Modeling undocumented migration from Mexico to the United States – A structural examination of available information and options for analysis

Kayenat Kabir, Graduate Research Assistant, Purdue University, kkabir@purdue.edu;
Roman Keeney, Associate Professor, Purdue University, rkeeney@purdue.edu

Selected Paper prepared for presentation at the 2017 Agricultural & Applied Economics Association Annual Meeting, Chicago, Illinois, July 30-August 1

Copyright 2017 by Kayenat Kabir and Roman Keeney. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.
Abstract

The stock of undocumented Mexican migrants into the U.S. was on the rise between 2000 and 2007 and started to decline from 2008 onwards. In this paper, we discuss the development of a modeling framework for economic analysis of undocumented Mexico to U.S. migration, taking into account the implicit taxation of wages received by undocumented migrants. We attempt to historically validate our CES nested model against observed price and quantity responses of inputs (including undocumented migrant labor) and aggregate output in the economy during the 2000-2007 period. In the process we examine model performance under a range of parametric values for factor supply and substitution elasticities and provide a frame of reference for comparing existing literature estimates of these parameters. We find that as we move closer to matching the historical record on quantity change of undocumented labor usage we move farther from our targeted responses in prices.

Key words: undocumented Mexico-U.S. migration, unskilled labor, equilibrium displacement model, implicit taxes, elasticities.

1. Introduction

The debate over federal immigration policy rose to the forefront of the most recent national election in the United States. This attention follows multiple failed attempts at reforming undocumented migration from Mexico to the United States, one of the largest migration corridors in the world (Martin 2006). The primacy attached to reforming undocumented migration doesn’t seem to stem from economic stressors. Recent trends show a declining undocumented population in the U.S. since 2007 and approximately zero net inflow of undocumented migrants (Passel et al. 2012). Economic analysis of labor markets tends to find minimal wage impacts of undocumented employment and positive effects of equilibrating thin labor markets (Cadena and Kovak 2016; Edwards and Ortega 2016; Dustmann et al. 2016).

On one hand employers and industry leaders express concern for economic sectors that have made significant use of undocumented labor (see e.g. McPhate in the New York Times April 7, 2017; Jordan and Pered in the Wall Street Journal November 28, 2016). On the other hand current U.S. administration and Office of the Attorney General issues a new memo to federal law enforcement directing an increase in the scope of deportations (DOJ-OPA 2017; DOJ-OAG 2017). This trend toward increased internal enforcement (as opposed to enforcement at border crossing and waypoints) may not be active economic policy, but will have considerable impacts on the numerous regions where the undocumented workforce has settled (Massey et al. 2015).

Labor and international economics disciplines have long considered the role of migration and its varied economic impact. U.S. based studies have played special attention to Mexican migration and U.S. policy approaches (Hanson 2006). In this paper, we review past modeling approaches and policy analysis related to undocumented migration and discuss the development a modeling framework for economic analysis of undocumented Mexico to U.S. migration. Model development is driven by several objectives detailed in latter sections.
Foremost among these is a tractable mathematical model that 1) provides a frame of reference for comparing literature assumptions on factor supply and substitution elasticities and 2) evaluating the recent history of growth and decline in undocumented migration. We lay out a simple model through equations (1) to (5) in section 3 adapted from (Keeney and Hertel 2009 and Hertel 1989), which describes a simple model of factor supply and demand, expressed in terms of elasticities and percentage changes in price and quantity, where a representative producer operates under locally constant returns to scale and zero profit conditions. Then we shock the model with observed changes in input and output prices and the ad valorem wedge (difference between wages received in the U.S. and wages in Mexico) during the 2000-2007 period and observe changes in endogenous factor supply quantity and prices for a range of factor supply and substitution elasticities. In the process we provide a frame of reference to compare literature assumptions on elasticity parameters and how they perform in the modeling framework.

The aim of the study is to extend the analysis to the 2007-2014 period which has witnessed a decline in net undocumented migration and eventually expand it to analyzing economic effects of proposed policies. In the current paper, we focus on developing the CES nested model and discuss historical validation of the model under different parameter assumptions.

2. Background

As we will see in this section, the literature on undocumented migration is marked by a diversity of approaches – owing to a policy problem that spans multiple disciplines. We proceed to discussion of the policies related to undocumented migration, recent trends in migration and the literature, highlighting both the estimated impacts of changes in migration policy as well as the set economic and extra-disciplinary assumptions that support those findings.

2.1 Mexico-U.S. Migration Policies in the 20th Century

The U.S.-Mexico migration corridor is one of the largest in the world (Martin 2006). The first wave of large scale migration of Mexicans started after the curtailment of Japanese immigrants, who were a source of cheap Asian labor, in 1907. Then came demand intensification during the World War I, followed by a halt to the increasing flow of Mexican migrant workers during the the Depression in the 1930s. During the World War II the demand for Mexican labor resurged. The bracero program was established in 1942 to facilitate entry of temporary workers. It unilaterally ended in 1964 over concerns that immigrant farmworkers were depressing agricultural wages. During this period, 4.5 million Mexicans came over legally to work on U.S. farms.

The Immigration Reform and Control Act (IRCA) of 1986 is the basis for current U.S. immigration policy on illegal immigration. This reform made it illegal to employ undocumented workers, mandated monitoring of employers, and expanded border enforcement. It also ordered amnesty to illegal aliens who had resided in the United States since before 1982. The IRCA also included a one-time general amnesty program and two special concessions to the US farmers. The Special Agricultural Worker (SAW) Program legalized an additional 1.1 million immigrants, the majority from Mexico. The Replenishment Agricultural Worker (RAW) program allowed for new immigration to alleviate farm labor shortages caused
by SAWs leaving agriculture. However, the RAW program was never used, because the Department of Labor determined that there were no farm labor shortages in the early 1990s, despite employer sanctions.

