Immigration Reform and Farm Labor Markets

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Abstract

Farmers throughout the United States report a shortage of workers. At the same time, there are proposals to strengthen the enforcement of existing immigration laws. In this paper, we develop an equilibrium approach to examine the impact of removing undocumented workers from the California agricultural labor market, and to infer whether there is evidence of shortages using individual-worker data. We find evidence that is consistent with a persistent shortage in some sub-sectors of the California farm labor market. Further, we conduct counter-factual policy simulations over a range of possible policy alternatives, and find that removing 50% all undocumented farm workers from the state would lead to an increase in wages of over 22%.

keywords: equilibrium models, farm labor markets, shortages, unemployment, wage distributions.

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1 Introduction

Farmers in California, and elsewhere, report a shortage of agricultural workers (Blanco 2016), yet changes to immigration policy under consideration promise to reduce the supply of agricultural workers even further. Supporters of tightening restrictions on immigrant labor argue that higher wages would increase the quantity of domestic labor supplied sufficient to remedy the problem, but others argue that there is simply not enough domestic labor available to fill the necessary jobs. Understanding the true state of affairs in the agricultural labor market is critical as debate continues regarding changes to immigration policy in general, and temporary agricultural worker programs more specifically. In this paper, we develop an equilibrium-search approach to examine whether there is evidence of shortage of agricultural labor, and the labor-market impact of reducing the supply of immigrant workers.

The economic performance of labor markets has long been one of the primary issues of interest to macroeconomists (Lucas and Prescott 1974; Postel-Vinay and Robin 2002; Launov and Waldes 2013; Coles and Mortensen 2016; Lise, Meghir and Robin 2016). Because labor supply is key to macroeconomic output, and wage demands are a primary determinant of the wage-price spiral, labor-market equilibrium is a primitive of many macroeconomic models. The insights from these models are also useful for our purposes, because equilibrium job-search behavior, wage-determination and unemployment should also drive outcomes in farm-labor markets. Eckstein and van den Berg (2007) provide a recent review of this literature, and argue that equilibrium labor-market models based on insights from the job-search literature (BM, Burdett and Mortensen 1998) can answer most of the labor-market puzzles we face, including wage dispersion, the duration of unemployment, job-acceptance, labor-force participation, and the equilibrium gap between labor productivity – or firm's willingness to pay for labor – and observed wages. We use this approach to answer a similar set of questions in the context of a particularly large and diverse market for agricultural labor – the market for workers in the California crop sector.

Equilibrium labor search models assume workers search for new jobs only up to the point where the marginal benefit of searching is equal to the marginal cost of doing so. In equilibrium, firms pay workers their marginal value product, up to some gap that is determined by search frictions, or variation in bargaining power between firms and workers (Wolinsky 1987). Wage dispersion is driven by variation in worker productivity, and by the existence of search frictions as in the consumer price-search literature (Burdett and Judd 1983; BM). Equilibrium in the labor market therefore generates a set of estimable relationships between the timing of worker entry, exit, and changes in employment-status.

Empirical models of labor-market equilibrium are essentially duration models that are parameterized by observing individual workers' experiences in and out of the labor market, with different employers, and earning different wages for different tasks. With data on individual worker histories, we are able to identify all of the parameters that define equilibrium in the labor market, and draw inferences for aggregate labor market performance (Van den Berg 2001; Eckstein and Van den Berg 2007). That is, by estimating the wage-productivity gap over time, we are able to precisely identify periods wherein firms were forced to raise wages up to the (fixed) productivity level, or let them go back again due to inherent search frictions in the labor market. A shortage is defined by periods where the wage-productivity gap moves toward zero, relative to a period of normal performance wherein firms earn a positive gap between productivities and wages. We also able to simulate the wage-effect of removing workers from the workforce, and calculate the increase in wages necessary to maintain a sufficient number of farm workers in the state.

Empirical labor search models that focus on unemployment and wage-compensation issues in the macroeconomy tend to find application to near-ideal data sets, with unemployment durations sharply defined, job-arrivals cleanly identified, and wages measured with little error over a deep panel of individual workers. However, a similar data set does not exist to examine agricultural employment issues. While the Quarterly Census of Employment and Wages (QCEW) provides a deep snapshot of labor-market trends on a regional basis throughout the US, it does not contain detail on the experiences of individual workers, and the impact of worker heterogeneity on labor market outcomes (Hertz and Zahniser 2013). Data sets such as the Agricultural Resource Management Survey (ARMS) and the Census of Agriculture (CoA) provide more detail from an employer-perspective, but still lack the type of detail necessary to study how individual search behavior can explain agricultural labor market conditions. Therefore, in this study, we use data from the National Agricultural

