Analysis of the Effects of Reduced Domestic Farm Employment on Food Prices

December 17, 2025

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Abstract

Agriculture in the United States (US) has long relied on a large, flexible labor force, driven in part by decades of migration from Mexico that supported the harvest of hundreds of labor-intensive crops. However, the labor market is undergoing significant change. Declining migration, an aging workforce, and rising labor demand have created persistent labor shortages that producers consistently identify as one of the most pressing challenges facing the industry. In response, many employers have turned to the rapidly expanding H-2A temporary agricultural worker program, yet its high costs, administrative complexity, and seasonal restrictions limit its effectiveness as a comprehensive solution. Tightening labor supplies have contributed to rising farm wages, higher production costs, and upward pressure on US food prices. In this study, I develop an Equilibrium Displacement Model linking the domestic farm labor market to labor-intensive agricultural output markets. The Equilibrium Displacement Model uses information from existing studies to parameterize an equation that relates domestic food prices to changes in domestic farm employment. The results from the model indicate that a 10% reduction in domestic farm employment causes a 2.94% increase in domestic food prices. According to US Congress, the farm gate value of labor-intensive specialty crops is worth about $115 billion annually (Neuhofer, 2025). Therefore, a 10% decrease in domestic farm employment translates to $3.4 billion in additional costs for consumers.

1 Introduction

Farmers across the United States produce hundreds of labor-intensive crops, and the majority of workers who harvest these crops were born outside the country. For decades, Mexico's geographic proximity and more limited economic opportunities supported a steady flow of migrants to the United States, many of whom found work on farms. This long-term migration helped US agriculture maintain a large, flexible labor pool and expand production to meet growing demand for fresh food.

In recent years, however, the structure of US farm labor markets has shifted. Reduced migration, an aging workforce, and rising labor demand have contributed to persistent labor shortages, creating new challenges for producers. Industry groups consistently identify labor scarcity as one of the most urgent issues facing American agriculture. Despite growing concern among producers, policy solutions have been slow to materialize. Many employers are increasingly turning to the H-2A temporary agricultural visa program to offset declining domestic labor availability. While the program has expanded rapidly, it remains costly, complex to administer, and limited to seasonal positions. Growers also cite ongoing challenges related to mandated wage rates and regulatory requirements.

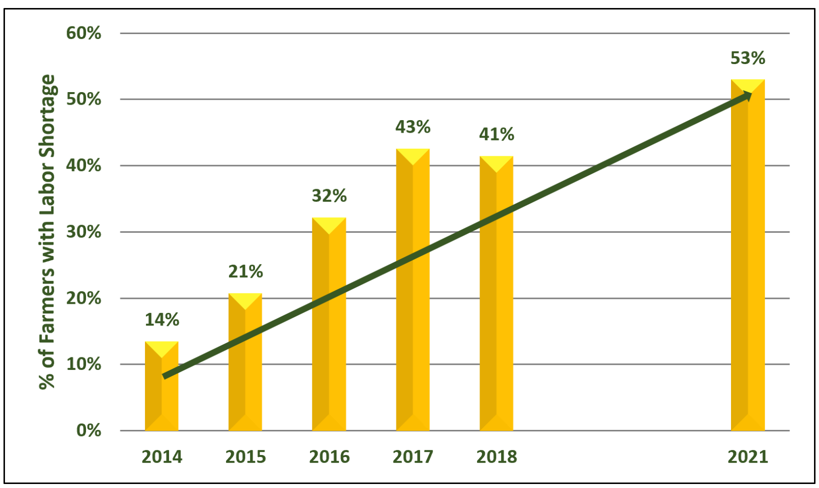
As labor supplies tighten, farm wages continue to rise, constraining growth opportunities, and putting upward pressure on food prices in the US. Additionally, labor scarcity creates greater dependence on imports, which carries additional risks for the United States, including increased exposure to food safety issues, higher transportation-related emissions, and reduced control over food quality. These trends also heighten concerns about the resilience of the domestic food supply in the face of future disruptions.