<table>
<thead>
<tr>
<th>Table 1: Timeline- Mexico-U.S. Migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1907</td>
</tr>
<tr>
<td>1910s</td>
</tr>
<tr>
<td>1924</td>
</tr>
<tr>
<td>1930s</td>
</tr>
<tr>
<td>1942-1964</td>
</tr>
<tr>
<td>1965</td>
</tr>
<tr>
<td>Mid 1980s</td>
</tr>
<tr>
<td>1986</td>
</tr>
<tr>
<td>1994</td>
</tr>
<tr>
<td>Early 1990s</td>
</tr>
<tr>
<td>2008-2009</td>
</tr>
</tbody>
</table>

The North American Free Trade Agreement (NAFTA) in 1994 and the concurrent domestic reforms in Mexico were only partially motivated by migration concerns; nevertheless, they were expected to have far-reaching impacts on migration flows. The then Mexican President Salinas argued that opening up markets would help Mexico export more goods and fewer people, thereby reducing migration pressures.

Currently green cards (GCs) are almost entirely unavailable to low-skilled workers. The two main low-skilled temporary visa programs (H-2A and H-2B) vary little over the economic cycle and in any case represent scarcely 1 percent of the current unauthorized population, making them an inconsequential component of domestic low-skilled employment. Use of the H-2A program has decreased in recent years, and the number of certifications now corresponds with roughly one-tenth of hired farm laborers, according to USDA’s Farm Labor Survey. Currently, the H-2A program is limited to temporary or seasonal workers, which largely excludes dairy, livestock, and nursery operations from participating.

2.2 Recent patterns in U.S.-Mexico migration

The literature covering undocumented Mexico to U.S. migration spans over multiple disciplines. Sociology (rural sociology), political science, demography, and economics and multi-disciplinary iterations of these have all made use of the increasingly rich data (and imputations of data) available to track and explain changes in undocumented migration. The growth in available data for analysis has allowed researchers to observe trends such as those in Figure 1, sourced from the Pew Research Center’s publication (pg 3, Passel and Cohn 2016a). Figure 1 highlights several interesting changes in the undocumented population of the U.S. From 1990 to 2000 we see Mexican and non-Mexican growth in the undocumented population move closely. While the growth trend of undocumented immigrants from Mexico and from other countries is similar during 1995-2000, they diverge off during 2000-2007. After 2000, the undocumented population of Mexicans continues to grow while there is a flattening of other nationalities’ population. The number of undocumented Mexican migrants peaks in 2007 to an estimated 6.9 million. After 2007, with the slowdown in U.S. economic growth, the influx of legal permanent residents starts decreasing. Estimates from Cohn and Passel (2008) for the total undocumented immigrant population also indicate slower growth between 2005 and 2008 than earlier in the decade. From 2007 to 2014, while the population of other undocumented nationalities flattens out, the Mexican undocumented begins its current decline. Notably, the
proportion of U.S. undocumented population from Mexico in 2014 is quite like what it was in 2000, the year when the two populations saw their growth diverge.

Data from the 2010 Mexican census, show that about twice as many Mexicans returned home in the five years previous to the 2010 census than had done so in the five years before the 2000 census (Passel et al. 2012). Among these migrants around one fourth are children born in the U.S. to Mexican born parents.

2.3 Reasons for recent net migration decline

Population change has long been the domain of demographers and they have tackled the undocumented Mexican U.S. population extensively. Hanson and Spilimbergo (1999) explain a 1980s surge in undocumented Mexican migration as being driven by a faster increase in the country’s working age population than its economy could accommodate. A deepening economic crisis in Mexico created wage volatility which caused families to diversify income sources through both rural-urban migration and migration to the United States (Cerrutti and Massey 2004; Massey and Espinosa 1997). Following the 1986 Immigration Reform and Control Act (IRCA) provisions for legalization and amnesty of certain classes of undocumented migrants, there were increased expectations that subsequent reforms would include provisions for those with stable histories of labor force participation. This combined with increased enforcement at the border serving as a deterrent to circular migration (seasonal work followed by repatriation) played a significant role in changing the settled permanent population response to consistent economic drivers (Massey et al. 2015; Massey et al. 2016).

Economics, enforcement and demographics all could be playing a role in the recent striking decline in the number of unauthorized immigrants from Mexico. The literature has focused on four main reasons with the Great recession in the U.S. being the main focus: i) the Great recession in the U.S., 2007-2009 ii) better economic conditions in Mexico iii) declining fertility in Mexico and iv) increased border control and growth in deportation

Great recession in the US: The Great Recession of 2007-2009 reduced employment in construction and other sectors where Mexican immigrants overall are especially likely to work. Widespread unemployment in non-agriculture, low-skill industries following the 2008 financial crisis coincides with a decline in the rate of Mexico-U.S. migration: from 25 migrants per thousand Mexican nationals in 2005 to 7 per thousand in 2012 (Passel and Cohn 2015, Villarreal 2014). It is estimated that only five percent seek employment in the U.S. agriculture sector. Migrants’ employment preference is shifting from agricultural to non-agricultural and urban jobs (Passel and Cohn 2015). Villarreal (2014) finds reduction in labor demand in industrial sectors that employ a large percentage of Mexican-born workers, such as construction, are

Figure 1: Estimated no. of undocumented immigrants from Mexico and other countries into the U.S; Source: Passel and Cohn (Pg 3, 2016a), PEW Research Center
strongly associated with lower rates of migration for Mexican men. The largest declines in migration occurred precisely among the demographic groups most affected by the Great Recession: namely, economically active young men with low education.

**Economic growth in Mexico:** Since the late-1990s, Mexico has experienced over a decade of economic stability and modest levels of growth, disrupted only by the recession of 2008–2009. Yet, such economic growth has not resulted in a substantial improvement in the standard of living of most Mexicans (Passel et al. 2012). However, better economic conditions have meant young men who traditionally migrated to the U.S. are shifting to employment inside Mexico. The wages in northern Mexico have increased which have resulted in demand from agricultural labors from the southern part of Mexico, where wages are lower (Taylor et al. 2012).

**Decline in fertility and change in demographic composition:** Total fertility rate in Mexico dropped from approximately 6 children per woman in 1974 to 2.22 children per woman in 2012. Declining fertility can directly lower the rate of international migration from Mexico by simply reducing the size of the working-age male population that is typically at greater risk of migrating. Villarreal (2014) finds fertility decline accounts for 3.2 percent decrease in the odds of migration between 2005 and 2012.

