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# The Effects of North American Free Trade Agreement and United States Farm Policies on Illegal Immigration and Agricultural Trade

Jeff Luckstead, Stephen Devadoss, and Abelardo Rodriguez

We analyze the effects of the North American Free Trade Agreement (NAFTA) and United States farm subsidies on U.S.-Mexican illegal immigration and agricultural trade. The theoretical analysis develops an integrated trade-migration model and shows that NAFTA and U.S. subsidies exacerbate the illegal labor flow and increase U.S. exports. The theoretical analysis is empirically implemented by simultaneous estimation and simulation analysis. The analysis shows that NAFTA increased the number of undocumented workers to U.S. agriculture and U.S. farm exports to Mexico by an average of 1573 and \$6.82 billion, respectively. U.S. farm subsidy reduction decreases unauthorized entry marginally and U.S. farm exports by an average of \$3.2 billion.

*Key Words:* farm policies, illegal migration, NAFTA, trade

**JEL Classifications:** F13, F16, F22

One of the major root causes of illegal immigration from Mexico to the United States is economic inequality. Because of the income gap between the two countries, Mexicans illegally enter the United States seeking better employment and living standards. The Heckscher-Ohlin (HO) theory predicts that when two countries enter into free trade, each country will export the good that uses its abundant factor intensively, and their relative output prices will equalize. The factor price equalization theorem asserts that through this equalization of relative output prices, factor prices will also equalize in both

countries. Even though the North American Free Trade Agreement (NAFTA) phased out tariffs, U.S. and Mexican factor prices are far from equal. For example, the U.S.-Mexican wage difference is 6–1 (Freeman, 2006). This non-equalization of factor prices is because many of the HO assumptions, such as no market distortions, do not hold in the real world. For instance, even after the removal of trade barriers, U.S.-Mexican trade remains distorted because of massive U.S. agricultural subsidies. Consequently, U.S. and Mexican agricultural output prices, and thus, factor prices (particularly wage rates) differ.

U.S. farm supports are far greater than those of Mexico. For example, U.S. farm subsidies peaked at over \$30 billion in 2000, and averaged about \$16 billion between 2002 and 2007 (U.S. Department of Agriculture, 2008g). In contrast, Mexico spent only about \$1.3 billion in 2004 for all rural development programs, not just farm supports (U.S. Department of Agriculture, 2008h). U.S. farm supports encourage over

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production in agriculture (Organisation for Economic Co-operation and Development, 2011), which floods the Mexican market as trade barriers are phased out, driving down agricultural output prices (Wise, 2010). This price decrease makes it difficult for Mexican farmers to compete, and these farmers are forced out of business (The Economist, 2003). Due to limited Mexican employment options, some of the displaced workers immigrate illegally to the United States in search of employment opportunities. Though NAFTA took a crucial step toward free trade, continuous U.S. agricultural subsidies undermine free trade and also augment U.S. agricultural labor demand, luring the displaced Mexican farm workers to migrate to the United States.

The culmination of the Bracero seasonal labor program in 1964 and the establishment of an annual quota for *legal* immigrants in 1965<sup>1</sup> led to a steady increase in *illegal* immigration. As a result, undocumented immigrants currently comprise about three-fourths of the U.S. farm workforce (see Calvin and Martin, 2010b; Devadoss and Luckstead, 2008; Martin, 2009 for more information on immigrant labor in agriculture). Due to this heavy reliance on immigrant labor by the agricultural sector and the increases in the U.S.-Mexican agricultural trade volume,<sup>2</sup> it is worth examining this trade relationship and immigration under NAFTA and U.S. farm policies.

The objectives of this study are: 1) to examine theoretically through trade and migration theory and empirically through econometric and simulation analysis the effects of U.S. farm subsidies and trade liberalization on illegal immigration and agricultural trade between the United States and Mexico and 2) to draw policy implications

and provide recommendations for guest-worker programs and freer trade. The next section develops the theoretical model. Section 3 presents the empirical estimation and simulation results. The final section concludes the paper.

## Theoretical Analysis

We develop a model with two countries (United States and Mexico) integrated through agricultural commodity trade and cross-border migration and analyze the effects of U.S. farm subsidies and trade liberalization on agricultural prices, illegal wage rate, trade flow, and illegal immigration.<sup>3</sup> Farm supports and trade barriers directly affect agricultural markets, which indirectly impact the labor markets. These interrelationships are captured in the mathematical model developed below.

### Commodity Market

The specifications for the agricultural commodity market<sup>4</sup> in the United States are

$$(1) \quad A_U^{ES} = A_U^S(P_U^S, W_U) - A_U^D(P_U, Z_U)$$

where  $A_U^{ES}$  is the excess supply of agricultural commodities,  $A_U^S$  is the U.S. commodity supply,  $A_U^D$  is the U.S. commodity demand,  $P_U^S$  is the support price,  $W_U$  is the U.S. unskilled wage rate,  $P_U$  is the consumer price, and  $Z_U$  is income.<sup>5</sup> U.S. producers receive an output subsidy ( $s_U$ ) for

<sup>3</sup> The theoretical analysis also incorporates immigration policies; however, the focus of this study is on U.S. farm policy and NAFTA impacts. See Devadoss and Luckstead (2011) for effects of domestic and border enforcement policies on unauthorized workers and the U.S. agricultural sector.

<sup>4</sup> Our initial intention was to model the labor-intensive agriculture sectors, particularly vegetables and fruits. However, we were unable to obtain production data for the vegetable sector and the fruit sector for both the United States and Mexico. In addition, data on illegal labor entering into the U.S. vegetable and fruit sectors are not available. We were able to obtain data on the illegal workforce in all of agriculture from U.S. Department of Labor (2008a). Thus, due to data availability, we focused on agriculture as a single sector.

<sup>5</sup> If agricultural supply is modeled using a dynamic formulation, producers will make hiring decisions after determining their desired output in response to commodity prices and subsidies.

<sup>1</sup> Under this act, an annual quota of 120,000 legal immigrants for all professional and family members was established, which paved the way for illegal immigration into the United States.

<sup>2</sup> According to the National Agricultural Worker Survey, in 2001–2002, immigrant labor accounts for 78% of all U.S. agricultural employment (U.S. Department of Labor, 2008a). Agricultural exports from the United States (Mexico) to Mexico (United States) have increased three (five) times since 1994 (U.S. Department of Agriculture Foreign Agricultural Services, 2008). Specifically, between 1994 and 2008, the U.S. net exports to Mexico increased from \$1.7 billion to \$5.8 billion (U.S. Department of Agriculture Foreign Agricultural Services, 2008).

their commodity production which is captured by the U.S. price wedge equation:

$$(2) \quad P_U^S = P_U + s_U.$$

Mexico is a net importer of the agricultural commodity and imposes an ad valorem tariff ( $T$ ) on agricultural imports, as was the case before and during the NAFTA period. The price linkage equation capturing this trade barrier through the tariff equivalent is expressed as

$$(3) \quad P_M = P_U(1 + T),$$

where  $P_M$  is the Mexican commodity prices. The specifications for the agricultural commodity market in Mexico are

$$(4) \quad A_M^{ED} = A_M^D(P_M, Z_M) - A_M^S(P_M, W_M),$$

where  $A_M^{ED}$  is the Mexican excess demand for commodity,  $A_M^D$  is the Mexican domestic demand,  $A_M^S$  is the Mexican domestic supply,  $Z_M$  is income, and  $W_M$  is the Mexican farm wage rate.

#### *Labor Market*

The labor supply in the United States ( $L_U^S$ ) includes domestic unskilled farm workers ( $L^S$ ) plus legal immigrant workers ( $L_L^S$ ) (see Zahniser, Hertz, Dixon, and Rimmer, 2011). Since legal immigrant laborers earn the same wage rate as domestic workers, because they do not pose any unnecessary additional risk to their farm employer, we include the legal immigrant labor supply with the U.S. domestic farm labor supply to form the U.S. agricultural labor supply:

$$L_U^S = L^S + L_L^S.$$

We focus on the impact of trade and farm policies on illegal immigration, and legal migrants are incorporated into the U.S. legal labor supply. The number of U.S. agricultural work visas are limited and tightly controlled by the U.S. government and, as such, the impact of the wage rate on this portion of the legal workforce is negligible.