The US fresh produce industry is approaching a pivotal moment. Without meaningful labor-focused policy reforms, labor-intensive agricultural production will likely continue to face growing labor costs, narrowing the diversity of American agriculture and increasing vulnerability to supply chain shocks. The decisions made today will influence not only the competitiveness of US producers but also broader national security considerations. In this study, I quantify the extent to which reduced farm employment affects the prices of labor-intensive agricultural goods in the US.

2 Background on Farm Labor Shortages in the United States

Surveys conducted by researchers at the University of California, Davis and Michigan State University show a dramatic increase in the share of farmers reporting labor shortages—from just 14% in 2014 to 41% in 2018 (Figure 1; Rutledge and Taylor, 2024). During the COVID-19 pandemic, this figure climbed even higher, with 53% of growers reporting they could not find enough workers (Rutledge et al., 2022, 2024a,b). On average, farmers indicated they were unable to hire roughly 21% of the labor force they needed under normal operating conditions (Figure 2).

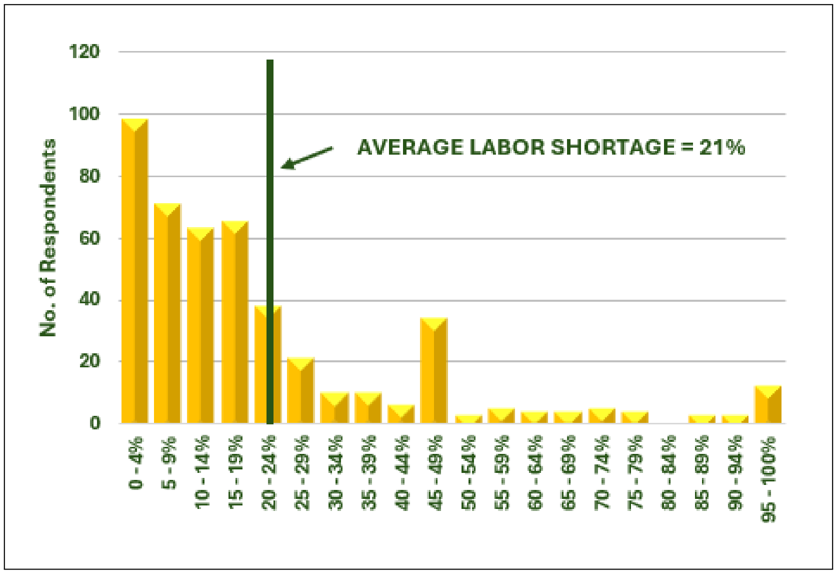
Figure 1: Prevalence of Domestic Farm Labor Shortages



Farm labor shortages pose a direct threat to the reliability of the domestic food supply—an issue that goes beyond agriculture and into national security. As US production capacity becomes increasingly constrained, the nation grows more dependent on foreign suppliers, reducing strategic autonomy and weakening America's geopolitical position. A country that cannot reliably produce the food it consumes is more vulnerable during periods of global instability.

Rising labor scarcity also drives up wages and forces producers to adjust production systems, scale back acreage, or change employment strategies. Without meaningful policy action, the US risks further erosion of its domestic specialty crop sector. Greater reliance on foreign suppliers for essential, healthy foods exposes the nation to avoidable supply