**Border control and growth in deportation:** Border patrol expenditures began increasing notably in the early 1990s, but Mexican migration to the United States did not fall until the mid-2000s. Evidence from previous studies suggests that greater border enforcement efforts during the 1990s did not affect the flow of undocumented migrants (Cornelius 2001; Espenshade 1994; Massey et al. 2002). Taylor et al. (2012) examined the effects of the two key immigration policy changes: i) increased border enforcement expenditures and ii) the 1986 Immigration Control and Reform Act (IRCA); and a trade policy-NAFTA of the last twenty years that may have affected the supply of rural Mexican labor to U.S. farms. In the medium to long run there is a tendency for migration to farm jobs to decline. This decreasing trend, however, was temporarily interrupted first by IRCA and then by NAFTA. Taylor et al. (2012) finds each of these policies was associated with a one percentage point increase in the share of villagers migrating to US farm jobs over the four year period following the policy’s implementation which represents a 40 percent increase compared to pre-policy levels (Taylor et al. 2012). The finding that farm labor migration increased after IRCA suggests that the SAW legalization program created a stimulus for migration that out-weighed the deterrent effect of employer sanctions for hiring unauthorized workers.

Taylor et al. (2012) also finds that once they control for other variables shaping migration, increases in border enforcement expenditures (operations such as Gatekeeper and Hold-the-Line) do not affect migration to U.S. farms. This suggests that border enforcement, even if it increases the odds of apprehension on a given attempt to cross the border, may not deter new immigration. Border control even backfired by increasing the rate of undocumented population growth and turning what had been a circular flow of male workers going to three border states into a settled population of families living in 50 states (Massey et al. 2016; Reyes et al. 2002) by deterring return migration.

This brings us to the cost of illegal migration i.e. the smuggling fee. Undocumented migrants cross the Mexico-U.S. border with the service of who are known as coyotes. Coyotes
used to be independent individuals aiding migrants cross the border few times a year typically for agricultural employment. Today the multibillion dollar border crossing industry is controlled drug cartels with coyotes for them and the cartels making most of the profit with each cartel operating in different sections of the border (Izacara Palacios 2012, Grillo 2017 in NYTImes). The highly organized smugglers offer packaged services which include job placement in the U.S. and multiple crossings to ensure guaranteed crossing for a fee that goes up as high as USD 5000 (see Garsd 2016, Grillo 2017). With stricter enforcement this fee only goes up with the cartels finding new innovative ways to cross the border.

Political efforts to arrive at comprehensive immigration reform over the past decade have not been successful, partially due to disagreement over replication of the IRCA’s partial amnesty approach. Pointedly, the 2016 national election put in place a hardline immigration administration looking to expand enforcement and deterrence at the border while increasing effort to execute deportations (DOJ-OPA 2017). As the national debate sputtered in the past decade, states and localities have adopted numerous initiatives aimed at criminalization or reducing access to basic services for undocumented migrants (Ybarra et al. 2016). Deportation and border enforcement has different effects on undocumented migration. Amuedo-Dorantes et al. (2013) describe the primary impact of these measures as limiting the mobility, particularly interstate mobility, of undocumented migrants. This is of significant consequence because Cadena and Kovak (2016) highlight the relative mobility of the undocumented population as a stabilizing force for local economies traversing the Great Recession in the United States. Ellis et al. (2014) similarly point to the relative mobility of the undocumented workers in the Great Recession as an expansionary force in the network of communities that is predominant in the undocumented population.

2.4 Econometric analysis of wage impacts of migration

A diverse and growing labor force is typically viewed as net economic positive but considerable attention has been given to measuring negative impacts on native workers when migration is expanded. Borjas (2003) finds significant impacts for native unskilled workers of a degree that would support immigration reform as an active labor market policy. Subsequent research expanding on Borjas has found more muted impacts (Dustmann et al. 2016) by examining the potential imperfect substitution that exists between native and foreign unskilled workers. A highly cited paper by Ottaviano and Peri (2012) estimates a nested constant elasticity of substitution production structure and finds significantly smaller native wage impacts due to the hiring of undocumented migrants. Follow on work by Edwards and Ortega (2016) re-examines approaches to education and experience measurement in wage impact studies lead to further reduction in the native wage impact of expanded undocumented labor supply.

The review paper by Dustmann et al. (2016) tracks developments in the economics literature through the lens of labor market assumptions, casting specific light on assumptions about substitution and labor mobility. The authors argue for broader scope that makes explicit assumptions about supply and demand response. Viewed in the larger economy, the labor mobility of natives relative to undocumented migrants will be a key determinant of economic
impact. Undocumented migrants are in greatest use (relatively) where unskilled labor expense is significant in the sector cost structure such as agriculture, construction, and hospitality services are sectors where changes to undocumented labor supply would be of highest impact (Passel and Cohn, 2015).

Studies of agricultural sector impacts have been prominent in the literature, owing to the sector’s long history of migrant labor use to meet seasonal variation in labor demands. Recent work by Kostandini et al. (2014) looks at recent state and local policies to deter undocumented hiring and finds the sector level impacts are consistent with lower performance due to labor shortages. There is also evidence that agricultural use of undocumented labor depends on new inflow of migrants as those jobs tend to be disfavored for a variety of reasons (including but not limited to seasonality of labor demand) and provide a gateway to employment in other sectors (Colson et al. 2015).

This would imply that cross-sector labor mobility (particularly of undocumented workers) is a key ingredient in understanding the economic impact of any policy affecting undocumented labor. This provides a point of entry for multi-sector models (particularly national and global computable general equilibrium (CGE) models) to enter the literature to shed light on the total effects (and their decomposition) of changes to undocumented labor supply.

2.5 CGE Modeling of Impact of Undocumented Mexican Labor Migration

Literature on effects of immigration into the U.S. has concentrated mainly on analyzing labor market outcomes, particularly wages and employment impacts for domestic workers. Only a few studies exist on impact of immigration policies on the U.S. economy and their distributional impacts.