The labor market specifications for the United States are:

$$(5) \quad L_U^{ED} = L_U^D(W_U, P_U^S) - L_U^S(W_U),$$

where  $L_U^{ED}$  is the excess agricultural labor demand, and  $L_U^D$  is the U.S. labor demand.

Domestic surveillance creates risk for agricultural employers hiring illegal immigrants due

to potential fines, jail terms, and the deportation of their undocumented laborers. Because of this risk, employers pay lower wage rates to undocumented farm workers, which create the legal-illegal wage gap. Following Bond and Chen (1987), this wage discrepancy is expressed as:

$$(6) \quad W_U = W_I + \beta(E)c,$$

where  $W_I$  is the wage rate for an illegal worker,  $\beta$  is the probability an employer is caught hiring an undocumented worker, which is defined as a function of the government expenditures ( $E$ ) allocated to domestic enforcement, and  $c$  is the fine for employing an illegal laborer.<sup>6</sup>

Next, we develop the Mexican illegal migration process, which is a slightly modified version of the illegal migration theory formulated by Bandyopadhyay and Bandyopadhyay (1998). Because potential wage earnings are higher in the United States than in Mexico, unauthorized laborers find it optimal to immigrate to the United States. However, because the United States imposes a limit on the number of legal immigrants and because of the difficult process of obtaining a legal work visa, only a portion of the immigrant farm laborers enter the United States legally.

These illegal Mexican farm workers spend considerable amount of time attempting to cross the border by seeking the assistance of coyotes (smugglers who bring illegal immigrants into the United States) and dangerously trekking across the border. The labor wasted ( $L_W$ ) in this migration process is a fraction of total labor attempting to migrate ( $L_I$ ):

$$(7a) \quad L_W = rL_I,$$

where  $r$  is the proportion of the labor wasted in crossing the border. The illegal immigrants could be caught at the border, and the probability of getting apprehended at the border is denoted by  $d$ . Then, the illegal labor that successfully enters the United States ( $L_I^S$ ) is:

<sup>6</sup> Even though immigration policies are not effective in eliminating illegal immigration, they do hinder the free flow of immigrants, causing a wage-wedge, as observed in the actual wage data among the U.S. legal, illegal, and Mexican farm workers. This wage wedge is further exacerbated by farm and trade policies, which is the motivation for this study. See Martin (1998), Calvin and Martin (2010a), and Calvin and Martin (2010b) for more information on illegal farm workers.

$$(7b) \quad L_I^S = (1-d)(1-r)L_I.$$

The Mexican illegal labor supply to the United States is total supply of labor ( $\bar{L}$ ) minus labor demand, legal labor supply ( $L_L^S$ ), and labor wasted:

$$(8a) \quad L_I^S = \bar{L} - L_L^S - L_M^D(W_M, P_M) - L_W,$$

where  $L_M^D$  is the demand for unskilled labor in Mexico.  $\bar{L}$  is exogenous because farm workers from Latin American countries illegally enter the United States via Mexico, the total supply of labor ( $\bar{L}$ ) includes farm workers from Mexico and these countries. Combining identities (7a) and (7b), substituting the result into Equation (8a), and solving for  $L_I^S$  yields:

$$(8b) \quad L_I^S = \psi [\bar{L} - L_L^S - L_M^D(W_M, P_M)],$$

where  $\psi = \frac{(1-d)(1-r)}{1-d(1-r)}$  measures the porosity of the U.S. border.

In their decision to immigrate, Mexican laborers consider the Mexican wage rate and the U.S. illegal wage rate. At the equilibrium, Mexican workers would be indifferent to migrating if the wage rate in Mexico is equal to the weighted average of the illegal wage rate in the United States and the Mexican wage rate. The weight for the illegal wage rate is the probability of successful entry into the United States and the weight for the Mexican wage rate is the probability of getting apprehended at the border and returned to Mexico:

$$(9a) \quad W_M = (1-d)(1-r)W_I + d(1-r)W_M.$$

Solving for  $W_M$  yields the linkage equation between Mexico's wage and the U.S. illegal wage rates:

$$(9b) \quad W_M = \psi W_I,$$

where  $\psi$  is as defined in Equation (8b).

The presence of wage rates in the commodity supply function in Equations (1) and (4) and output price in the labor demand functions in Equations (5) and (8a) captures the vertical link between the labor market and the commodity market. The equilibrium conditions require that the Mexican excess supply of unskilled labor (supply of illegal labor) equal the U.S. excess demand for farm labor, and that the Mexican commodity excess demand equal the U.S. commodity excess supply. After equating these equations and substituting for the wage

and price linkage identities, these equilibrium conditions are written as:

$$(10a) \quad \begin{aligned} &L_U^D(W_I + \beta(E)c, P_U + s_U) \\ &- L_U^S(W_I + \beta(E)c) \\ &- \psi [\bar{L} - L_M^D(\psi W_I, P_U(1+T))] = 0 \end{aligned}$$

$$(10b) \quad \begin{aligned} &A_M^D(P_U(1+T), Z_M) - A_M^S(P_U(1+T), \psi W_I) \\ &- A_U^S(P_U + s_U, W_I + \beta(E)c) \\ &+ A_U^D(P_U, Z_U) = 0, \end{aligned}$$

which is a system of two equations containing two endogenous variables:  $W_I$  and  $P_U$ .

### Impacts on Illegal Wage and Commodity Price

To examine the effects of marginal changes in the tariff and subsidy rate on the endogenous variables, Equations (10a) and (10b) are totally differentiated holding all other exogenous variables ( $E, c, \psi, Z_M, Z_U$ , and  $\bar{L}$ ) constant, and using Cramer's rule,  $dW_I$  and  $dP_U$  are solved for in terms of the tariffs and subsidies.

*Tariff Effect.* The effect of a tariff reduction— as implemented in NAFTA—on the illegal wage rate is shown in Equation (11a).<sup>7</sup>

<sup>7</sup> Totally differentiating Equations (10a) and (10b) and rewriting in the form  $Ax = d$  and solving for the determinant of  $A$  yields

$$\begin{aligned} |A| = & \left( \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} \right) + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \\ & \times \left( \frac{\partial A_M^D}{\partial P_M} (1+T) + \frac{\partial A_U^D}{\partial P_U} \right) \\ & + \frac{\partial L_U^S}{\partial W_U} \left( \frac{\partial A_M^S}{\partial P_M} (1+T) + \frac{\partial A_U^S}{\partial P_U} \right) \\ & - \left( (1+T) \frac{\partial A_M^S}{\partial P_M} \frac{\partial L_U^D}{\partial W_U} \right) \\ & - \left( \psi^2 (1+T) \frac{\partial A_M^S}{\partial P_M} \frac{\partial L_M^D}{\partial W_M} \right) - \left( \frac{\partial A_U^S}{\partial P_U} \frac{\partial L_U^D}{\partial W_U} \right) \\ & - \left( \psi^2 \frac{\partial A_U^S}{\partial P_U} \frac{\partial L_M^D}{\partial W_M} \right) + \left( \psi \frac{\partial A_M^S}{\partial P_M} \frac{\partial L_U^D}{\partial W_U} \right) \\ & + \left( \psi^2 (1+T) \frac{\partial A_M^S}{\partial P_M} \frac{\partial L_M^D}{\partial W_M} \right) + \left( \frac{\partial A_U^S}{\partial P_U} \frac{\partial L_U^D}{\partial P_U^S} \right) \\ & + \left( \psi (1+T) \frac{\partial A_U^S}{\partial W_U} \frac{\partial L_M^D}{\partial P_M} \right). \end{aligned}$$

Comparing the similar terms and using plausible coefficients of the demand and supply functions, one can ascertain that the determinant is positive.

$$(11a) \quad \frac{dW_I}{dT} = \frac{P_U \left\{ \overbrace{\left[ \psi \left( \frac{\partial A_U^S}{\partial P_U^S} - \frac{\partial A_U^D}{\partial P_U} \right) \left( \frac{\partial L_M^D}{\partial P_M} \right) \right]}^{(+)} + \overbrace{\left[ \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \left( \frac{\partial L_U^D}{\partial P_U^S} \right) \right]}^{(-)} \right\}}{|A|}.$$

$$(11b) \quad \frac{dP_U}{dT} = \frac{\left\{ \overbrace{\left[ -P_U \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \right]}^{(-)} + \overbrace{\left[ \psi P_U \frac{\partial L_M^D}{\partial P_M} \left( -\frac{\partial A_M^S}{\partial W_M} \psi - \frac{\partial A_U^S}{\partial W_U} \right) \right]}^{(+)} \right\}}{|A|}.$$

The first set of terms in the right hand side of Equation (11a) relates the push effect of labor released in Mexico. As the tariff rate decreases, Mexican commodity price and production decline, leading to a lower demand for labor in Mexico and releasing more labor to enter into the United States. This results in a reduction of the illegal wage rate. The magnitude of the change in the illegal wage rate depends on how the U.S. commodity supply and demand, and thus, excess supply reacts to the U.S. price increase and how porous the border is ( $\psi$ ). The second set of terms captures the pull effect of labor demand in the United States.<sup>8</sup> That is, a decrease in the tariff rate will increase the U.S. price and commodity production and augment the demand for farm labor, and thus, raise the illegal wage rate. The level of increase in the illegal wage rate depends on the responsiveness of agricultural demand and supply in Mexico, i.e., excess demand, to a decrease in the Mexican commodity price. The overall effect on the illegal wage rate is indeterminate and will be empirically determined.