Figure 2: Farm Labor Shortage Intensity



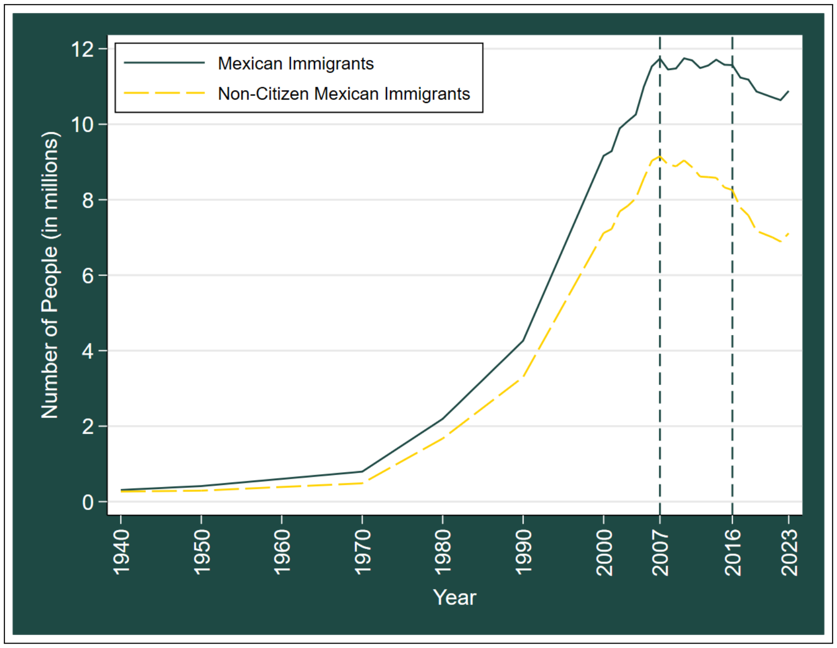
chain vulnerabilities, particularly during emergencies such as pandemics, natural disasters, or geopolitical conflict.

The US crop farm workforce is predominantly immigrant, with most workers originating from Mexico. According to the National Agricultural Workers Survey (NAWS), about 70% of crop workers were born outside the United States, and roughly 90% of these individuals are from Mexico. Additionally, about 40% of the workforce lacks legal authorization to work in the country. This heavy reliance on immigrant labor leaves agriculture highly sensitive to immigration enforcement actions, shifts in other industries that employ immigrant workers, and broader demographic or economic trends.

Figure 3 illustrates long-term changes in the Mexican-born population living in the United States. The number grew from under 1 million in 1940 to nearly 12 million at the onset of the Great Recession. Since 2016, however, that population has been declining. The number of non-citizen Mexican immigrants—historically a core source of US farm labor—has fallen steadily from its peak of about 9 million and continues downward. A shrinking Mexican immigrant population translates into fewer workers available for US farms at a time when growers need more labor, not less.

Compounding the issue, agriculture is losing workers to competing industries such as construction and food service. These competitive pressures further strain the supply of available farm labor. Before 2000, many Mexican-born farmworkers engaged in "follow-the-crop" migration, moving throughout the country to meet seasonal harvest demand. Since then, these workers have become more settled geographically and less likely to travel for harvest jobs (Fan et al., 2015). As a result, farm labor markets have become more localized, with fewer workers willing to move to where labor is needed, intensifying shortages in key production regions.

Figure 3: US Mexican Population



3 Declining Farm Employment and Food Prices

To analyze the impacts of declining domestic farm employment on the prices of labor-intensive agricultural goods, I develop an Equilibrium Displacement Model (EDM) linking the domestic farm labor market to labor-intensive agricultural output markets. EDMs provide a straightforward way to estimate the short-run effects of economic shocks on prices and quantities. Because they are transparent and relatively easy to interpret, EDMs are especially useful for policy discussions: they allow industry stakeholders to see how a specific disruption—such as a tightening farm labor supply—translates into changes in market conditions, including prices. Using this approach, I identify how reductions in domestic farm employment affect the prices of labor-intensive agricultural products in the US, offering clear insights for agricultural stakeholders concerned about supply chain stability.

Technical details about the EDM model and derivations are presented in Appendix A, but the procedure essentially involves setting up a system of equations that characterize equilibria in the farm labor market and the labor-intensive agricultural markets and solving the system of equations in a manner that allows the researcher to derive an expression that relates changes in food prices to changes in employment. When labor supply shocks reduce domestic employment, the supply of domestically-produced agricultural products declines, which puts upward pressure on food prices. Once the derivations are complete, the researcher utilizes parameter information from existing studies to generate numerical values that quantify the effects of interest. In specifying the distributions for the structural parameters for the simulation analysis, I drew on the strongest available evidence to establish plausible ranges and central tendencies for the model's parameters. The analysis essentially produces a measure of the elasticity of labor-intensive crop prices with respect to employment, which measures the percentage change in prices as a result of a percentage change in domestic farm employment. The effect of a decline in domestic employment on the prices of labor-intensive agricultural commodities is expressed mathematically in elasticity terms as follows:

$$-\frac{\partial \ln P^U}{\partial \ln L} = \frac{-k_L k_U(e_K + \sigma)}{(\eta - e_M k_M)(e_K k_L + e_L k_K + \sigma) - k_U[e_K e_L + \sigma(e_K k_K + e_L k_L)]} > 0. \quad (1)$$