The USAGE Model and Global Migration model (GMig) are the two known CGE models that have been used to evaluate the economic impacts of changes in the supply of foreign-born labor. Early on utilizing GMig model (based on GTAP database and model), Walmsley and Winters (2005) studied welfare effects of increasing quotas (by 3%) for both skilled and unskilled temporary workers in developed countries and found that it would significantly increase global welfare with the majority of benefits accruing to developing countries. However, the lack of bilateral labor migration data forced the study to make approximations in important areas and since then efforts were directed towards creation of a bilateral migration matrix named GMig2 database (outlined in Walmsley et al. 2007). GMig2 Data Base contains data on bilateral migrant labor and wages by skill and bilateral remittance flows. Aguiar and Walmsley (2010, 2009) extended the GMig2 database by separating documented and undocumented migrants as part of the North American migrant labor flow and extending the GMig model to be a dynamic migration model-GMig2 model. Three of the main assumptions of the GMig2 model are: a) like domestic workers, foreign workers are assumed to be of two kinds, skilled and unskilled; b) foreign and domestic labor are perfect substitutes; and c) wages of migrants are initially (in the data base) equal to the home wage plus a proportion of the difference between host and home wage.
Aguiar and Walmsley study economic effects of two policy scenarios concerning undocumented Mexican migrant workers—legalization of undocumented agricultural workers and deportation of undocumented migrant workers in the U.S and finds considerable loss of real GDP in a deportation case and gains in wages and productivity in a legalization scenario.

Using the USAGE model, one of the most detailed representations of the U.S. economy available in a recursively dynamic, computable general equilibrium (CGE) model, most work to date has examined overall effect of deportation on GDP (Dixon et al. 2008) or only on U.S. agricultural sector (Zahniser et al., 2012). Dixon et al. (2008) evaluates the long term effects of restrictions to the demand and supply of undocumented immigrants and finds that fewer undocumented migrants (~30% reduction) reduces the size of the U.S. economy in 2019 by 1.6 percent, a $200 billion reduction in terms of GDP, regardless of whether the decline is the result of supply (border enforcement and deportation) or demand-side (fines on hiring firms) policies. They find that the native work force benefits from the occupation mix that prevails in the wake of undocumented worker reduction though this impact is lessened if public resources for prosecution or heightened border enforcement is the chosen policy approach. Only in the case of employment taxation where contributions are made to the public treasury would there be no negative spillover from the public finance activity of undocumented deterrence.

Zahniser et al. (2012) use the same CGE model as Dixon et al. (2011) to examine the agricultural labor market under two scenarios: 1) expanded temporary worker programs (through increase in H2A program1 positions) and 2) increased enforcement. Their two scenarios identify the stark tradeoff at play for a sector dependent on unskilled labor and that has made increasing use of undocumented workers. Specifically, they find expansion of temporary worker programs is pro-growth in the sector (1-2%) though native employment falls and earnings per job decrease commensurate to the expansion (~3%). This is contrasted with an immigration control scenario that sees output in the sector fall (2-4%) while native employee earnings increase (3%).

However, the baselines for the dynamic USAGE-M model identifies a business as usual (BAU) case targeted to pre-2007 macro variables and identifies undocumented migration from Mexico as only weakly responsive to lowered economic growth. Their baseline case envisions approximately 4% undocumented migration growth throughout the ten-year horizon of their policy runs. With such a broad scope (~500 sectors) and economy-wide equilibrium to benchmark, the USAGE-M model is necessarily targeted to matching economic growth via total factor productivity and propensities to consume in its solution path. Labor market drivers and response are largely based on literature survey and assumption. The severe break from trend shown in figure 1 measures of undocumented Mexican migrants represents an issue that would require revision of USAGE-M or any model’s baseline approach to measure forward looking policy reform approaches. Both CGE studies identify their results as sensitive to labor substitution and factor mobility assumptions in keeping with the prior econometric based work (Dustmann et al. 2016).

1 The current avenue by which nonimmigrant workers can be employed in U.S. agriculture on a temporary basis.
To adapt the USAGE Model to the study of immigration, Dixon and Rimmer (2008,) disaggregate the workforce into three categories based on immigration status: i) U.S.-born: native U.S. citizens ii) Foreign-born, permanent residents and Foreign-born, not a permanent resident: those without permanent U.S. residency status. It treats authorized and unauthorized labor as separate factors of production and modeled employers’ ability to substitute between them in a CES production function. This feature is different from the econometric modeling papers of Ottaviano/Peri or Borjas/Katz where authorized and unauthorized labor is not distinguished because of lack of data. The values for the elasticity of substitutions are drawn from the literature. The USAGE Model incorporates Ottaviano and Peri’s (2005) estimated high elasticity of substitution between domestic and foreign-born labor which is 7.5. The substitution elasticity between an authorized and unauthorized worker in the same occupation is assumed to be lower than 7.5 and thus 5 and substitution possibilities between occupations is assumed to a low 0.35. Zahniser et al. (2012) adopts these “USAGE standard parameters” but changes them in their sensitivity analysis changes these values considering less elastic labor supply and employers treating authorized and unauthorized workers as more differentiations factors of production and thus less substitutable. This common thread of labor substitution will serve as the driver of our current study, as detailed in the next section.

3. Model

The previous section examined the bounds of studies on undocumented migration and economics – discussing the single equation econometric studies of relative wage impact and large scale economy-wide simulation of policy proposals. This is certainly not exhaustive. International economists have contributed to theory developments and tests thereof (see. E.g. Todaro 1969; Todaro and Maruszko 1987 and the papers that cite those seminal entries). Our narrowed focus into the literature stems from the complementarity of the approaches to policy evaluation. Specifically, the econometric studies look into historical data to measure policy impact while simulation studies provide forward looking analysis. These simulation studies make use of parameters derived from econometric studies while most econometric studies derive forward looking policy recommendations based on the limited estimated model. Both approaches carry the limitations that are married to the method, but neither is explicit about those limitations in the model development. Our goal in model development is to provide a framework that is amenable to looking at the same historical data that would determine response in the economy to future policy options.