The effect of the tariff reduction under NAFTA on U.S. commodity prices is shown in

Equation (11b). The first set of terms in Equation (11b) captures the effect of the tariff reduction on U.S. prices through the labor market and Mexican commodity market. As a result of free trade, the Mexican commodity price declines, which leads to a higher demand and lower supply. This increases the excess demand, causing U.S. commodity prices to rise. The magnitude of this increase depends on the labor release in Mexico and labor absorption in the United States. The second set of terms is related to the push effect in Mexico. Specifically, a reduction in the tariff rate decreases the Mexican commodity price; this forces the labor demand to go down which negatively affects the wage rate in both countries. This lower wage rate increases the commodity supply in both countries, which lowers the U.S. commodity price. The magnitude of this decrease in the U.S. commodity price depends on the response of commodity supply to a lower wage rate in both countries. Because the tariff directly influences the Mexican commodity price, the direct effect in the first term is likely to dominate the indirect effect through the labor market in the second term. The overall effect of Mexico's tariff reduction is expected to increase the U.S. commodity price.

*Subsidy Effect.* The effect of an increase in the U.S. commodity subsidy on the illegal wage rate is shown in Equation (12a). The first set of terms in Equation (12a) reflects the effect of the subsidy on the illegal wage rate through an output price change and Mexican labor demand. That is, an increase in

<sup>8</sup> According to U.S. Department of Agriculture (2011) production and exports of U.S. fruits and vegetables have been increasing even though U.S. does import vegetables from Mexico. This growth of vegetable and fruit production has further increased the demand for unskilled labor because of the labor-intensive nature of production, which intensifies the pull effect of labor from Mexico to the United States.

$$(12a) \quad \frac{dW_I}{ds_U} = \frac{\left\{ \overbrace{\left[ -\psi(1+T) \frac{\partial A_U^S}{\partial P_U^S} \frac{\partial L_M^D}{\partial P_M} \right]}^{(-)} + \overbrace{\left[ -\left( \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) (1+T) + \left( \frac{\partial A_U^D}{\partial P_U} \right) \frac{\partial L_U^D}{\partial P_U^S} \right]}^{(+)} \right\}}{|A|}.$$

$$(12b) \quad \frac{dP_U}{ds_U} = \frac{\left\{ \overbrace{\left[ \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \frac{\partial A_U^S}{\partial P_U^S} \right]}^{(-)} + \overbrace{\left[ \left( -\frac{\partial A_M^S}{\partial W_M} \psi - \frac{\partial A_U^S}{\partial W_U} \right) \frac{\partial L_U^D}{\partial P_U^S} \right]}^{(+)} \right\}}{|A|}.$$

the subsidy raises the U.S. producer price and expands the U.S. commodity production. This surplus production is dumped in Mexico, forcing the Mexican commodity price to fall (Puyana and Romero, 2005). As a result of the price decrease, Mexican labor demand contracts and displaces agricultural workers. A portion of these unemployed farm workers tend to migrate illegally to the United States, which leads to excess supply of labor and depresses the illegal wage rate. The second set of terms in Equation (12a) outlines the effect of the U.S. farm subsidy on the illegal wage rate through the output price change and U.S. labor demand. The U.S. farm subsidy increases the producer price and expands production, which leads to higher demand for labor and wage rate. The magnitude of the increase in the wage rate depends on how responsive the commodity demand and supply, and thus, the excess demand in Mexico and the domestic demand in the United States are to the price change. The net effect of the U.S. production subsidy on the illegal wage rate will likely be positive because the demand effect of a U.S. price increase on labor will be larger than the supply effect of a labor release from a lower commodity price in Mexico.

The effect of an increase in the U.S. production subsidy on the commodity price is presented in Equation (12b). The first set of terms in Equation (12b) traces the effect of a change in the subsidy on the market price through an increase in the producer price, the U.S. commodity supply, and the resulting labor

market changes in both countries. An increase in the U.S. production subsidy increases the price to producers, which expands output and decreases the market or consumer price. The magnitude of the decline in the market price depends on the responsiveness of the U.S. excess demand for labor and labor release in Mexico. The second set of terms tracks the effect of the change in subsidy on the U.S. producer price through labor demand and the repercussions on wage rates and production. That is, an increase in the subsidy raises the U.S. producer price, which increases the labor demand and the wage rates in both countries. This causes the production to decline and the commodity price to rise. The first set of terms is the direct price effect and the second set of terms is the indirect wage effect. The direct effect should dominate the indirect effect, and thus the commodity price should decrease in response to a production subsidy.

#### *Direction of Labor Flow and Trade*

This subsection analyzes the effects of changes in the tariff and subsidy on illegal labor migration and trade flows. Since excess demand and supply for illegal labor are equal (Equation (10a)), and excess demand and supply for the agricultural commodity are equal (Equation (10b)), we can totally differentiate the excess supply of labor (Equation (8b)) and excess demand for the commodity (Equation (4)) to determine, respectively, changes in the U.S. illegal labor employment and U.S. commodity exports to Mexico:

$$\begin{aligned}
 dL_I^S = & [\bar{L} - L_M^D] d\psi + \psi d\bar{L} - \psi^2 \frac{\partial L_M^D}{\partial W_M} dW_I \\
 (13a) \quad & - \psi W_I \frac{\partial L_M^D}{\partial W_M} d\psi - \psi(1+T) \frac{\partial L_M^D}{\partial P_M} dP_U \\
 & - P_U \frac{\partial L_M^D}{\partial P_M} dT
 \end{aligned}$$

$$\begin{aligned}
 dA_M^{ED} = & \frac{\partial A_M^D}{\partial P_M} (1+T) dP_U + \frac{\partial A_M^D}{\partial P_M} P_U dT \\
 (13b) \quad & + \frac{\partial A_M^D}{\partial Z_M} dZ_M - \frac{\partial A_M^S}{\partial P_M} (1+T) dP_U \\
 & - \frac{\partial A_M^S}{\partial P_M} P_U dT - \frac{\partial A_M^S}{\partial W_M} \frac{\partial W_M}{\partial W_I} dw_I \\
 & - \frac{\partial A_M^S}{\partial W_M} \frac{\partial W_M}{\partial \psi} d\psi.
 \end{aligned}$$

*Tariff Effect.* To analyze the effect of trade liberalization under NAFTA on illegal labor flows,  $dW_I$  and  $dP_U$  from Equations (11a) and (11b) are substituted into Equation (13a). The change in illegal labor flow resulting from a tariff reduction, holding all other exogenous variables constant in Equation (13a), is expressed in Equation (14a). The first set of terms on the right-hand side of Equation (14a) expresses the impact of the illegal wage

rate change, the second set of terms articulates the effect of a price change, and the third set of terms shows the direct effect of a tariff change on illegal labor flows. Even though the effect of a tariff reduction on commodity prices is positive (see Equation (11b)), the effect on the illegal wage rate is indeterminate (see Equation (11a)), and the direction of the illegal labor flow change is ambiguous in Equation (14a). However, this tariff reduction will decrease Mexican production, resulting in a release of farm workers. The net effects of all three terms are likely to expand the illegal immigration into the United States.