Descriptions of the parameters can be found in Table 1. Equation (1) identifies the percentage change in domestic food prices with respect to a percentage decrease in domestic farm employment.

Table 1: Structural Parameter Definitions

$\eta=$	US demand elasticity for specialty crops	$k_M=$	Import share of US demand
$k_L=$	Domestic labor production cost share	$e_L=$	US farm labor supply elasticity
$k_K=$	Capital production cost share	$e_K=$	Capital supply elasticity
$\sigma=$	US input substitution elasticity	$e_M=$	Import supply elasticity
$k_U=$	US production share of US demand		

Next, I parameterize equation (1) with distributions of values obtained from existing studies and simulate the effects 100,000 times. From the set of 100,000 simulations, I identify the mean, median, 95% confidence intervals, and the p-values to determine whether the simulated effects are statistically significant.

4 Results

Table 2 shows summary statistics from the simulation exercise. Of primary importance is the column that refers to the "Mean" of the 100,000 simulations. My analysis indicates that the mean of the simulated effects is a statistically significant 0.249, which means that when domestic farm employment declines by 10%, labor-intensive food prices increase by an average of 2.94%. According to the US Congress, labor-intensive specialty crops generate roughly \$115 billion in farm-gate value annually (Neuhofer, 2025). Consequently, a 10% reduction in domestic farm employment would result in an estimated \$3.4 billion in additional costs to consumers.

Table 2: Summary Statistics for Estimated Effects

Outcome of Interest	N	Mean	Median	95% C.I.	p-value	S.D.	Kurtosis	Skewness
$-\partial \ln P^U / \partial \ln L$	100,000	0.294**	0.289	(0.124, 0.463)	0.017	0.038	4.11	-0.719

Significance levels are reported for the mean of the simulated effects. 95% confidence intervals and p-values are calculated from Chebychev's Inequality. Specifically, 95% confidence intervals are calculated using the formula $\bar{X} \pm 4.47 \times$ S.D. where $\bar{X}$ denotes the mean and S.D. denotes the standard deviation of the posterior distribution. P-values are calculated using the formula $\frac{1}{k^2}$ where $k = \frac{\bar{X}}{\text{S.D.}}$. p $< .05$ **.

5 Conclusion

Farm labor shortages in the United States are increasingly consequential for the fresh produce sector. A substantial body of evidence shows that the domestic farm labor supply continues to shrink, driving up wages and forcing producers to adjust their operations, scale back acreage, or shift to less labor-intensive crops. At the same time, fruit and vegetable imports have surged to record levels, intensifying competitive pressures. With farm wages in Mexico at roughly 15% of those in the United States, American growers—many of whom pay $25.00 or more per hour for H-2A labor once housing and other requirements are included—face a clear competitive disadvantage relative to producers in foreign countries that pay closer to $2.00 per hour. According to my analysis, a 10% decline in domestic farm employment would lead to an average 2.94% increase in labor-intensive crop prices, which would cause the American food bill to increase by $3.4 billion over the course of a year.

While rising domestic production costs will likely lead to increased imports, rising dependence on foreign suppliers for essential, healthy foods introduces avoidable food-security risks and places the United States at a strategic disadvantage. Sustaining robust domestic production of fresh fruits and vegetables is critical for reducing vulnerability to supply-chain disruptions and geopolitical shocks.