Workers Survey (NAWS). NAWS is a retrospective, cross-sectional survey, in which workers report their most recent 52 weeks of labor history, in addition to their current status, and a range of demographic and socioeconomic variables. As such, the NAWS data represents a panel data set, albeit with each time-series limited to a relatively short period. We use the NAWS data to first draw some stylized facts regarding trends in wages and employment for workers in California agriculture, and then to estimate a structural model of agricultural labor search, bargaining, and equilibrium. With this data, we are able to identify key elements of the BM model, test structural hypotheses that shed light on the presence, or absence, of a shortage of agricultural workers, and calculate the expected effects of immigration-reform on the agricultural labor market in California.

Other studies use NAWS data to address questions similar to ours. For example, Tran and Perloff (2002) study whether farmworkers are likely to move to other occupations once they become legalized. If the security of citizenship causes farmworkers to move to other occupations, as critics of the then-proposed amnesty components of the 1986 Immigration Reform and Control Act (IRCA) contended, then legalization may in fact worsen farm-labor shortages. Using NAWS data, and a duration-like model similar to the one we develop below, the authors find that workers are not likely to move between occupations, so any amnesty program similar to the Special Agricultural Worker (SAW) program in the 1986 Act is not likely to worsen farm-labor problems. Further, Pena (2010) uses NAWS data to show that undocumented workers are paid between 5% and 6% less than workers with legal status – estimates that are remarkably close to ours, but using a different timeframe, and a different estimation method. Considering the opposite question from the same data, Kandilov and Kandilov (2010) find that legalization, or becoming a naturalized citizen, is associated with a 5% increase in wages, and a substantially higher probability of obtaining other benefits, such as healthcare insurance. Therefore, while the NAWS data set is not perfect for answering all agricultural-labor market questions, it is appropriate for the task at hand.

We account for the idiosyncrasies of agricultural labor markets. One of the primary differences between agricultural and non-agricultural labor markets, particularly in California, is the prevalent, and increasing, use of farm labor contractors (FLCs). FLCs are private firms that recruit workers looking for agricultural jobs, sub-contract them for a fee to individual farmers, either on a temporary or longer-term basis, and manage many facets of the traditional human-resource function, including regulatory compliance and payroll (Thilmany 1996). FLCs serve a valuable service, both to the workers and farmers, because they are able to provide relatively large numbers of workers, on short notice, and reduce the cost of searching for, validating, and conducting background checks on individual workers. From the employee's perspective, FLCs reduce their own cost of searching, provide a relatively stable flow of employment, and assure some form of continuity from job to job. In recent years, the majority of immigrant workers have been employed through FLCs (Martin 2016). Importantly for our purposes, although FLCs assume an important job-matching role in agriculture, they do not obviate the need for workers to search because FLC-workers tend to earn below-average wages (see table 2 below) and must move from employer to employer as part of the FLC relationship.[1] Clearly, if workers are not sufficiently satisfied with FLCs, they will continue to search for new opportunities.

We contribute to both the empirical literature on equilibrium search-and-matching, and the substantial literature on agricultural labor markets. While equilibrium labor-market models are in common use in the macroeconomics literature, we are not aware of any applications to agricultural labor issues. By demonstrating that this type of empirical model can be applied to the type of data available to researchers in agricultural economics, we hope to open up a new way of looking at farm-labor markets. Our application to agricultural labor markets is both inherently important because of the economic size of the sector, and interesting due to the special role played by the pool of low-skilled immigrant labor that is dominated by workers who are undocumented. In fact, we find that excluding all undocumented workers from the California farm sector will result in a 42.0% increase in wages – an increase of sufficient size to cause a dramatic change in the structure of the agricultural industry, and US food imports more generally. By studying the market-impact of undocumented workers, our research provides insight as to what radical changes to immigration-enforcement policy

[1] Thilmany (1996) provides survey evidence that documents the primary reasons why growers use FLCs, namely their ability to absorb the risk associated with immigration-enforcement actions, their greater knowledge of labor-market rules and regulations, and the relatively low cost of FLC-hired labor. This latter effect, however, may be partly due to some measure of monopsony power on the part of the FLC managers (Krissman 1995).

may portend for the larger economy if special consideration is not given to specific sectors of the economy.