To examine the effect of a tariff reduction on commodity trade,  $dW_I$  and  $dP_U$  from Equations (11a) and (11b) are substituted into Equation (13b). The effect of a tariff reduction on trade flow, holding all other exogenous variables constant in Equation (13b), is shown in Equation (14b). The first set of terms on the right-hand side of Equation (14b) illustrates the illegal wage rate effect, the second set of terms captures the price effect, and the third set of terms shows the direct effect of a change in the tariff rate on U.S. exports. Even though the

$$\begin{aligned}
 (14a) \quad \frac{dL_I^S}{dT} = & \overbrace{-\psi^2 \frac{\partial L_M^D}{\partial W_M} P_U \left\{ \left[ -\psi \frac{\partial L_M^D}{\partial P_M} \left( \frac{\partial A_U^D}{\partial P_U} - \frac{\partial A_U^S}{\partial P_U^S} \right) \right] + \left[ \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \left( \frac{\partial L_U^D}{\partial P_U^S} \right) \right] \right\}}^{(\pm)} \\
 & \overbrace{-\psi(1+T) \frac{\partial L_M^D}{\partial P_M} \left\{ \left[ -P_U \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \right] + \left[ \psi P_U \left( -\frac{\partial A_M^S}{\partial W_M} \psi - \frac{\partial A_U^S}{\partial W_U} \right) \frac{\partial L_M^D}{\partial P_M} \right] \right\}}^{(+)} \\
 & \overbrace{-P_U \frac{\partial L_M^D}{\partial P_M}}^{(+)} \\
 (14b) \quad \frac{dA_M^{ED}}{dT} = & \overbrace{-\psi \frac{\partial A_M^S}{\partial W_M} P_U \left\{ \left[ -\psi \frac{\partial L_M^D}{\partial P_M} \left( \frac{\partial A_U^D}{\partial P_U} - \frac{\partial A_U^S}{\partial P_U^S} \right) \right] + \left[ \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \left( \frac{\partial L_U^D}{\partial P_U^S} \right) \right] \right\}}^{(\pm)} \\
 & \overbrace{+ (1+T) \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \left\{ \left[ -P_U \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) \right] + \left[ \psi P_U \left( -\frac{\partial A_M^S}{\partial W_M} \psi - \frac{\partial A_U^S}{\partial W_U} \right) \frac{\partial L_M^D}{\partial P_M} \right] \right\}}^{(+)} \\
 & \overbrace{+ \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) P_U}^{(-)}.
 \end{aligned}$$

$$(15a) \quad \frac{dL_I^S}{ds_U} = -\psi^2 \frac{\partial L_M^D}{\partial W_M} \frac{\overbrace{\left\{ \left[ -\left( \psi(1+T) \frac{\partial L_M^D}{\partial P_M} \frac{\partial A_U^S}{\partial P_U^S} \right] - \left[ \frac{\partial L_U^D}{\partial P_U^S} \left( \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) (1+T) + \left( \frac{\partial A_U^D}{\partial P_U} \right) \right) \right] \right\}}^{(+)}}{|A|} - \psi(1+T) \frac{\partial L_M^D}{\partial P_M} \frac{\overbrace{\left\{ \left[ \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \frac{\partial A_U^S}{\partial P_U^S} \right] + \left[ \left( -\frac{\partial A_M^S}{\partial W_M} \psi - \frac{\partial A_U^S}{\partial W_U} \right) \frac{\partial L_U^D}{\partial P_U^S} \right] \right\}}^{(+)}}{|A|}.$$

$$(15b) \quad \frac{dA_M^{ED}}{ds_U} = -\frac{\partial A_M^S}{\partial W_M} \psi \frac{\overbrace{\left\{ \left[ -\left( \psi(1+T) \frac{\partial L_M^D}{\partial P_M} \frac{\partial A_U^S}{\partial P_U^S} \right] - \left[ \frac{\partial L_U^D}{\partial P_U^S} \left( \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) (1+T) + \left( \frac{\partial A_U^D}{\partial P_U} \right) \right) \right] \right\}}^{(+)}}{|A|} - \left( \frac{\partial A_M^D}{\partial P_M} - \frac{\partial A_M^S}{\partial P_M} \right) (1+T) \frac{\overbrace{\left\{ \left[ \left( \frac{\partial L_U^D}{\partial W_U} - \frac{\partial L_U^S}{\partial W_U} + \psi^2 \frac{\partial L_M^D}{\partial W_M} \right) \frac{\partial A_U^S}{\partial P_U^S} \right] + \left[ \left( -\frac{\partial A_M^S}{\partial W_M} \psi - \frac{\partial A_U^S}{\partial W_U} \right) \frac{\partial L_U^D}{\partial P_U^S} \right] \right\}}^{(+)}}{|A|}.$$

effect of a tariff reduction on the commodity price is positive, the effect on the illegal wage rate is ambiguous, and thus, the direction of commodity trade is unclear. However, since a reduction in the tariff rate increases the excess demand, U.S. exports are expected to increase.

*Subsidy Effect.* To consider the effect of a massive U.S. farm support on illegal labor flows,  $dW_I$  and  $dP_U$  from Equations (12a) and (12b) are substituted into Equation (13a). The change in illegal labor flow in response to a higher subsidy, holding all other exogenous variables constant, is expressed in Equation (15a).

The first set of terms in Equation (15a) tracks the effect of a change in the illegal wage rate, which is likely to increase in response to a production subsidy and attract illegal labor to the United States. The second set of terms demonstrates the effect of the U.S. commodity price change. An increase in the subsidy will lead to a higher U.S. producer price and commodity production, which results in an increase in labor demand, and thus, draws illegal labor from Mexico.

To analyze the effect of an increase in the U.S. farm subsidy on commodity trade,  $dW_I$  and  $dP_U$  from Equations (12a) and (12b) are substituted into Equation (13b). The change in commodity trade arising from a subsidy increase, holding all other exogenous variables constant, is written in Equation (15b).

The first set of terms traces the effect of a change in the illegal wage rate. Since the illegal wage rate is likely to increase in response to the production subsidy, illegal immigrants are lured to the United States. This reduces the labor supply in Mexico and raises the Mexican wage rate, causing the Mexican commodity supply to decrease and the import demand to rise. The second set of terms captures the effect of a price change. Greater U.S. subsidies will lead to a higher U.S. producer price and excess production, which augments U.S. exports to Mexico.

### Empirical Analysis

This section presents the empirical specifications for labor and agricultural commodity supply and demand, and simulation results. The general specifications for labor demand and supply functions used in the econometric analysis follow the work of Duffield and Coltrane (1992):

$$(16) \quad L^D = \alpha_0 + \alpha_1 W + \alpha_2 P + \alpha_3 L_{t-1}^D + \alpha_4 V_1 + \alpha_5 V_2 + \alpha_6 V_3 + \mu_1$$

$$(17) \quad L^S = \beta_0 + \beta_1 W + \beta_2 L_{t-1}^S + \beta_3 NW + \beta_4 CL + \mu_2,$$

where  $L^D$  is the hired farm-labor employment,  $W$  is the hired farm real wage rate,  $P$  is the price

of agricultural products,  $L_{t-1}^D$  is the one-year lagged dependent variable,  $V_1$  is the number of farms,  $V_2$  is the index of technology or productivity,  $V_3$  is the non-farm income,  $L^S$  is the domestic farm-labor supply,  $L_{t-1}^S$  is the lagged dependent variable,  $NW$  is the index of nonfarm wage rates, and  $CL$  is the nonfarm employment.

The empirical specifications for the commodity market demand and supply functions are:

$$(18) \quad A^D = \theta_0 + \theta_1 P^C + \theta_2 Y + \theta_3 \mathbf{H} + \mu_4$$

$$(19) \quad A^S = \gamma_0 + \gamma_1 P^S + \gamma_2 W + \gamma_3 \mathbf{G} + \mu_5$$

where  $A^D$  is the demand for agricultural products consumed,  $P^C$  is the consumer price,  $Y$  is the personal disposable income,  $\mathbf{H}$  is a vector of variables that influence demand,  $A^S$  is the supply of agricultural products,  $P^S$  is the producer price including government support,  $W$  is the legal wage rate paid to laborers, and  $\mathbf{G}$  is a vector of input costs to produce agricultural products.