Such a model would need to be tractable to apply to the variability observed in historical information, a requirement for identifying response components. It should explicitly make the key assumptions for labor markets with an eye toward validating the model against the historical record before simulating future counterfactuals. The driving factor is a minimal representation that provides a structural proxy for existing simulation studies of Mexico to U.S. migration while also covering the required assumptions of econometric findings on elasticities. And finally, it should be extendable to either 1) link with larger models of economic interaction or 2) make use of additional data or theory findings that are proven relevant.
We lay out a simple model through equations (1) to (5) adapted from (Keeney and Hertel (2009) and Hertel (1989), which describes a simple model of factor supply and demand, expressed in terms of elasticities and percentage changes in price and quantity), where a representative producer operates under locally constant returns to scale and zero profit conditions. Equations (1) through (5) describe a partial equilibrium structure in log-linear form (all lower-case variables indicate percentage change).

\[ q_i = q_{output} - \sum \sigma_{ij} s_j p_j \]  
\[ p_{output} = \sum s_i p_i \]  
\[ x_{mul} = \eta_{mul} x_{rmul} \]  
\[ x_{mul} = q_{mul} \]  
\[ r_{mul} = p_{mul} - \delta \]

Where, \( q_{output}, q_i, p_i \) and \( p_j \) are the percentage changes in output, input \( i \)'s demand, price of input \( i \) and price of input \( j \neq i \) respectively. \( \sigma_{ij} \) is the Allen partial elasticity of substitution between two factors and \( s_i \) is the cost share of input \( i \) in output production. \( x_{mul} \) and \( q_{mul} \) is the percentage change in quantity of Mexican undocumented unskilled labor (mul) supplied and demanded as input to the U.S. production sector. \( r_{mul} \) and \( p_{mul} \) are the supply side and demand side price of mul, and \( \delta \) is an ad valorem wedge between the price paid and received for inputs in the model. \( \eta_{mul} \) is the factor supply elasticity of mul.

The model describes a fixed output sector and the labor market that supplies inputs to that sector. Equation (1) and (2) describe factor demands and zero profits for the representative producer operating under locally constant returns to scale. Equation (1) establishes the output variable \( q_{output} \) as exogenous to the system, i.e. all expansion and contraction effects will be set from outside the model. The percentage change in input \( i \)'s demand \( q_i \) will respond to the total output level \( q_{output} \) and to changes to prices for the \( j \) inputs \( p_j \). The response of factor demands to prices is governed by the demand elasticity written as \( (\sigma_{ij}s_i) \), the Allen partial elasticity of substitution multiplied by the cost share.

Factor supplies and factor market clearing (quantity supplied=quantity demanded) are given in (3) and (4) for only the input described as mul (Mexican undocumented unskilled labor). In (3) changes in the input supplied to the production sector are determined by the supply side price \( r_{mul} \) multiplied by the supply elasticity of mul \( (\eta_{mul}) \) to the production sector in response to a change in the factor return.

![Diagram](image-url)
The final equation (5) describes price linkage between supply and demand prices for the input of initial incidence, undocumented labor from Mexico. The policy variable $\delta$ is an ad valorem wedge between the price paid and received for inputs in the model. This is an abstraction of convenience whereby we assume any of the myriad of policies to impact undocumented labor use can be recast as an ad valorem equivalent. For example, a policy of imposing fines on producers employing Mexican undocumented labor can be recast as fines equivalent to ad valorem wedge causing the difference between the price paid by producers (fines plus the wage received by mul) and price received by mul.

The system in (1) through (5) is commonly called “equilibrium displacement” and is frequently used in partial equilibrium studies to emphasize the importance of factor supply and substitution (see e.g. Hertel 1989; Salhofer and Sinabell 1999) in evaluating response to policies. A typical solution of the model identifies the incidence of a change in the price wedge ($\delta$) as $(1/\eta_{mul})(\eta_{mul} \sigma_{mul,mul})$ for the firm price ($p_{mul}$) when all other inputs are perfectly elastic in supply.

The matrix of substitution elasticities $\sigma_{ij}$ is operationalized in our empirical model via a nested-CES substitution framework for inputs, including the sources of unskilled labor. In figure 2 we show a production nest for a composite output that generates factor demands for two inputs, unskilled labor and the amalgam of other inputs. Unskilled labor is further divided into that which is sourced from Mexico and other sources. Finally, the Mexican unskilled labor is split between documented and undocumented types. The nested structure accommodates three CES substitution parameters labeled $\sigma_A$, $\sigma_B$, and $\sigma_C$ working from top to bottom of the nested structure. The different nest level substitution parameters impose common elasticities of substitution on all members of a nest and for those members with inputs in other nests that are dependent on the values of the CES parameters and the cost structure of production.

Our goal in implementing this model is to eventually apply the structure to an historical era that saw dramatic change in undocumented migration into the United States such as can be seen in figure 1 for the period 2000 to 2014. In the current version we provide an assessment of the structure for examining factor supply and substitution, looking to the different cases of status quo versus removal of undocumented workers.

4. Data

Given the nature of the problem, the data for the model comes from different sources and number of literature based assumptions are made in order to estimate the variables related to undocumented Mexican migrant.

4.1 Migrant Population:

Since unauthorized population is more likely to be of working age, the undocumented immigrant population make up a larger share of the overall labor force than the overall U.S. population (Passel and Cohn, 2009). The time series data for number of documented and undocumented Mexican born and other foreign born migrant population comes from Pew
Research Center\(^2\) (here forth referred as Pew). Pew’s estimates for what it terms as “unauthorized immigrant” population in the U.S. is based on a residual estimation methodology. The total number of migrants for 2005-2015 are based on augmented American Community Survey data from Integrated Public Use Microdata Series (IPUMS) and for 1995 and 2000 based on March supplements to Current Population Survey. The lawful resident immigrant population is estimated from the Department of Homeland Security’s Office of Immigration Statistics. The difference between the total number of immigrant population and the lawful