In the next section, we describe how agricultural labor markets have evolved in recent years, and provide some evidence, from both anecdotal and previous empirical sources, that suggests how labor-shortages may arise. In the third section, we describe several alternative sources of data, and present some stylized facts regarding the performance of the California labor market over both a recent (2011 - 2016) and longer-term (1989 - 2014) period using a variety of observations from the available data. In section four, we develop an empirical equilibrium search model that is appropriate for identifying conditions of shortage, and for simulating a range of policy solutions. Section five consists of a discussion of our estimation results, and our findings regarding the likelihood that agricultural labor markets are in shortage, or surplus, and how equilibrium wages are likely to be affected by proposed changes in immigration policy. A final section concludes, offers some implications for farm-labor policy, and offers some suggestions for how our findings generalize beyond California, and beyond the agricultural labor market itself.

2 Background on Farm Labor Markets

Whether there is a sufficient number of agricultural workers in California is a matter of considerable controversy, and broader policy importance. While some argue that shortages are typical in US agriculture more generally (Holt 2008; Levine 2009; Fisher and Knutson 2012; Mercier 2015), Martin et al. (2016) claim that the opposite is true.[2] Because of a gen-

[2]Martin et al. (2016) use California Employment Development Department (EDD) data to argue that there are fully 829,000 agricultural workers in California, and only 410,900 agricultural jobs. The implication of this finding is that there is a dramatic surplus of agricultural workers, not the shortage that is widely claimed by growers. They arrive at this conclusion by counting the number of unique social security numbers (SSNs) attached to workers claiming agriculture as their primary source of income, and defining this number as the supply of workers. They then record the number of SSNs paid by employers, averaged by month, during the 2014 calendar year. The number of unique SSNs reported by growers is defined as the number of jobs, or the demand for workers. Because the supply is greater than the demand, the authors claim this as evidence of a surplus of agricultural workers. While this argument appears to be logically sound, the number of unique SSNs is a notoriously poor measure of the number of workers, simply because many undocumented workers have several. For example, the investigation following the infamous Agriprocessors raid by immigration authorities in 2008 found that "...76 percent of the 968 employees on the company's payroll over the last three months of 2007 used false or suspect Social Security numbers..." (Hsu 2008). SSNs are freely traded in many agricultural areas, and are regarded as much a commodity as the produce in the fields. Economic analysis cannot be based solely on a count of SSNs because they do not uniquely identify

eral lack of empirical research on this issue, the question remains as to whether agricultural labor markets are in shortage, surplus, or neither? More importantly, if farm labor markets are indeed in chronic shortage, how will tighter immigration enforcement affect market outcomes?

Agricultural labor markets have changed considerably over the past two decades. Fisher and Knutson (2012) explain that labor shortages and relatively high unemployment in rural areas can coexist because of the heterogeneity of labor markets. Aggregate data obscure the reality of labor markets that are highly local, and specialized. At one time, farm workers would travel across the state for the promise of a new job. However, Fan, et al. (2015) argue that the labor migration rate dropped some 60% between 1989 and 2009, essentially making the notion of a huge agricultural labor market willing to harvest any crop, anywhere, at a moment's notice, a fictional description of the modern farm labor market. Only 1/3 of the reduction in the rate of migration can be explained by demographic changes – workers becoming older and more established, for example – while 2/3 is due to "structural changes" or behavioral changes that mean farm workers are simply less willing to migrate at any wage differential. If workers are unwilling to move, then apparent surpluses may arise in certain localities, while more general shortages persist elsewhere.

There is no shortage of anecdotal evidence that growers have been forced to leave crops in the field unharvested due to a lack of available workers (Blanco 2016). For example, after passage of a strict immigrant-documentation law in Alabama lead many undocumented workers to leave the state, one grower said that "...of more than 50 people he recruited for the work, only a few worked more than two or three days, and just one stuck with the job for the last two weeks..." (Reeves 2011). Domestic workers simply will not do the types of jobs filled by immigrant laborers, and persistent labor shortages result (Mercier 2015).

Some argue that growers could attract the necessary number of laborers simply by raising wages enough to increase the quantity of labor supplied. However, this logic assumes that farm labor is relatively elastically supplied. Wei et al. (2016) find that the rate of substitution between domestic and immigrant labor (which forms nearly 50% of the workers in our California sample) is too low to make a plausible case for wage-induced substitution

a worker.

into agriculture. Further, Taylor et al. (2012) argue that expansion of job opportunities in Mexico, combined with a declining birthrate in the primary source for US farm workers, means that the elasticity of supply for workers is likely low due to structural factors that are not likely to change soon.