A range of policy options exists to help alleviate the labor shortage and support the long-term viability of labor-intensive agriculture. Some solutions can be pursued at the state level, while others will require federal legislative or regulatory action. Without timely and targeted intervention, the United States risks continued erosion of domestic production capacity in high-value specialty crops. Swift policy action is essential to stabilize the labor market, strengthen the competitiveness of US growers, and prevent further loss of market share to foreign competitors.

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Technical Appendices

A Equilibrium Displacement Model

We consider an aggregate US.producer that supplies a homogeneous bundle of labor-intensive agricultural goods (Q_S^U) using domestic labor (L) and capital (K). The domestic production technology is assumed to be homogeneous of degree one, and all markets operate under perfect competition. Let W denote the domestic wage rate and R the rental rate of capital. Aggregate US demand for the bundle of goods (Q_D^U) is satisfied by domestic output (Q_S^U) together with import supply (Q_S^M). Under these assumptions, domestic demand is modeled as a function of domestic prices (P^U), while import supply depends on prices received by foreign exporters (P^M). We assume all markets clear.

These conditions define an equilibrium represented by nine equations in nine endogenous variables, listed below.[1] Equation (A.1) specifies domestic demand, equation (A.2) defines import supply, and equation (A.3) describes domestic production. Equations (A.4) and (A.5) represent labor and capital supply, while (A.6) and (A.7) are the profit-maximizing conditions. Finally, equations (A.8) and (A.9) impose market-clearing requirements.

$$\begin{aligned}
&\text{Domestic Demand:} && Q_D^U = a(P^U) && \text{(A.1)}\\
&\text{Import Supply:} && Q_S^M = b(P^M) && \text{(A.2)}\\
&\text{Domestic Production:} && Q_S^U = c(L, K) && \text{(A.3)}\\
&\text{Domestic Labor Supply:} && L = d(W) && \text{(A.4)}\\
&\text{Capital Supply:} && K = e(R) && \text{(A.5)}\\
&\text{Profit Maximizing Condition:} && P^U Q_{SL}^U = W && \text{(A.6)}\\
&\text{Profit Maximizing Condition:} && P^U Q_{SK}^U = R && \text{(A.7)}\\
&\text{Market Clearing Condition:} && Q_D^U = Q_S^U + Q_S^M && \text{(A.8)}\\
&\text{Market Clearing Condition:} && P^U = P^M && \text{(A.9)}
\end{aligned}$$

By applying differential calculus and algebraic manipulation to equations (A.1)–(A.9), I obtain equations (A.1′)–(A.9′), which rewrite the system in terms of relative changes, structural parameters, and exogenous shocks to the equilibrium. For any variable X, I adopt the notation $dX^* \equiv d\ln X \approx \frac{\triangle X}{X}$ to represent its relative change.

I introduce three shocks into the equilibrium system. The first is a shift in the domestic farm labor supply curve ($d\ln\alpha$), defined as a horizontal displacement (in percentage terms) from the initial equilibrium wage. The second shock ($d\ln\beta$) captures a horizontal shift (in percentage terms) in aggregate US demand for fruits and vegetables relative to the initial equilibrium price. The third shock ($d\ln\gamma$) represents a horizontal shift (in percentage terms) in import supply relative to the initial price.

The structural parameters used in the model are summarized in Table A.1.

[1] I follow the convention that Q_{SL}^U and Q_{SK}^U denote the marginal products of domestic labor and capital, respectively.

$$dQ_D^{U*} - \eta dP^{U*} = \beta \tag{A.1$'$}$$
$$dQ_S^{M*} - e_M dP^{M*} = \gamma \tag{A.2$'$}$$
$$dQ_S^{U*} - k_L dL^* - k_K dK^* = 0 \tag{A.3$'$}$$
$$dL^* - e_L dW^* = \alpha \tag{A.4$'$}$$
$$dK^* - e_K dR^* = 0 \tag{A.5$'$}$$
$$-dP^{U*} + \frac{k_K}{\sigma} dL^* - \frac{k_K}{\sigma} dK^* + dW^* = 0 \tag{A.6$'$}$$
$$-dP^{U*} - \frac{k_L}{\sigma} dL^* + \frac{k_L}{\sigma} dK^* + dR^* = 0 \tag{A.7$'$}$$
$$dQ_D^{U*} - k_U dQ_S^{U*} - k_M dQ_S^{M*} = 0 \tag{A.8$'$}$$
$$dP^{U*} - dP^{M*} = 0 \tag{A.9$'$}$$