### Data

The data period covers 1989–2007. The U.S. agricultural labor data were collected from the July Farm Labor report of the National Agricultural Statistics Service because this is the peak month for agricultural operations (Duffield and Coltrane, 1992; U.S. Department of Agriculture, 2008a). To account for the proportion of legal and illegal laborers, we use the National Agricultural Workers Survey (NAWS) (U.S. Department of Labor, 2008a), which represents a national sample of farm labor and is specific to hired farm workers. These laborers are asked questions, which cover legal status and wages paid. We multiply the percentage of legal laborers that identify themselves as legal by the farm labor data to obtain the U.S. labor supply. Using NAWS, the agricultural legal and illegal wage rates were calculated by averaging the wage rates of workers that identify themselves as legal and illegal for each year. Other data used in the labor market estimation include the gross domestic product

(GDP) deflator (U.S. Department of Commerce Bureau of Economic Analysis, 2008a), total number of U.S. farms in operation (U.S. Department of Agriculture, 2008b), and total nonfarm employment and manufacturing wage rates (U.S. Department of Labor, 2008b). The variables used for the Mexican labor market include the economically active population in agriculture (Food and Agricultural Organization of the United Nations, 2008c), unskilled wage rate (Comision Nacional De Los Salarios Minimos, 2008), producer price indexes for agriculture, manufacturing, and textiles (Banco de Mexico, 2008), and the Mexican GDP deflator (International Monetary Fund—World Economic and Financial Surveys, 2008).

The data used for the U.S. and Mexican commodity markets are U.S. total value of agricultural output (U.S. Department of Agriculture, 2008e), U.S. value of agricultural exports and imports (U.S. Department of Agriculture Foreign Agricultural Services, 2008), personal income and food and beverage consumer price index (CPI) (U.S. Department of Commerce Bureau of Economic Analysis, 2008b, c), Mexican total value of agricultural production (Food and Agricultural Organization of the United Nations, 2008a), Mexican value of exports and imports (Food and Agricultural Organization of the United Nations, 2008b), agricultural consumer price index (Banco de Mexico, 2008), and Mexican GDP (International Monetary Fund—World Economic and Financial Surveys, 2008).

The U.S. producer support price (U.S. Department of Agriculture, 2008b–d) is linked to the U.S. producer price by adding the producer subsidy equivalent (PSE) (Organisation for Economic Cooperation and Development, 2011), which is a comprehensive measure of *all* agricultural subsidies. The data collected for other price linkage equations includes the U.S. prices received, U.S. food and beverage consumer price, Mexican producer price, Mexican agricultural consumer price, U.S.-Mexican exchange rate (U.S. Department of Agriculture, 2008f), and Mexican tariff schedule (U.S. Congress, 1993).

The data collected for the wage linkage equations includes the previously discussed

wage data, the probability of an undocumented worker apprehended at the border, the worksite enforcement budget, average employer fine for hiring an undocumented worker, and the probability of an illegal worker being caught domestically. The border apprehension probability is the ratio of the total number of border apprehensions to the total number of undocumented workers attempting to enter the United States (U.S. Department of Homeland Security, 2007a,b). The U.S. Immigration and Customs Enforcement (ICE) provided the worksite enforcement budget. The average fine resulting from worksite raids is the ratio of ICE fines to the total number of criminal arrests and administrative arrests resulting from ICE raids (U.S. Immigration and Customs Enforcement, 2008a,b). The probability of an undocumented worker being caught is calculated using wage linkage equation for the U.S. legal and illegal wage rates. For more information on data and sources, see Luckstead (2008).

### *Estimated Model*

Following the theoretical model, we use the structural specifications for labor and commodity supply and demand, price linkage equations, and equilibrium identities in the estimation of simultaneous equations. The three-stage least squares (3SLS) results of the estimated system of equations are presented in Table 1 and the variable definitions are provided in Table 2. The exogenous variables given in Table 2 are used as instrumental variables because they are exogenous to the model but correlated to the endogenous variables in their respective equations.

The U.S. agricultural labor demand is estimated using the U.S. real legal wage rate, real producer price including subsidies, number of U.S. farms, and a dichotomous variable as explanatory variables. The U.S. agricultural labor supply estimation utilizes the real agricultural wage rate, real manufacturing wage rate, and total non-farm employment as regressors.

The U.S. agricultural commodity demand is estimated as a function of real food and beverage CPI and real personal income as explanatory variables. The explanatory variables for

the U.S. commodity supply are prices received including subsidy and the real wage rate, which are essential determinants of commodity supply, as revealed by the significances of the estimated coefficients.

The U.S. consumer-producer price linkage equation is necessary because, unlike in the theoretical model, the empirical analysis distinguishes producer and consumer prices by accounting for the transportation cost and market margins. As a result, prices received by farmers including subsidies are used in the supply estimation, while the food and beverage price is used in the demand estimation. To estimate the U.S. price linkage equation, the food and beverage CPI is regressed on the supply price.

The U.S. agricultural legal and illegal wage linkage equation illustrates the relationship between these two wage rates by accounting for the probability of unauthorized workers getting caught and fines for employing undocumented workers. Farm employers offer lower wages to undocumented workers because of the risk involved in hiring them, and the wage gap between the agricultural legal and illegal wage rate is captured by this probability and the average employer fine for hiring an undocumented worker. This probability, which is low because raids of illegal workers on the farm are very rare, is computed based on the federal budget allocated for worksite raids and the number of arrests.

The commodity market equilibrium states that U.S. exports to Mexico (U.S. supply minus demand minus net exports to the rest of the world excluding Mexico) are equal to Mexico's imports of U.S. commodities. Mexico's imports from the U.S. equal Mexico's demand plus exports to the rest of the world excluding the United States minus Mexico's supply minus imports from the rest of the world excluding the United States.

The explanatory variables in the Mexican labor demand are the real wage rate, real agricultural producer price index, and real textile producer price index. As highlighted in the theoretical analysis, the wage and agricultural price variables are key determinants of labor demand. Furthermore, labor supply is considered as exogenous because this labor supply

**Table 1.** Empirical Results for the United States and Mexico<sup>a</sup>

<u>US Labor Demand</u>	<u>Mexican Labor Demand</u>
USALD = 194.26 – 61.02USRLWR (0.22) (–2.16)** [–0.41]	MALD = 8316.76 – 18.77MRW (59.92)*** (–5.34)*** [–0.10]
+ 2.50USRPRS + 0.43USF + 90.91D99 (1.93)* (1.40) (2.48)** [0.30]	+ 0.39MRAPPI + 10.32MRTTPI (0.23) (5.96)*** [0.004] [0.13]
<u>US Labor Supply</u>	<u>Mexican Agricultural Demand</u>
USALS = 1387.47 + 96.88USRLWR (6.99)** (3.51)*** [1.12]	MRVDAP = 1227.66 – 17.87MACPI (23.24)*** (–9.24)*** [–2.46]
– 54.52USRMW – 6.35USTNFE (–3.59)*** (–2.44)*** [–1.16]	+ 0.13 MGD (5.38)*** [1.09]
<u>US Agricultural Demand</u>	<u>Mexican Agricultural Supply</u>
USRVDP = 200.11 – 0.49USRFBCPI (1.35) (–0.48) [–0.43]	MRVAP = 375.97 + 0.77LMRVAP (1.69) (18.18)***
+ 0.01USRPI (2.69)** [0.37]	+ 2.05MRAPPI – 1.97MW – 4.87MRMPPI (1.80)* (–1.57) (–2.97)*** [0.40] [–0.11]
<u>US Agricultural Supply</u>	<u>Mexican Producer and Consumer Price Linkage</u>
USRVAP = 79.35 + 1.30USNPRS (3.98)*** (7.37)*** [0.80]	MRAPPI = 21.74 + 0.72MRACPI (1.79)* (6.54)***
– 4.86USRLWR (–2.00)** [–0.16]	
<u>US Net Exports to the Rest of the World</u>	<u>Mexican and US Price Linkage Identity</u>
USNEROW = 37.75 – 0.14USRFBCPI	MRACPI = USRFBCPI(ER) (1 + T) + TC
<u>US Consumer and Producer Price Linkage</u>	<u>Mexican Wage and US Illegal Wage Linkage Identity</u>
USRFBCPI = 139.70 + 0.25USPR (20.04)** (3.78)*	MRW = (1 – 0.61)(1 – 0.21)USRIWR + 0.61(1 – 0.21)MRW
	MRW = 0.59USRIWR
<u>US Real Legal and Illegal Wage Rate Identity<sup>b</sup></u>	<u>Labor Market Equilibrium</u>
USRLWR = USRIWR + 0.0003(6072.87)	USALD – USALS = $\psi$ (MALS – MALD)
<u>Commodity Market Equilibrium</u>	
USRVAP – USRVDP – USNEROW = (ER) MRVDAP + MREREUS – (ER)MRVAP – MRIREUS	

<sup>a</sup> Values in parentheses are t-ratios and values in brackets are elasticities.