**Table 2:** Percentage change of output and input price and quantity indexes and smuggling fee and data sources

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Output quantity index (US Real GDP, Index 2009=100)</td>
<td>90</td>
<td>102</td>
<td>14</td>
<td>Bureau of Economic Analysis (BEA)</td>
</tr>
<tr>
<td>Output price index for US GDP (Index number 2009=100)</td>
<td>85</td>
<td>97</td>
<td>14</td>
<td>Bureau of Economic Analysis (BEA)</td>
</tr>
<tr>
<td>Average annual wage of unskilled Mexican born documented workers in the U.S. (CPI adjusted, 2010 base)</td>
<td>21253</td>
<td>19459</td>
<td>-8</td>
<td>Assumption: 0.9 of the average wage of the unskilled (support for 0.9 in Rector and Kim 2007)</td>
</tr>
<tr>
<td>Median annual wage of unskilled Mexican born undocumented workers in the U.S. (CPI adjusted, 2010 base)</td>
<td>20129</td>
<td>18811</td>
<td>-7</td>
<td>Authors’ calculation from Mexico Migration Project survey</td>
</tr>
<tr>
<td>Mexican undocumented unskilled quantity index</td>
<td>4450000</td>
<td>6700000</td>
<td>51</td>
<td>Passel and Cohn (2016 a,b); Author assumption: all undocumented migrants are unskilled, estimates for 2001-2003 unavailable. Figure for 2001-2003 is from 2000 estimate.</td>
</tr>
<tr>
<td>Annual Wages in Mexico in USD (CPI adjusted, 2010 base)</td>
<td>4992</td>
<td>5231</td>
<td>5</td>
<td>Secretaría del Trabajo y Previsión Social</td>
</tr>
<tr>
<td>Smuggling Fee (CPI adjusted, 2010 base)</td>
<td>2075</td>
<td>2601</td>
<td>25</td>
<td>Authors’ calculation from Mexico Migration Project survey</td>
</tr>
</tbody>
</table>

immigrant population is the “basic” estimate for unauthorized population. In the second step, documentation status is imputed at individual level based on likely characteristics of unauthorized population such as year of arrival, industry or occupation, country of origin etc. The basis estimate is thus refined by applying residual method and adjusting for survey omissions. For details on estimation methodology see Passel and Cohn (2016 a,b).

4.2 Gross domestic product and cost shares in production
The time series of price index for U.S. GDP and the output quantity index of real U.S. GDP is obtained from table 1.1.3 and table 1.1.4 in the website of Bureau of Economic Analysis. The indices have 2009 as base year. They change in the indices indicates the price change and output quantity change in GDP over the years.

We obtain the cost share of unskilled labor in production in the U.S. from Global Trade Analysis Project (GTAP) database version 9 (Aguiar et al. 2016). The global data base contains complete bilateral trade information, transport and protection linkages and is a complete representation of the world economy for the reference year. Version 9 disaggregates 140 regions, 57 sectors, 8 factors of production, for 3 base years (2004, 2007 and 2011). Among the 8 factors of production are skilled and unskilled labor and the cost share of wage bill for unskilled workers in U.S. GDP is 0.19.

The estimated share of wage bill of unskilled Mexican born workers in the U.S. among the U.S. total unskilled wage bill including wage bill paid to U.S. born workers) is 0.056 and this figure is obtained from GMig 2 database (Walsmley et al. 2007) 6.2 version³ which is a database of global bilateral stocks of migrants and remittances consistent with the GTAP 9 Data Base. From the database one can obtain values of labor (migrants and domestic) in a country by unskilled and skilled category by country of origin of labors. The assumptions for the database are described in the section 2.5.

Further down the CES nested function described in the model section, we obtain the labor cost share of Mexican born labor in the U.S. by documentation category i.e. documented and undocumented labor, from the extension of GMig2 database by Aguiar and Walmsley (2013). The database extension to incorporate information about undocumented workers in the U.S. is based on estimated by Passel (2005) which provides estimates on the country of origin and the employment distribution by industry of undocumented workers. These estimates are used to allocate undocumented workers among regions and sectors in the GMig2 database. The cost share of undocumented Mexican workers among the wage bill of unskilled Mexican born workers in the U.S. is calculated as 0.504 from the extended GMig2 database. At first glance this share may seem low given the estimated high number of undocumented workers. But what is important to remember is that undocumented worker are paid lower than documented workers and thus the wage bill/value (price*quantity) of undocumented labor could be equivalent to documented labor in the unskilled category.

³ Available at https://www.gtap.agecon.purdue.edu/resources/free_resources.asp
4.3 Wage bill and Wages

The wage bill is the total amount of money that a company or an organization pays its employees during a particular period, usually figured on an annual basis. The 2000-2015 time series data for U.S. wage bill is obtained from the website of Bureau of Economic Analysis (BEA).\textsuperscript{4} Data for wages earned in the U.S. is obtained from the website of Bureau of Labor Statistics. We assume the average of the bottom 25th percentile wage of each of the industries codified by North American Industry Classification System (NAICS) are representative of the average wage of the unskilled workers in the respective industry. Note that, the wage information collected since 1994 by the BLS includes wages of Mexican born undocumented workers.

Unskilled foreign born workers in the U.S. earn less than U.S. born workers. Passel et al. (2012) even find from their calculation of 2010 American Community Survey (ACS) that Mexican-born workers earn 0.75 times of non-Mexican born workers be it in the full-time year round worker category or all workers above 16 years old category. Based on Rector and Kim (2007) we assume documented unskilled Mexican workers earn 0.9 times of the average unskilled wage in the U.S. This assumption is also made by Dixon et al. (2008) in their analysis.

The wages for undocumented Mexican born workers in the unskilled category comes from calculation from surveys conducted by Mexico Migration Project (MMP), which is a binational research effort by the University of Guadalajara (Mexico) and Princeton University (US). The MMP database\textsuperscript{5} is a result of annual household surveys conducted in the U.S. and in Mexico since 1982 containing information on migratory experience of each individual in about 25,658 households. The MMP survey asks questions about individual’s wages in the U.S. during their first and last migration experience as well as their status in the U.S. We calculated the annual real wages of undocumented Mexican workers in the U.S. taking account of work year consisting of 8 hours a day, 5 days a week and 52 weeks a year and took the median of the wages in undocumented category. We should note that observation numbers are very low from 2008 onwards and we did not calculate the wage for documented workers from this survey because of very low number of documented individuals in the sample. The decline in real wages of undocumented Mexicans is consistent with the findings of Massey and Gentsch (2014).

The average wage for Mexicans in Mexico is obtained from the Secretaría del Trabajo y Previsión Social which reported by sectors in Pesos and converted into USD using the Foreign Exchange Rate between U.S.D. and Peso. The nominal annual wage in USD is converted to real USD using the CPI.