Table A.1: Structural Parameter Definitions

$\eta=$	US demand elasticity for specialty crops	$k_M=$	Import share of US demand
$k_L=$	Domestic labor production cost share	$e_L=$	US farm labor supply elasticity
$k_K=$	Capital production cost share	$e_K=$	Capital supply elasticity
$\sigma=$	US input substitution elasticity	$e_M=$	Import supply elasticity
$k_U=$	US production share of US demand		

The solution for the relative change in US prices $d\ln P^U$ can be found in Equation (A.10), and the solution for the relative change in domestic farm employment $d\ln L$ can be found in Equation (A.11).[2]

$$d\ln P^U = \left[\frac{k_L k_U(e_K+\sigma)}{D}\right] d\ln\alpha - \left[\frac{e_K k_L + e_L k_K + \sigma}{D}\right] d\ln\beta + \left[\frac{k_M(e_K k_L + e_L k_K + \sigma)}{D}\right] d\ln\gamma \tag{A.10}$$

and

$$\begin{aligned} d\ln L = &\left[\frac{\eta(e_K k_L + \sigma) - e_M e_K k_L k_M - \sigma(e_M k_M + e_K k_K k_U)}{D}\right] d\ln\alpha - \left[\frac{e_L(e_K+\sigma)}{D}\right] d\ln\beta \\ &+ \left[\frac{e_L k_M(e_K+\sigma)}{D}\right] d\ln\gamma \end{aligned} \tag{A.11}$$

where

$$D = (\eta - e_M k_M)(e_K k_L + e_L k_K + \sigma) - k_U[e_K e_L + \sigma(e_K k_K + e_L k_L)] < 0.$$

To identify the effects of a change in employment on domestic food prices, I solve equation (A.11) for $d\ln\alpha$, substitute $d\ln\alpha$ into equation (A.10), and rearrange terms to express domestic prices in terms of changes in domestic farm employment. After making this substitution, the effects of a decrease in the domestic farm employment is determined by taking the partial derivative of log prices with respect to log domestic employment and multiplying by negative one as follows:

[2] The full set of solutions for all equilibrium market outcome variables can be found in Appendix C.

$$-\frac{\partial \ln P^U}{\partial \ln L} = \frac{-k_L k_U (e_K + \sigma)}{\eta(e_K k_L + \sigma) - e_M e_K k_L k_M - \sigma(e_M k_M + e_K k_K k_U)} > 0. \tag{A.12}$$

Thus, a decline in domestic employment will cause an increase in the price of labor intensive agricultural goods.

To establish the distributions for the structural parameters used in our simulation analysis, I drew on the best available research to identify credible ranges and central values for the key relationships in our model. For the elasticity of demand for fresh fruits and vegetables (η), I adopted a value of -0.72 based on Huang and Lin (2000), who reported estimates of -0.7186 for fruit and -0.7238 for vegetables. I modeled η using a normal distribution centered at -0.72 with a standard deviation of 0.15, ensuring the draws remain negative in line with economic theory. Under this distribution, values of η range from -1.44 to -0.07.

For the labor cost share of production (k_L), I applied the USDA estimate from Subedi and Giri (2024), assigning a value of 0.38. This parameter is held fixed throughout the analysis. The corresponding capital cost share (k_K) is set to 0.62, consistent with $1.00 - 0.38$. For the input substitution elasticity (σ), I followed Knoblach et al. (2020) and used a normal distribution centered on 0.66 with a standard deviation of 0.10, generating values from 0.26 to 1.08.

I drew on estimates of the capital supply elasticity (e_K) reported by Diamond and Zodrow (2021), who identify a value of roughly two as a reasonable benchmark. Accordingly, I specified a normal distribution for e_K with a mean of 2.00 and a standard deviation of 0.40, allowing values to span from 0.15 to 3.82.

