different industries in the GTAP-LAB model, and wage gains expressed as a percentage change are the highest in the U.S. food and agricultural sector, where the extent of tariff liberalization is the biggest.

Meanwhile, wages of services sector workers also increase slightly from a tariff liberalization, mainly due to an overall income increase among U.S. households and therefore a reallocation of resources from extraction and manufacturing industries to services sectors. The full bilateral tariff liberalization between the United States and the EU also leads to worker movement across industries, with an increase in employment in U.S. food and agriculture and services sector, and a decline in employment in the U.S. extraction, metals and other manufacturing industries.

Sensitivity analaysis shows that the bigger frictions to labor reallocation are, the larger the differences in sectoral wages would be, and that the simulated results are sensitive to the labor substitution elasticities used. The wage results could be different not only in magnitude, but also in signs when using different labor substitution elasticities in the GTAP-LAB model.

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