<sup>b</sup> As in Equation (6)  $\beta(E) = 0.0003$  and  $c = 6072.87$ .

\* Significant at 10% level; \*\*Significant at 5% level; and \*\*\*Significant at 1% level.

Note: Variables are defined in Table 2.

includes not only Mexican workers attempting to enter the United States but also workers from Latin American countries trekking through Mexico to illegally enter the United States.

The Mexican agricultural commodity demand is estimated as a function of the agricultural CPI and GDP. The regressors for the

Mexican agricultural commodity supply are the lagged dependent variable, agricultural producer price index, wage rate, and manufacturing producer price index as a proxy for input prices. Production in a given year is highly dependent on the level of the last year's production because of the inflexibility in switching the crop pattern in

**Table 2.** Variable Definitions

Name	Description	Unit
<b>Endogenous</b>		
USALD	U.S. July Farm Employment	(1000s)
USRLWR	U.S. Real Legal Wage Rate	(\$/hr)
USRPRS	Real Price Received by Farmers including the PSE	(index \$)
USALS	U.S. July Legal Farm Employment	(1000s)
USRVDA	U.S. Real Value of Agricultural Products Demand	(bil. \$)
USRFBCPI	U.S. Real Food and Beverage CPI	(index \$)
USRVAP	U.S. Real Value of Agricultural Production	(bil. \$)
USNPRS	U.S. Nominal Price Received by Farmers Including PSE	(index \$)
USPR	U.S. Price Received Excluding PSE	(index \$)
USRIWR	U.S. Real Illegal Wage Rate	(\$/hr)
MALD	Mexican Total Employment in Agriculture	(1000s)
MRW	Mexican Real Wage Rate	(NP/hr) <sup>a</sup>
MRAPPI	Mexican Real Agricultural PPI	(index NP)
MRVDAP	Mexican Real Value of Agricultural Commodity Demand	(bil. NP)
MACPI	Mexican Agricultural CPI	(index NP)
MRVAP	Mexican Real Value of Agricultural Production	(bil. NP)
LMRVAP	Lagged Mexican Real Value of Agricultural Production	(bil. NP)
MW	Mexican Nominal Wage Rate	(NP/hr)
MRACPI	Mexican Real Agricultural CPI	(index NP)
<b>Exogenous</b>		
USF	Number of Farms in the United States	(1000s)
D99	Binary Variable for the year 1999	
USRMW	U.S. Real Manufacturing Wage	(\$/hr)
USTNFE	Total Non-Farm Employment	(1000s)
USRPI	U.S. Real Personal Income	(bil. \$)
MRTPI	Mexican Real Textile PPI	(index NP)
MGDP	Mexican GDP	(bil. NP)
MRMPPI	Mexican Real Manufacturing PPI	(index NP)
<b>Policy/Other</b>		
T	Mexican Tariff Rate	(percent)
TC	Transportation Costs	(NP)
MALS	Mexican Agricultural Labor Supply	(1000s)
USNEROW	U.S. Net Exports to the Rest of the World Excluding Mexico	(bil. \$)
ER	Exchange Rate between the United States and Mexico	(NP/\$)
MREREUS	Mexican Real Exports to the Rest of the World Excluding U.S.	(bil. NP)
MRIREUS	Mexican Real Imports from the Rest of the World Excluding U.S.	(bil. NP)

<sup>a</sup> New Pesos.

developing countries such as Mexico. Because of this inflexibility, the lagged dependent variable is included in the estimation.

The linkage equation for Mexican producer-consumer prices is necessary to account for the domestic transportation cost and market margins. The Mexican-U.S. price linkage equation is constructed to show the relationship between the Mexican and U.S. agricultural CPI after taking into account the exchange rate, ad valorem

tariff imposed by Mexico, and transportation cost between the countries. The ad valorem tariff is included in the price linkage identity, which is part of the simultaneous equation estimation. Because NAFTA calls for phasing out of tariffs, we can examine the effect of tariffs on commodity trade and labor migration.

The relationship between the Mexican wage rate and U.S. illegal wage rate, as captured in Equation (9a), is established from the data by

computing the probability of getting apprehended (0.61) and time wasted during the migration (0.21). Then, by applying Equation (9b), the value of the porosity coefficient ( $\psi$ ) is computed to be  $-0.59$ .

The estimated coefficients for the explanatory variables have the appropriate signs and are consistent with the theoretical specifications. Most of the variables are significant at a 1, 5, or 10% level indicating that the standard errors for these variables are statistically acceptable. The t-ratios for the estimated coefficients are provided in the parentheses, and the elasticity estimates are given in brackets in Table 1. The system-weighted R-square from the 3SLS is 0.97, which supports the validity of the model. See Luckstead (2008) for additional information on the estimation.

### *Simulation Results*

In this subsection, we use the estimated equations to simulate the effects of changes in the tariffs and subsidies on the endogenous variables for the *ex post* simulation over the period 1994–2007. Using the historical values of the exogenous variables, a benchmark simulation is run. Two alternate scenarios are simulated to analyze the impact of a) NAFTA and b) U.S. farm policy. Comparisons of the results of the alternate and benchmark scenarios provide the effects of these policies. Due to the strong interrelationships in the model, the repercussions of changes in the tariff or subsidy rate reverberate through both the labor and commodity markets in both countries. The model solves for the endogenous variables: U.S. and Mexican commodity demand and supply, prices received by U.S. and Mexican producers, prices paid by consumers, U.S. labor supply and demand, Mexican labor demand, U.S. illegal wage rate, U.S. legal wage rate, Mexican wage rate, and labor and trade flows.

**NAFTA Effect.** The baseline incorporates the reduction of the tariff rate from 71% in 1994 to 0% in 2007, as phased out under NAFTA. In the alternate scenario, the tariff was reduced linearly from 71% at the beginning of the simulation period to 36% in 2004, resembling the Uruguay Round tariff

schedule fairly closely for developing countries, and from 36% in 2004–10% in 2007. Thus, the alternate scenario predicts the effects on the endogenous variables if the tariffs were not cut as deeply as that under NAFTA. It should be noted that the theoretical analysis examines a reduction in tariffs as in NAFTA, but the simulation analysis compares the results of higher tariffs under the alternate scenario to lower NAFTA tariffs under baseline, i.e., the reverse of the theoretical analysis. The simulation results, presented in Table 3, are consistent with the theoretical predictions. Specifically, the higher tariff under the alternate scenario leads to a decrease in Mexico's excess demand, causing U.S. exports to Mexico to decrease, as shown in the theoretical analysis. The simulation results show the net change in trade for 1994 is \$  $-0.29$  billion, which is further exacerbated to \$  $-17.10$  billion by the end of the NAFTA period. The reduction in exports causes U.S. commodity price (food and beverage CPI) to decrease from  $-0.03\%$  in 1994 to  $-1.50\%$  in 2007. In response to lower market prices, the U.S. producer price also falls. Because of this lower price, U.S. commodity supply decreases and demand increases. As imports are restricted by Mexico, the commodity price in Mexico increases, which causes supply to rise and demand to fall. In response to higher trade barriers and lower imports by Mexico in the alternate scenario, U.S. diverts its exports to the rest of the world.