If farmers in the US cannot access immigrant labor markets, then they will have to rely on attracting domestic workers. But, agricultural labor markets do not work as smoothly as many would hope because many unemployed workers – workers who were laid off from jobs in other industries, for example – simply will not do the jobs that have been historically filled by immigrant workers (Richards and Patterson 1998). There is evidence to support this point, both empirical and anecdotal. In the academic literature on this topic, Kostandini, et al. (2013) and Illif and Jodlowski (2016) both examine whether immigrant employment is lower in counties that use section 287(g) agreements relative to those that do not. Briefly, section 287(g) agreements are county-level programs created under the Delegation of Immigration Authority provision of the Illegal Immigration Reform and Immigrant Responsibility Act (IIRIRA) of 1996 that allow local law enforcement agencies to enforce immigration laws, normally a job for ICE officers. Because some counties use 287(g) agreements, and others do not, if agricultural labor were fully fungible, we would see no difference in employment levels as laborers would naturally flow to areas where immigrant laborers have fled. However, both found the opposite as farmers responded to the resulting labor shortages by changing their output mix, reducing output, and losing income.

Market dysfunction has also favored farm-employers, however. Prior to passage of the 1986 Immigration Reform and Control Act (IRCA), which famously granted amnesty to thousands of undocumented farmworkers, many feared that newly-minted legal workers would leave the relatively obscurity of farm jobs for more skilled, and higher paying, jobs. However, Tran and Perloff (2002) use NAWS data to show that this was not the case – workers did not leave agriculture nearly at the rate that was expected, and shortages were no more problematic than before the Act.

Arguing that growers can remedy any perceived shortages through higher wages also assumes that growers are able to pay any amount necessary to attract workers. In equilibrium, however, the maximum wage a firm can pay is the worker's marginal value product, which depends on the nature of the production technology, and the state of the output market, neither of which is fully under the grower's control. Hand-harvesting, for example, cannot be fully automated. At the same, because agriculture is extremely competitive, output prices are typically determined in either national, or global, markets, so are out of the grower's control. Therefore, it is not simply a matter of paying more as there are hard limits to what a grower can pay.

The "infinite supply of labor" argument also assumes that agricultural labor is homogeneous in that anyone can do the jobs, and will be equally as productive. However, there is evidence that more experienced agricultural workers, because they are generally paid on piece-rates, can make far more than the minimum wage. In this environment, unskilled workers who are unwilling to stay with the job long enough to become efficient, will not make enough money to make farm jobs immediately rewarding. Immediate rewards, it seems, are necessary to induce the supply of labor necessary to fill all available harvesting jobs (Powell 2012). Moreover, partial attempts to address the issues surrounding immigrant labor are also fraught with unintended consequences. Most prominently, the executive orders limiting deportation by the Obama administration, while seeming to preserve the existing immigrant labor pool, may have had the unintended effect of providing workers the incentive to move up the career ladder, perhaps from farm jobs to higher-paying construction or service jobs. Over the long-term, these workers will not move back into the labor pool should job-market conditions change (Richards and Patterson 1998). Rather than move back to agriculture, these workers will instead become unemployed construction workers, essentially "ratcheting up" their labor prospects and creating a phantom pool of potential farm workers.

While there are strong *a priori* arguments for a low, or even zero, elasticity of labor supply, there are counter-arguments. Buccola, Li, and Reimer (2011) suggest that their estimated labor-supply-elasticity of between 5.3 and 6.3 is due to a large pool of unemployed workers in the state of Oregon. Over the sample period of our study, the unemployment rate in most counties of the Central Valley of California was well over 10% (California EDD), so the same general economic conditions that generated the Oregon results prevailed in California. Ultimately, therefore, whether the elasticity of labor supply is zero, small, or large in a qualitative sense remains an empirical question.

Empirically testing for labor-market shortages is problematic. Many have examined the nature of equilibrium in the agricultural labor market, whether it is integrated with non-agricultural labor markets (Richards and Patterson 1998), or whether it is simply in disequilibrium (Duffield and Coltrane 1992). However, given the inherent flexibility of the US labor market, it is unsatisfying to assume that disequilibrium can persist for more than a short period of time, so it is more likely that observed wages and employment outcomes are dominated by movement toward some steady-state equilibrium. Therefore, we adopt an equilibrium-search approach, and examine what the data tells us about labor-market equilibria in the past, and what equilibria may look like in the future through simulating proposed changes to immigration enforcement practices.

In summary, therefore, any treatment of agricultural labor markets must be within the context of a more general model of labor market equilibrium. There are a number of such tools at the disposal of labor economists (Eckstein and Van den Berg 2007), but none have yet been applied to the analysis of agricultural labor market issues. In this study, we develop an empirical model of equilibrium job-search, and use this approach to determine whether or not farm labor markets in California appear to be in surplus, or in shortage.