For the domestic labor supply elasticity (e_L), I relied on the comprehensive review by Hill et al. (2021). Focusing on US-based studies, which consistently show that farm labor supply is inelastic, I specified a normal distribution with a mean of 0.53 and a standard deviation of 0.10, producing values ranging from 0.11 to 0.96. Because no empirical estimates were available for the import supply elasticity (e_M), I adopted a normal distribution with a mean of 1.00 and a standard deviation of 0.15, generating values from 0.36 to 1.72.

Using trade data and estimates from USDA Foreign Agricultural Service (2025), I calculated the domestic share of US consumption for hand-harvested fresh fruits and vegetables. Our results indicate that roughly 60% of consumption (by weight) is supplied domestically, while the remaining 40% comes from imports. Table A.2 summarizes the data-driven parameter distributions that inform the simulation outcomes.[3]

[3]Details on the calculations used to obtain k_U and k_M are provided in Appendix B.

Table A.2: Summary Statistics for Parameter Distributions

Parameter	Mean	Median	Min.	Max.	S.D.	Kurtosis	Skewness
η	-0.720	-0.721	-1.438	-0.071	0.150	3.007	-0.003
e_L	0.530	0.530	0.107	0.959	0.100	3.032	0.001
e_K	2.000	2.001	0.145	3.817	0.401	3.013	-0.007
e_M	0.999	1.000	0.356	1.719	0.150	3.012	-0.0135
σ	0.660	0.660	0.258	1.076	0.100	2.975	0.002
k_L	0.380	0.380	0.380	0.380	0.000	.	.
k_K	0.620	0.620	0.620	0.620	0.000	.	.
k_U	0.596	0.596	0.596	0.596	0.000	.	.
k_M	0.404	0.404	0.404	0.404	0.000	.	.
N	100,000	100,000	100,000	100,000	100,000	100,000	100,000

B Calculations for k_U and k_M

To estimate the parameter κ_U, I draw on data from the USDA ERS *Vegetables and Pulses Yearbook* (Davis et al., 2025). According to this source, domestic availability of fresh vegetables in 2023 (excluding melons, potatoes, sweet potatoes, mushrooms, dry peas, and lentils) totaled 50.371 billion pounds. Converting this amount from pounds to metric tons gives:

$$50.371 \times 10^9 \text{ lb} \times 0.45359237 \, \frac{\text{kg}}{\text{lb}} \div 1000 = 22{,}847{,}901 \text{ metric tons.} \tag{B.1}$$

Imported vegetables comprised approximately 35.2% of total consumption.

For fruit, I rely on the USDA ERS *Import Share of Domestic Availability* dataset (fresh, canned, frozen, juice, and dried fruit) (Weber et al., 2025). In 2023, imports accounted for 58.8% of total citrus and non-citrus fruit consumption, and 46.8% when bananas are excluded.

Using import volume figures from USDA Foreign Agricultural Service (2025), I find that the US imported 8,571,448.1 metric tons of fresh fruit (excluding bananas) in 2023. With an import share of 46.8%, implied total consumption of fresh fruit (excluding bananas) is:

$$\frac{8,571,448.1}{0.468} \approx 18,315,060 \text{ metric tons} \tag{B.2}$$

To compute the combined import share for fruits and vegetables, I take a weighted average of the two categories:

$$\begin{aligned} k_M &= \frac{(18{,}315{,}060 \times 0.468) + (22{,}847{,}901 \times 0.352)}{18{,}315{,}060 + 22{,}847{,}901} \\ &= 0.4036, \\ k_U &= 1 - k_M = 0.5964. \end{aligned}$$

Thus, $k_U = 0.5964$ represents the share of labor-intensive agricultural consumption produced domestically in our analysis.