As a result of the higher tariff in the alternate scenario, the U.S. producer prices decline and U.S. farmers curtail their production, leading to lower demand for farm workers. As shown in Table 3, the U.S. labor demand decreases range from  $-0.04\%$  in 1994 to  $-1.70\%$  in 2007. This decreases the legal farm wage rate and the illegal wage rate for immigrant workers. The illegal wage rate decreases range from  $-0.06\%$  in 1994 to  $-1.83\%$  in 2007. In response to this lower illegal wage rate, fewer illegal immigrants enter the United States because of the reduced pull effect. Furthermore, as the Mexican farm price rises in response to larger trade barriers in the alternate scenario,

Table 3. Effects of NAFTA on the U.S. and Mexican Agricultural and Labor Markets

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
U.S. Ag. Demand (bil. \$)	161.93	168.09	178.46	185.63	182.73	176.37	184.15	193.90	189.77	202.92	222.42	232.95	234.30	265.73
Impact (%)	0.02	0.04	0.07	0.10	0.14	0.20	0.24	0.29	0.35	0.40	0.43	0.48	0.56	0.56
U.S. Ag. Supply (bil. \$)	182.35	198.43	206.57	206.63	201.44	188.59	195.94	208.98	203.20	219.40	235.96	237.05	242.19	287.35
Impact (%)	-0.14	-0.32	-0.57	-0.89	-1.27	-1.86	-2.33	-2.69	-3.35	-3.72	-4.14	-4.80	-5.50	-5.29
Mexican Ag. Demand (bil. NP)	216.26	232.15	235.76	240.52	244.96	254.01	250.53	263.01	267.78	276.82	285.17	277.65	274.03	285.39
Impact (%)	-0.10	-0.65	-1.96	-3.71	-6.66	-10.86	-15.61	-18.88	-24.26	-33.59	-43.24	-51.38	-61.34	-68.06
Mexican Ag. Supply (bil. NP)	210.14	219.67	223.99	234.59	226.47	244.04	249.66	257.75	255.31	256.39	245.92	276.57	264.58	271.91
Impact (%)	0.03	0.15	0.34	0.54	0.88	1.21	1.50	1.74	2.15	2.83	3.64	3.56	4.20	4.58
U.S. Food CPI (index)	146.85	147.63	151.97	159.05	159.37	165.17	169.29	174.65	178.25	180.41	185.68	189.29	196.28	201.31
Impact (%)	-0.03	-0.09	-0.16	-0.23	-0.32	-0.43	-0.54	-0.64	-0.76	-0.90	-1.05	-1.20	-1.35	-1.50
U.S. Price Received (index)	103.29	103.51	110.15	107.52	103.43	92.90	95.05	100.18	97.34	110.10	116.41	112.62	115.73	134.87
Impact (%)	-0.22	-0.54	-0.93	-1.46	-2.08	-3.13	-3.89	-4.45	-5.45	-5.64	-6.20	-7.22	-7.95	-7.57
Mexican Ag. CPI (index)	30.48	39.83	56.45	69.29	77.56	89.65	92.96	97.16	101.88	106.76	114.07	119.36	126.65	130.55
Impact (%)	0.15	0.55	0.91	1.21	1.72	2.19	2.66	3.06	3.57	4.49	5.19	5.44	5.79	6.28
Mexican PPI (index)	30.12	37.25	51.87	63.11	71.09	82.10	82.17	90.74	92.59	97.72	108.02	113.23	119.70	123.43
Impact (%)	0.11	0.42	0.72	0.97	1.36	1.73	2.19	2.37	2.85	3.56	3.97	4.16	4.44	4.82
U.S. Net Exports to ROW (bil. \$)	15.78	25.62	24.01	19.02	14.60	10.42	10.58	12.70	10.76	13.35	9.34	3.20	5.51	17.68
Impact (%)	0.04	0.07	0.13	0.27	0.48	0.92	1.18	1.21	1.73	1.67	2.85	9.70	6.57	2.34
Net Exports to Mex. (bil. \$)	4.64	4.72	4.09	1.98	4.11	1.80	1.21	2.38	2.67	3.13	4.21	0.90	2.37	3.94
Impact (%)	-0.29	-0.71	-1.32	-2.07	-2.87	-3.95	-5.13	-6.33	-7.67	-9.19	-11.00	-12.81	-14.98	-17.10
U.S. Labor Demand (1000s)	1095.90	1062.68	1015.18	1086.94	1058.47	1095.01	1036.01	1019.41	975.14	967.90	966.38	942.79	884.78	841.28
Impact (%)	-0.04	-0.10	-0.18	-0.26	-0.36	-0.46	-0.60	-0.72	-0.88	-1.01	-1.15	-1.28	-1.49	-1.70
U.S. Labor Supply (1000s)	658.37	646.74	571.27	542.21	562.44	570.37	514.67	480.17	474.07	467.69	494.81	466.28	410.14	399.45
Impact (%)	-0.05	-0.12	-0.24	-0.39	-0.50	-0.67	-0.93	-1.18	-1.40	-1.62	-1.73	-2.02	-2.52	-2.80
Mexican Labor Demand (1000s)	8650.46	8634.45	8653.15	8648.83	8615.21	8571.25	8630.80	8612.62	8623.00	8586.92	8576.75	8537.29	8470.13	8518.32

Table 3. Continued.

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Impact (%)	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04
U.S. Legal Wage Rate (\$)	5.62	5.96	5.69	5.89	6.53	7.11	7.64	7.17	7.43	7.75	8.05	8.27	8.79	9.17
Impact (%)	-0.06	-0.12	-0.23	-0.35	-0.43	-0.54	-0.65	-0.83	-0.96	-1.08	-1.20	-1.33	-1.42	-1.51
U.S. Illegal Wage Rate (\$)	5.51	5.84	5.56	5.74	6.36	6.63	6.93	6.89	7.06	7.25	7.39	7.37	7.58	7.56
Impact (%)	-0.06	-0.13	-0.24	-0.36	-0.44	-0.58	-0.71	-0.87	-1.01	-1.15	-1.31	-1.49	-1.64	-1.83
Mexican Wage Rate (NP)	14.18	17.08	22.29	24.99	30.66	32.61	35.95	38.12	40.17	42.07	43.70	45.33	47.31	48.95
Impact (%)	-0.01	-0.01	-0.02	-0.04	-0.05	-0.07	-0.09	-0.10	-0.11	-0.13	-0.15	-0.17	-0.18	-0.19
Illegal Immigration (1000s)	437.53	415.93	443.91	544.73	496.03	524.64	521.34	539.24	501.07	500.21	471.57	476.51	474.64	441.83
Impact (%)	-0.02	-0.06	-0.11	-0.13	-0.19	-0.23	-0.28	-0.31	-0.38	-0.44	-0.53	-0.56	-0.60	-0.70

agricultural production and labor demand increase in Mexico. The empirical results show Mexico's labor demand increases marginally by the end of the NAFTA period, which further contracts the emigration out of Mexico because of the reduced push effect. Thus, because of the higher tariff under the alternate scenario, undocumented workers in U.S. agriculture fall by about 3,092 laborers in 2007.

These results show that NAFTA actually enhanced illegal entry, rather than reducing it as predicted by the NAFTA proponents. The rationale for this contradictory result is that NAFTA does not achieve complete free trade because farm subsidies are not covered in the agreement, which is the topic of discussion next.

*Subsidy Effect.* The baseline scenario for the U.S. farm subsidy analysis is simulated using the historical farm support as measured by the PSE. In the alternate scenario, the subsidy is phased out linearly by 7.14% per year from 1994–2007. Comparing the alternate scenario to the baseline offers insight into the impacts of lowering the farm supports. Again, it should be observed that the simulation analysis examines the effects of phasing out the farm subsidy, which is the reverse of the theoretical analysis that investigates the effect of a higher subsidy. The subsidy reduction causes the U.S. commodity supply to decline by an average of about 2.0% per year and contracts the U.S. exports to Mexico by an average of \$3.42 billion over the simulation period (Table 4). The U.S. exports to the rest of the world also decline by an average of about 4%. The reduced U.S. supply and lower exports result in higher consumer/market prices both in the United States and in Mexico. The U.S. market price increases by an average of about 0.8%. As the market price increases, the price received by farmers from the open market also increases. Because of the higher consumer price, commodity demand declines in both countries.