3 Empirical Model of Wage Determination

3.1 Overview

In this section, we derive our equilibrium model of job-search, and employer matching in the agricultural labor market. The model begins with the structural, asset-valuation approach developed by BM as a means of motivating the types of insights that equilibrium search models can provide for labor-market analysis. Because this model is excessively simple to extract any specific insights to the agricultural labor case, however, we then derive a variant of their structural approach that is both able to answer the questions at hand, and is appropriate for the data we have available. We then complete this section with a number of extensions that are intended to examine the robustness of our approach, and to admit perhaps other counter-explanations for what we find.

3.2 A Structural Model of Agricultural Job Search

There are essentially three types of labor-search models, developed in roughly chronological order: (1) optimal job-search (Lucas and Prescott 1974), (2) search and bargaining (Wolinsky 1987), and (3) equilibrium job search between firms and workers (BM). To briefly characterize the main difference between these models, in the first the employee is assumed to search optimally for a job that maximizes his or her lifetime earnings, without a strategic firm on the other side of the market. In this sense, Lucas-Prescott labor-search models are often termed "partial equilibrium" search models. The second type proposes an active firm in a more general equilibrium setting, but bargaining power determines the allocation of any employment surplus in an axiomatic Nash-in-Nash bargaining framework. The third, which is the approach taken here, assumes a posted-wage environment in which firms simply post wage offers, in competition with other firms, on the assumption that a relatively homogeneous labor pool exists to fulfill their needs. Meghir et al. (2015) describe the wage-posted model as most appropriate for unskilled labor-market environments in which, in normal times, there is an ample pool of potential applicants for any opening.

For our purposes, we briefly develop the theoretical structure of the BM approach, with a goal of highlighting the structural basis of our empirical model of labor-market equilibrium. Our focus is on the primary hypotheses that can be tested within this structure as they relate to determining whether markets are in shortage, or in surplus. The simplest version of the BM model proposes a rational employee who maximizes lifetime earnings by searching in an environment in which wage offers are randomly distributed, and employment offers arrive at random time intervals. Both unemployed and currently-employed workers search for jobs, and accept offers that are either greater than the flow of unemployed-utility in the former case, or than their current income flow in the employed case. In the most basic model, there is a continuum of homogeneous workers, and a similarly homogeneous continuum of firms. The key insight from BM is that if workers continue to search for a new job while working, and face some positive probability that their search will fail, then equilibrium wages will be disperse even if all workers and firms are homogeneous.

From the workers' perspective, BM assume workers solve an asset-valuation problem that embodies a real option value to searching for work if unemployed:

$$\rho V_0 = b + \lambda_0 \left(\int \max\{V_0, V_1(x)\} dF(x) - V_0 \right), \tag{1}$$

where ρ is the opportunity cost of capital, which determines the flow-return to the asset, b is the flow of utility if unemployed, λ_0 is the rate of job-arrival if unemployed, and the expectation is taken over the distribution of wage offers, $F(w)$. The intuition of the unemployed worker's problem is straightforward: He will continue to search so long as the value forgone if employed (rV_0) is greater than the flow of utility if unemployed (b) plus the expected capital gain earned by taking a job, provided that job is preferred to the current state. Analogously, a currently-employed worker solves a similar problem, but his opportunity cost is the forgone return on an asset value determined by his current employment situation:

$$\rho V_1 = w + \lambda_1 \left(\int \max\{V_1(w), V_1(x)\} - V_1(w) \right) dF(x) + \delta(V_0 - V_1(w)), \tag{2}$$

where V_1 is the value of an employed-worker's career, w is the wage, and λ_1 is the arrival rate, or probability of arrival in cross-sectional data, of a new job offer while employed, and δ is the rate at which worker-firm matches are destroyed. In equilibrium, the worker must be indifferent between being employed, and being unemployed, subject to frictions in the labor market that derive from uncertainty in the wage that will actually be earned in employment. This condition, and because V_1 is increasing in w, means that there is a reservation wage, r, such that:

$$r - b = (\lambda_0 - \lambda_1) \int_R^{\infty} \left(\frac{1 - F(w)}{r + \delta + \lambda_1(1 - F(w))} \right) dw, \tag{3}$$

where $r - b$ is the minimum opportunity cost of choosing to become employed, and the right side is the expected benefit of doing so. But, the flow of workers into unemployment, and out, depends not only on the distribution of offers ($F(w)$), but the distribution of earnings ($G(w)$), or of wages from those who have accepted offers. If u is the number of unemployed workers out of a total workforce of m, then van den Berg and Ridder (1998) show that the relationship between the two distributions is given by:

$$G(w) = \frac{F(w)}{\delta + \lambda_1(1 - F(w))} \frac{\lambda_0 u}{(m - u)}, \tag{4}$$

because the flow of workers into unemployment must equal the flow back out in a steady-state equilibrium. Because these flows must equal in the steady-state, we know $u/m = \delta/(\delta + \lambda_0)$, so the wage and earnings distributions are related by:

$$G(w) = \frac{\delta F(w)}{\delta + \lambda_1(1 - F(w))}, \tag{5}$$

in equilibrium. To this point, however, the equilibrium search relationships assume firm behavior is fixed. In the more general equilibrium approach of BM, however, firm behavior is endogenous, and strategic with respect to employee decisions.

We now describe the firm's role in endogenizing the wage-offer distribution. In the BM model, firms are assumed to post wages, instead of negotiating them with workers, while the surplus to employed labor is shared based on structural conditions in the labor market. This assumption is descriptive of agricultural labor markets as large-scale wage negotiations are not nearly as important as in other sectors of the economy. Posted wages are set in order to attract a labor force of $l(w; r, F)$, which is conditional on the reservation wage of workers, and the distribution of offers from other firms. Profit flow to firms is then given by: $(p - w)l(w; r, F)$ where p is the marginal value product per worker, and $(p - w)$ is the surplus offered to each worker, depending on the condition of the labor market. Because firms are identical, and the model describes a general equilibrium, profits must be equal across firms. Van den Berg and Ridder (1998) show that measure of firms paying a wage w is given by $g(w)(m - u)dw$, and the measure of employees earning w is $f(w)dw$, so the unique equilibrium workforce must satisfy:

$$l(w; r, F) = \frac{g(w)dw}{f(w)dw}(m - u) = \frac{m\lambda_0\delta(\delta + \lambda_1)}{(\delta + \lambda_0)(\delta + \lambda_1(1 - F(w)))^2}, \tag{6}$$

on the support of $w \in [w_L, w_H]$ where w_L is the maximum of any mandated minimum or the reservation wage, and $g(w)$ and $f(w)$ are the densities corresponding to the earnings and offer distributions, respectively. Intuitively, this equilibrium condition states that, in the steady-state, the flow into and out of unemployment must be equal. Further, if this equilibrium condition holds, and if a firm pays a wage on the lower support of the wage distribution, then its labor force will be:

$$l(w; r, F) = \frac{m\lambda_0\delta}{(\delta + \lambda_0)(\delta + \lambda_1)}, \tag{7}$$

in a steady-stage equilibrium. We use this condition in the empirical application below to simulate the equilibrium number of workers employed in California agriculture, conditional on the estimated parameters of the model.

Formally incorporating firm decisions allows us to fully endogenize the wage decisions of competitive firms in the industry. That is, each firm knows that all other firms must pay this wage in order to attract an efficient labor force. Wage dispersion in the steady-state arises due to the random nature of individual-worker reservation wages, and the fact that firms do not know what these wages are with perfect information. Imposing the market-equilibrium condition allows us to derive an expression for the distribution of equilibrium wage-offers:

$$F(w) = \frac{\delta + \lambda_1}{\lambda_1}\left(1 - \sqrt{\frac{p - w}{p - w_L}}\right), \tag{8}$$

which provides a functional form that serves as a basis for the empirical hypotheses that we test. The density function associated with $F(w)$, which is necessary to control for the truncated nature of our retrospective cross-sectional data described below, is given by:

$$f(w) = \frac{\delta + \lambda_1}{2\lambda_1\sqrt{p - w_L}}\frac{1}{\sqrt{p - w}}, \tag{9}$$

and the density associated with the earnings distribution, $G(w)$, is given by:

$$g(w) = \frac{\delta\sqrt{p - w_L}}{2\lambda_1}\frac{1}{(p - w)^{3/2}}, \tag{10}$$

both with support on $[w_L, w_H]$. Further, in the steady-state equilibrium, if the wage-offer distribution is as given in (8), then Van den Berg and Ridder (1998) show that the reservation wage is given by:

$$r = \left\{\begin{array}{ll} \frac{(\delta+\lambda_1)^2 b + (\lambda_0-\lambda_1)\lambda_1 p + \delta(\lambda_0-\lambda_1)w_L}{(\delta+\lambda_0)(\delta+\lambda_1)} & if\ r < w_L \\ \frac{(\delta+\lambda_1)^2 b + (\lambda_0-\lambda_1)\lambda_1 p}{(\delta+\lambda_1)^2 + (\lambda_0-\lambda_1)\lambda_1} & if\ r \geqslant w_L \end{array}\right\}, \tag{11}$$

and that the upper-support for the wage distribution will be:

$$w_H = \left(\frac{\delta}{\delta + \lambda_1}\right)^2 w_L + \left(1 - \left(\frac{\delta}{\delta + \lambda_1}\right)^2\right) p. \tag{12}$$