C Reduced-Form Solutions for the Equilibrium Displacement Model

$$
\begin{aligned}
d\ln Q_S^U =& \left[\frac{k_L(\eta - e_M k_M)(e_K + \sigma)}{D}\right] d\ln\alpha - \left[\frac{e_K e_L + \sigma(e_K k_K + e_L k_K)}{D}\right] d\ln\beta \\
&+ \left[\frac{k_M[e_K e_L + \sigma(e_K k_K + e_L k_L)]}{D}\right] d\ln\gamma \qquad \text{(C.1)} \\
d\ln L =& \left[\frac{\eta(e_K k_L + \sigma) - e_M e_K k_L k_M - \sigma(e_M k_M + e_K k_K k_U)}{D}\right] d\ln\alpha - \left[\frac{e_L(e_K + \sigma)}{D}\right] d\ln\beta \\
&+ \left[\frac{e_L k_M(e_K + \sigma)}{D}\right] d\ln\gamma \qquad \text{(C.2)} \\
d\ln K =& \left[\frac{e_K k_L(\eta - e_M k_M + k_U\sigma)}{D}\right] d\ln\alpha - \left[\frac{e_K(e_L + \sigma)}{D}\right] d\ln\beta + \left[\frac{e_K e_M(e_L + \sigma)}{D}\right] d\ln\gamma \qquad \text{(C.3)} \\
d\ln P^U =& \left[\frac{k_L k_U(e_K + \sigma)}{D}\right] d\ln\alpha - \left[\frac{e_K k_L + e_L k_K + \sigma}{D}\right] d\ln\beta + \left[\frac{k_M(e_K k_L + e_L k_K + \sigma)}{D}\right] d\ln\gamma \qquad \text{(C.4)} \\
d\ln w =& \left[\frac{k_K(e_M k_M - \eta) + k_U(e_K + k_L\sigma)}{D}\right] d\ln\alpha - \left[\frac{e_K + \sigma}{D}\right] d\ln\beta + \left[\frac{k_M(e_K + \sigma)}{D}\right] d\ln\gamma - \left[\frac{e_M k_M(e_K + \sigma)}{D}\right] \tau \qquad \text{(C.5)} \\
d\ln r =& \left[\frac{k_L(\eta - e_M k_M + k_U\sigma)}{D}\right] d\ln\alpha - \left[\frac{e_L + \sigma}{D}\right] d\ln\beta + \left[\frac{k_M(e_L + \sigma)}{D}\right] d\ln\gamma \qquad \text{(C.6)} \\
d\ln Q_D^U =& \left[\frac{\eta k_L k_U(e_K + \sigma)}{D}\right] d\ln\alpha - \left[\frac{e_M k_M(e_K k_L + e_L k_K + \sigma) + k_U[e_K e_L + \sigma(e_K k_K + e_L k_L)]}{D}\right] d\ln\beta \\
&+ \left[\frac{\eta k_M(e_K k_L + e_L k_K + \sigma)}{D}\right] d\ln\gamma \qquad \text{(C.7)} \\
d\ln Q^M =& \left[\frac{e_M k_L k_U(e_K + \sigma)}{D}\right] d\ln\alpha - \left[\frac{e_M(e_K k_L + e_L k_K + \sigma)}{D}\right] d\ln\beta \qquad \text{(C.8)} \\
&+ \left[\frac{\eta(e_K k_L + e_L k_K + \sigma) - k_U[e_K e_L + \sigma(e_K k_K + e_L k_L)]}{D}\right] d\ln\gamma \\
d\ln P^M =& \left[\frac{k_L k_U(e_K + \sigma)}{D}\right] d\ln\alpha - \left[\frac{e_K k_L + e_L k_K + \sigma}{D}\right] d\ln\beta + \left[\frac{k_M(e_K k_L + e_L k_K + \sigma)}{D}\right] d\ln\gamma \qquad \text{(C.9)}
\end{aligned}
$$

where

$$D = (\eta - e_M k_M)(e_K k_L + e_L k_K + \sigma) - k_U[e_K e_L + \sigma(e_K k_K + e_L k_L)] < 0$$

Table C.1: Definition of Shock Variables

$\alpha =$	Labor Supply Shock	$\gamma =$	Import Supply Shock
$\beta =$	Domestic Output Demand Shock		