The decline in the U.S. commodity supply leads to lower demand for labor, which causes both the U.S. legal and illegal wage rates to fall. The illegal wage rate declines by an average of 0.65%. As a result of this wage decline, the flow of illegal immigrants to U.S. agriculture falls by an average of 1,352 illegal immigrants

**Table 4.** Effects of U.S. Farm Subsidy on the U.S. and Mexican Agricultural and Labor Markets

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
U.S. Ag. Demand (bil. \$)	161.93	168.09	178.46	185.63	182.73	176.37	184.15	193.90	189.77	202.92	222.42	232.95	234.30	265.73
Impact (%)	-0.05	-0.07	-0.13	-0.16	-0.33	-0.47	-0.48	-0.51	-0.49	-0.42	-0.46	-0.47	-0.39	-0.33
U.S. Ag. Supply (bil. \$)	182.35	198.43	206.57	206.63	201.44	188.59	195.94	208.98	203.20	219.40	235.96	237.05	242.19	287.35
Impact (%)	-0.16	-0.24	-0.50	-0.74	-1.59	-2.55	-2.78	-2.92	-2.91	-2.51	-2.89	-3.09	-2.51	-2.01
Mexican Ag. Demand (bil. NP)	216.26	232.15	235.76	240.52	244.96	254.01	250.53	263.01	267.78	276.82	285.17	277.65	274.03	285.39
Impact (%)	-0.07	-0.29	-1.11	-2.03	-5.66	-10.28	-13.10	-14.41	-14.90	-16.20	-21.68	-23.74	-20.11	-18.52
Mexican Ag. Supply (bil. NP)	210.14	219.67	223.99	234.59	226.47	244.04	249.66	257.75	255.31	256.39	245.92	276.57	264.58	271.91
Impact (%)	0.02	0.07	0.20	0.30	0.76	1.15	1.26	1.34	1.33	1.37	1.84	1.66	1.39	1.26
U.S. Food CPI (index)	146.85	147.63	151.97	159.05	159.37	165.17	169.29	174.65	178.25	180.41	185.68	189.29	196.28	201.31
Impact (%)	0.12	0.16	0.30	0.39	0.76	1.02	1.07	1.14	1.06	0.95	1.12	1.17	0.93	0.88
U.S. Price Received (index)	103.29	103.51	110.15	107.52	103.43	92.90	95.05	100.18	97.34	110.10	116.41	112.62	115.73	134.87
Impact (%)	0.75	1.01	1.79	2.44	4.91	7.51	7.70	7.88	7.57	5.93	6.61	7.03	5.51	4.43
Mexican Ag. CPI (index)	30.48	39.83	56.45	69.29	77.56	89.65	92.96	97.16	101.88	106.76	114.07	119.36	126.65	130.55
Impact (%)	0.10	0.25	0.52	0.66	1.46	2.07	2.24	2.33	2.19	2.17	2.60	2.51	1.90	1.71
Mexican PPI (index)	30.12	37.25	51.87	63.11	71.09	82.10	82.17	90.74	92.59	97.72	108.02	113.23	119.70	123.43
Impact (%)	0.07	0.19	0.41	0.53	1.16	1.64	1.83	1.81	1.75	1.72	1.99	1.92	1.45	1.31
U.S. Net Exports to ROW (bil. \$)	15.78	25.62	24.01	19.02	14.60	10.42	10.58	12.70	10.76	13.35	9.34	3.20	5.51	17.68
Impact (%)	-0.15	-0.13	-0.26	-0.44	-1.13	-2.21	-2.34	-2.15	-2.41	-1.76	-3.04	-9.45	-4.55	-1.37
Net Exports to Mex. (bil. \$)	4.64	4.72	4.09	1.98	4.11	1.80	1.21	2.38	2.67	3.13	4.21	0.90	2.37	3.94
Impact (%)	-0.19	-0.32	-0.75	-1.14	-2.44	-3.74	-4.31	-4.84	-4.71	-4.43	-5.52	-5.92	-4.91	-4.66
U.S. Labor Demand (1000s)	1095.90	1062.68	1015.18	1086.94	1058.47	1095.01	1036.01	1019.41	975.14	967.90	966.38	942.79	884.78	841.28
Impact (%)	-0.04	-0.07	-0.16	-0.21	-0.44	-0.62	-0.71	-0.77	-0.75	-0.68	-0.79	-0.81	-0.67	-0.64
U.S. Labor Supply (1000s)	658.37	646.74	571.27	542.21	562.44	570.37	514.67	480.17	474.07	467.69	494.81	466.28	410.14	399.45
Impact (%)	-0.06	-0.09	-0.22	-0.33	-0.66	-0.95	-1.14	-1.31	-1.25	-1.13	-1.25	-1.33	-1.18	-1.09
Mexican Labor Demand (1000s)	8650.46	8634.45	8653.15	8648.83	8615.21	8571.25	8630.80	8612.62	8623.00	8586.92	8576.75	8537.29	8470.13	8518.32

**Table 4.** Continued.

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Impact (%)	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01
U.S. Legal Wage Rate (\$)	5.62	5.96	5.69	5.89	6.53	7.11	7.64	7.17	7.43	7.75	8.05	8.27	8.79	9.17
Impact (%)	-0.07	-0.10	-0.22	-0.30	-0.56	-0.77	-0.80	-0.93	-0.86	-0.75	-0.86	-0.88	-0.66	-0.59
U.S. Illegal Wage Rate (\$)	5.51	5.84	5.56	5.74	6.36	6.63	6.93	6.89	7.06	7.25	7.39	7.37	7.58	7.56
Impact (%)	-0.07	-0.10	-0.22	-0.31	-0.58	-0.82	-0.88	-0.96	-0.90	-0.80	-0.94	-0.98	-0.77	-0.71
Mexican Wage Rate (NP)	14.18	17.08	22.29	24.99	30.66	32.61	35.95	38.12	40.17	42.07	43.70	45.33	47.31	48.95
Impact (%)	-0.01	-0.01	-0.02	-0.03	-0.06	-0.10	-0.11	-0.11	-0.10	-0.09	-0.11	-0.11	-0.08	-0.07
Illegal Immigration (1000s)	437.53	415.93	443.91	544.73	496.03	524.64	521.34	539.24	501.07	500.21	471.57	476.51	474.64	441.83
Impact (%)	-0.02	-0.04	-0.08	-0.09	-0.20	-0.27	-0.28	-0.29	-0.28	-0.25	-0.32	-0.31	-0.24	-0.23

over the period 2000–2007. This effect on illegal labor flow is relatively small because of the inelastic demand for farm labor. As the Mexican supply price increases, production and farm employment increase.

The empirical results corroborate the theoretical findings that a reduction in the U.S. farm subsidy leads to less saturation of Mexican markets with U.S. exports. Consequently, the Mexican commodity price is not depressed and Mexican farmers continue to produce and effectively compete with U.S. exports. As a result, farmers are not displaced and fewer Mexicans tend to migrate to the United States. Furthermore, the impacts of the NAFTA and farm subsidy scenarios indicate that liberalizing agricultural trade without phasing out the U.S. farm subsidy hurts Mexican farmers.

## Conclusions

Given the importance of immigrant workers to U.S. agriculture, this study investigates the effects of NAFTA and U.S. farm policy on immigrant flow and agricultural trade. We develop a model of the United States and Mexico that is vertically integrated through employment and commodity production and horizontally integrated through agricultural trade and cross-border migration to analyze the effects of NAFTA and farm policies on illegal immigration and commodity trade. The results of the theoretical analysis show that trade liberalization and greater farm supports increase commodity trade and intensify the illegal labor flow. The empirical model implements the theoretical analysis by structurally estimating the agricultural commodity and labor markets in the United States and Mexico. The empirical analysis also incorporates U.S. exports to the rest of the world. Using the estimated equations, a dynamic simulation analyzes the effects of NAFTA and U.S. farm policies. The results of the simulation analysis are consistent with the theoretical findings. Specifically, trade liberalization under NAFTA increases the illegal labor flow to U.S. agriculture by about 3,092 laborers and increases commodity trade by \$17.10 billion by the end of NAFTA. In contrast, a decrease in subsidies paid to agricultural

producers contracts the illegal labor flow to U.S. agriculture by an average of about 1,352 workers and commodity trade by \$3.42 billion over the simulation period. The elimination of U.S. farm supports will allow free trade to benefit Mexico's farm sector, resulting in lower unemployment and higher income for Mexican farmers, decreasing the incentives for illegal immigration.

Further research in this area could consider disaggregating the agricultural sector into labor-intensive (fruits and vegetables) and capital-intensive (grains) sectors. This will capture the impact of NAFTA and farm policies on illegal immigrants entering into these sectors.

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