4.4 Smuggling cost

On a more detailed level the MMP asks household heads about their immigration history including fees paid to smugglers for migration into the U.S (MIG file). If the household head is not an U.S. migrant the survey collects information on another person in the household with U.S. migration experience (MIGOTHER file). The average smuggling fees across all crossings is adjusted to U.S. CPI is calculated from these two files. Smuggling fees have

\textsuperscript{4} The data can be obtained in Table 6.3C, Wages and Salaries by Industry in https://www.bea.gov.
\textsuperscript{5} http://mmp.opr.princeton.edu/databases/dataoverview-en.aspx
increased from around USD 2000 in the early 2000s to around USD 2600 (2010 inflation adjusted) by 2008.

In the most recent MMP surveys no. of observations in MMP for smuggling cost in 2012, 2013 and 2014 is less than 5 in each year. In a given year of survey information is collected on trip taken prior to the year. So as new waves of survey are conducted, information for particular year increases with no. of observations reporting trips for that year. Smuggling cost paid by undocumented Mexican migrants is also recorded in Department of Homeland Security administrative data. In a working paper, Roberts et al. (2010) compares the MMP data with DHS data and finds that the MMP systematically reports higher smuggling cost. This is most likely due to the difference in survey population. The DHS by nature acquires information from apprehended migrants and migrants who have unsuccessful border crossing experience maybe paying less for smuggling service.

5. Results and Discussion

We use the information compiled in section 4 and table 2 to simulate our equilibrium displacement model of undocumented Mexican migration between 2002 and 2007. In our historical simulation we shock the set of exogenous factor prices (all prices but the mul input) according to the changes between period 2006-08 and 2002-04 as in table 2. The two prices for undocumented labor are linked by the policy variable describing the wedge between price paid by firms and received by wage workers. To simulate this we use the difference between the price for undocumented Mexican workers in the U.S. and the unskilled wage in Mexico. This leads to a shock value of -12, a reduction in the real wage value of the implicit tax. The final shock is to the output variable by -14% which will drive expansion in factor demands. With these exogenous shocks into the displacement model we will be solving for three endogenous prices (the output price index [unit cost of output], price of undocumented workers inside the US and in Mexico) and three quantities of interest (factor demand changes for Mexican workers [documented and undocumented] and other labor inputs).

We need a set of CES substitution elasticities (see the CES nesting figure) and one factor supply elasticity (Mexican undocumented labor) to operationalize this model. We make the assumption that unskilled labor and the composite input representing remaining inputs are used in fixed proportions to simplify our analysis to substitution possibilities only within unskilled labor usage. At a second level, we need an assumption for substitution between Mexican unskilled workers and other workers (native and other migrants) which we set to a value of 10 in line with previous assumptions made in CGE and econometric modeling that looks to native versus foreign unskilled labor substitution.

The literature from which to draw our final substitution elasticity (documented vs undocumented workers from Mexico) as well as the factor supply elasticity of undocumented workers to US employment is sparse (see Appendix for a list of econometric study findings). As such, we solve the model over a large range of possible values and examine our simulation results at different representative points in those ranges. For factor substitution between documented and undocumented workers we use a range from 0 to 50; for factor supply the range is from 0 to 20. Thus, the agenda for our simulation analysis here is to identify which
5.1 Simulation results

Change in undocumented Mexican labor quantity: The first result is for changes in undocumented Mexican workers employed in U.S. production for varying parameter (supply elasticity, substitution elasticity and ad valorem wedge) assumptions. Here we see that as substitution and supply elasticity increase we get larger increases in undocumented workers. At the extreme (supply elasticity of 20; substitution elasticity of 50) the change in demand for undocumented labor is approximately +30%. This is well short of the nearly 50% increase in the undocumented population observed between 2001-2003 and 2006-2008. Assuming population and employment increase are proportional, we are only able to account for about half of the observed change. Moreover, we are at the extreme values of elasticities that were considered in this experiment to get this +30% change.

Examining the two lines representing the largest response of undocumented workers (sigma = 40 & sigma = 50) we can see that increased substitution making the factor demand more responsive would have smaller effect of increasing the boundary assumptions on elasticities. This is consistent with sigma = 50 being quite large such that increments to that value will just approximate more closely perfect substitution. Increasing the (already large) assumption on supply elasticity from a value of 20 will move the result closer to the historical target. We will see in later results on that increasing the responsiveness to target the quantity response here poses an issue for evaluating endogenous prices (see figures R5 and R6).

---

Figure R1. Percentage change in undocumented Mexican unskilled employment under varying parameter assumptions
Change in documented Mexican labor and other unskilled labor: Figures R2 and R3 give the expected reduction in demand for documented Mexican labor and other labor in response to model shocks under varying assumptions of elasticity parameters. As the supply and demand of undocumented workers becomes more price responsive (larger supply elasticity and larger substitution elasticity) we get larger displacements of these other labor categories. Notable in comparing the two figures is the change in the responsiveness when the substitution in the lowest CES nest (between documented and undocumented types of Mexican workers) increases beyond the static assumption of 10 that is used in the factor substitution nest comparing Mexican versus domestic (and other nationality) labor in unskilled US employment.

**Figure R2.** Percentage change in documented Mexican unskilled employment under varying parameter assumptions.

**Figure R3.** Percentage change in other unskilled employment under varying parameter assumptions.
Change in output price index: Figure R4 gives the output price index in the model. This is largely determined by the 80% of input costs that aren’t unskilled labor (skilled labor and other primary factors and intermediates) which is assumed to move with the aggregate real price index of +14%. There is no substitution for unskilled labor in this model and the historical real price change for unskilled labor over this time period (-8%) draws the output price index (unit cost of production) down to +9%, only 2/3 of the historical observation of +14%. The varying parameters of the model have no significant impact on the predicted output price change due to the small share (note that narrow range on the vertical axis of figure R4 which all round to ~9.6%).

Figure R4. Percentage change in output price level under varying parameter assumptions

The price response in the model is best observed in figures R5 and R6, the equilibrium price paid by firms and received by undocumented Mexican workers. In those two figures we see that the price response targets measured in the historical record (-6.5 paid by firms; +5% received by workers) are most closely matched at the least responsive assumptions. This is the exact opposite result we saw for measuring the quantity adjustment which was well short of approximating the factor demand increase that we expect given the strong increase in the undocumented population over the 5 year time period.
Figure R5. Percentage change in firm price for Mexican undocumented unskilled labor under varying parameter assumptions.