Our equilibrium job-search model holds a number of testable hypotheses that are relevant to identifying conditions in the agricultural labor market. First, the size of the labor force in

(6) is an increasing function of the wage, so we are able to test how changes in employment are affected by changes in the equilibrium wage. Assertions that firms can solve their perceived labor shortage problems simply by offering higher wages implicitly assume that this function is relatively elastic with respect to the wage. By identifying the parameters of the labor-supply function, we are able to test this hypothesis empirically. Second, parameterizing the reservation-wage function in (9) allows us to examine the how the reservation wage varies in the level of productivity (p), or the marginal-value product of agricultural employers. If we find that employers retain a relatively large share of the excess productivity ($p - w_L$) then this implies that they are able to offer substantially more, even in light of the relatively competitive state of California agricultural markets. Third, and most importantly, with this model we are able to conduct counter-factual simulations regarding potential changes to the enforcement of US immigration laws. Using the data described below, we are able to infer how many farm workers in California are undocumented. By removing all, or even some, of these workers, we quantify the wage-effects of the resulting backward-shift in the labor supply curve, and derive implications for the structure of the California agricultural industry.

3.3 Data and Identification Strategy

In this section, we describe the data used in our analysis, and establish some stylized facts about the agricultural labor market. We use both NAWS and QCEW data, but for different purposes. Namely, we use the NAWS data to estimate the equilibrium search model, and to examine wage behavior at the individual-worker level, and use data from the QCEW data to provide some model-free evidence of more general labor market conditions, across industries, in specific geographic areas. After presenting this summary evidence, we then describe our identification strategy in some detail.

We use NAWS survey findings for the state of California, from 1989 through 2014. In total, we have usable survey data from some 20,875 respondents, engaged in 6 separate work-tasks, and categorized by 6 different sub-sectors of agriculture. Our QCEW data describe employment and wage trends in the agriculture and construction industries from the first quarter of 2007 through the final quarter of 2012 for every county in California.

We use data from the QCEW as a means of investigating whether there is any evidence of farm-labor shortages from a data source that is complementary to our core NAWS data. The NAWS and QCEW data sets are related in that the universe of farmers sampled for the NAWS are drawn from the QCEW registry of farm employers.[3] We first summarize aggregate wage and employment data, by sector, from the QCEW. From this summary data, we observe an apparent relationship between equilibrium wages and the number of workers across two sectors that are likely to share a large number of potential employees. Figure 1 below shows that, for a county with substantial employment in both agriculture and construction (Fresno), wages and employment in agriculture appear to show a negative correlation, while the same is not true for construction.[4] While this summary evidence likely admits many different explanations, it appears to support the argument that growers are having a relatively difficult time finding workers, despite offering higher wages.

[figure 1 in here]

Data from the QCEW is at an aggregate level, however, so can tell us little about the attributes of workers that comprise the agricultural labor force. For this purpose, we use the NAWS data base, which is drawn from the same employer population as the QCEW, but surveys employees of the firms that report administrative wage and employment data to their respective state Employment and Development Department (EDD, or its non-California analog) offices. With the depth of the NAWS data, even for a specific region such as California, we are able to draw a number of important insights regarding worker-specific wage behavior from simple summary statistics and reduced-form wage regressions. We begin by examining a series of simple, "Mincerian" wage regressions. These regressions consist of linear, reduced-form regression models, that are estimated with ordinary least squares, and are intended to show how worker attributes are associated with average wages paid across different job-categories and industry sub-sectors. We show results from four models, each providing a successively more complete picture of the wage-model, and better fit from Model 1 through Model 4, in table 2 below.

[table 2 in here]

[3]See Hertz and Zahniser (2013) for an excellent summary of alternative data sets for agricultural-labor research.

[4]This figure shows data only for Fresno County, but others show a similar relationship.