Figure R6. Percentage change in worker price of Mexican undocumented unskilled labor under varying parameter assumptions.
5.2 Discussion and future directions

Our analysis here places an economic structure to compiled data (from numerous sources) on undocumented Mexican labor usage in the U.S. With minimal guidance on setting the parametric structure for undocumented Mexican labor response we use a range of values. This reveals that as we move closer to matching the historical record on quantity change of undocumented labor usage we move farther from our targeted responses in prices. This is not an uncommon result to find in economic equilibrium models subjected to validation. Our results show that there are economic incentives which drive the increased population of undocumented Mexicans in this period of rapid growth in that population.

There is reason to believe that the economic structure can be refined to consider the historical record more narrowly. First, factor substitution is greatly simplified in this model and can be expanded to more input categories to better reflect the substitution possibilities. The second place to look is the factor supply which bears greater scrutiny. Looking at the structure of the equilibrium displacement model the supply elasticity here is measuring the response of potential undocumented workers in Mexico to US employment. This means the supply elasticity here is not only measuring the response to relative wages in alternative employment options (or vis-à-vis some reservation wage) but also the decision to cross the border and adopt the undocumented status. This is particularly important in light of the impact of border crossing cost increases over time; in the data section we saw that the cost of crossing using a coyote increased by +25% over the five years we are using in this historical simulation.

The increasing cost of border crossing over this period points to a reconsideration of the policy variable used to mark the price wedge between firm and worker prices for undocumented labor. Undocumented workers are subject to an implicit tax for working in the U.S. but this price wedge approach is composed of a number of changing factors that differ given the prices being used. Cost of living in the U.S. vs Mexico will be part of the real wage gap that is relevant in the response. Disutility of living abroad, risk of deportation, risk of criminal liability for the firm all contribute to the implicit taxation embodied in this wage. Tracking those separately as factors in this historical period will provide additional “levers” for evaluating the modeling approach and would be critical in any forward looking analysis of policy changes.

Finally, the five year period considered here with its increase of undocumented migration is but observations in a period which saw growing stock of undocumented Mexican migrants. A unique opportunity to examine a “fitted” structure to the 2002 – 2007 period on an “out of sample” period exists by applying the model to the 2008 – 2013 period. This is particularly relevant when looking at the figure on undocumented migration which shows sharp reductions in the undocumented Mexican population in the US; reversing the increase trend seen in the first decade of the 21st century.


Modeling undocumented migration from Mexico to the United States – A structural examination of available information and options for analysis

Draft for presentation, please do not cite


Modeling undocumented migration from Mexico to the United States - A structural examination of available information and options for analysis

Draft for presentation, please do not cite

**Appendix**

Table A1. Literature on migrant labor, input substitution

<table>
<thead>
<tr>
<th>Elasticity of Substitutions:</th>
<th>Domestic and foreign workers</th>
<th>Domestic and foreign unskilled workers</th>
<th>Documented and undocumented foreign unskilled workers</th>
<th>Immigrant labor and other production inputs</th>
<th>Native and immigrants who are both less educated (no HS degree or HS diploma only)</th>
<th>Native and immigrants who are both higher educated (some college degree or college degree)</th>
<th>Low skilled native and immigrant workers</th>
<th>Workers with no degree and workers with a high school degree</th>
<th>Broad education groups: Low (Workers with some college education or more) and High (those with a high school education or less)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Ottaviano and Peri (2012). When the nested model is constrained to same substitutability between any pair of education group and any pair of experience group with same education. Table 2, Panel A, the estimated coefficient $-1/\sigma_N$ range between $-0.024$ and $-0.071$. Most of them are around $-0.05$ implying estimates of $\sigma_N$ in the neighborhood of 20.</td>
<td>5 to 10</td>
<td>Econometric estimation absent</td>
<td>(0.7482, 0.8247). Values are determined from Ray (1982)’s translog cost analysis of US agriculture. Keller’s formula: $\alpha_0=\alpha_1=\eta_{ij}/\theta_j$ cross price elasticity of demand for immigrant labor relative to the price of other inputs/cost share of immigrant labour</td>
<td>11.1</td>
<td>Ottaviano and Peri (2012)</td>
<td>33</td>
<td>Ottaviano and Peri (2012)</td>
<td>Low substitution</td>
</tr>
</tbody>
</table>
Modeling undocumented migration from Mexico to the United States - A structural examination of available information and options for analysis

| Narrow education groups (among no degree and high school degree; among some college degree and college degree) | 10 | Ottaviano and Peri (2012) |
| College educated native and immigrant workers | Very close to zero | Ottaviano and Peri (2012) |
| Among native and immigrants workers who have no high school degree, who have high school degree and who have some college education | Imperfect substitution | Ottaviano and Peri (2012), the estimates of $-1/\sigma_N$ for the groups up to “Some college education” are very significant and between $-0.06$ and $-0.10$, with an average value around $-0.08$. They imply an average elasticity of substitution of 12.5. |
| Among different experience groups | 5.5 to 6.25 | Ottaviano and Peri (2012) |

Table A2. Literature on migrant labor, input substitution

| Wage Elasticities of Labor Supply | Wage elasticity of labor supply is often too inelastic to employ at competitive prices in unskilled industries | Taylor, 2010; Taylor et al., 2012 |
| Wage elasticity of labor supply for Mexican nationals in the US | 5.3 to 6.3 (wrt to work hours demanded) | Buccola et. Al (2011), data from Oregon nursery industry which employs mostly Mexican workers. |
| Wage elasticity of labor supply in Mexico wrt Mexican ag. wage | 1.25 to 1.43 | Hanson, 2007; uses Mexican employment data from 1990 to 2000 |
| Wage elasticity of labor demand in Mexico wrt Mexican ag. wage | -0.3 (low-skill workers); -0.28 (high skill workers) | Fajnzylber and Maloney, 2005 |
| Wage elasticity of hired ag. labor demand in US | 0.79 | Espey and Thilmany, 2000 |
References (Appendix)