A few remarkable, and robust, observations are readily apparent from these summary regressions. First, workers employed by FLCs earn over $0.46 / hour, on average, less than those who are employed directly. While some of this discount may reflect lower transactions costs associated with finding employment, it may also measure some of the lower risk associated with working through a FLC instead of sorting through dozens of individual employees (Thilmany 1996). Second, agricultural wages are trending upward at approximately 3.0% per year. While this rate of increase is reflective of a broader return to wage-inflation across the general economy, the fact that it is greater than the rate of increase of farm prices (USDA) or even unskilled-wages in other closely-related sectors (BLS) suggests that growers are indeed increasing wages in response to their inability to attract sufficient workers to harvest the crops that they planted, in expectation of meeting market demand. Third, growers tend to pay female workers over 5.5% less than male workers in the same employment categories, and in the same industries. Whether this reflects a perception of lower productivity, or a broader pattern of discrimination in the agricultural labor market is beyond the scope of this paper, but is indeed a feature of the data. Fourth, our reduced-form model shows that there are statistically significant, yet small, returns to education. Each additional year of education provides an incremental $0.04 per hour, on average, or less than a 1.0% increase in wages. Fifth, relative to the base-case hourly rate, workers who work in a piece-rate environment (paid by the pound, basket, or carton) or are paid on a fixed salary, tend to earn significantly more than those who are paid on a straight hourly rate. Unlike other marginal effects, the payment-method variables are economically important as they represent a 23.2% premium in the case of piece-rate payments, and nearly double when the worker is on salary. Keeping in mind that these estimates are holding job-assignment, experience, and education constant, they suggest that different payment arrangements are associated with dramatically larger wage-rates, and annual incomes. Unfortunately, the NAWS data do not contain productivity measures that would allow us to estimate whether these wages are associated with higher levels of production, in an objective sense.

Perhaps most importantly, we find that there is a substantial discount associated with undocumented status.[5] In fact, the estimates in table 2 suggest that the discount is fully 4.2%

[5] Our data also contains an indicator of whether the worker was "foreign born" or "domestic," but this

of average wages – enough to fully offset any gains from the general trend in agricultural wages noted above.[6] While it is tempting to form a conclusion that this is statistical evidence of employer-discrimination against undocumented workers, an equally plausible explanation is that they are simply, and rationally, accounting for the risk that the worker could be removed at any time during the harvest. Having to account for the uncertainty of losing workers at the time of greatest need by discounting wages is surely a reasoned response to a volatile policy environment. However, these estimates remain reduced-form in nature, so may not represent equilibrium responses in which firms and workers optimize over their respective decisions. Moreover, Sampaio et al. (2013) show that any estimated immigrant-wage discount may instead be explained by properly accounting for skill deficiencies. In section 5, we present the results from estimating a model that takes these structural considerations explicitly into account.

Before describing our structural model of labor-market equilibrium, we first discuss how we identify the key parameters of the equilibrium search model. Other empirical models in this literature (see Eckstein and Van den Berg 2007) have access to far richer, panel data sets such as the National Longitudinal Survey of Youth (NLSY) in which each cross-sectional observation (individual) may experience several employment and unemployment durations over the years throughout their work career. Identification in this case is clear as panel-data methods are used to exploit both temporal and cross-sectional variation within and between survey participants. In our case, the NAWS data does not follow the same individuals on an annual basis, but provides more frequent observations within each employment-year. Because each survey respondent reports a retrospective on his or her prior 52 weeks of work experience, our data reveal multiple-spells of employment, unemployment, or changes in employer that are sufficient to identify the parameters of the duration model.

Van den Berg (2001) provides a detailed and rigorous derivation of the conditions for identification in single- and multiple-spell mixed-proportional hazard (MPH) models, a class of models that includes ours. He finds that identification is likely not possible in data covering

effect was not separately identified from the variable measuring work-authorization status, so we include the latter as it is more important for policy purposes.

[6]This estimate is very similar to findings of Pena (2010) and Kandlikov and Kandlikov (2010), both also from NAWS data.

single-spells, but is assured in models with multiple-spells per respondent. So, whether or not the duration model we present is identified in our data hinges on the existence of a mix of multiple- and single-spells of employment and unemployment. In the NAWS data, a "spell" is defined as any period of time within the 52 weeks if the respondent reported stopping work for a period of time, regardless of the reason. In our sample, fully 96.7% of the respondents reported the type of multiple-spells that are required for identification. Therefore, we are confident that the parameters of our duration model are identified given the conditions specified in Van den Berg (2001). We provide more detail on the nature of the empirical model in the next section.

3.4 Empirical Model of Farm Wage Dispersion

In this section, we derive an empirical model of equilibrium job search and wage dispersion, and describe its application to the NAWS data. While existing empirical applications of the BM model all rely on highly-disaggregate panel data, largely gathered for purposes that do not lie far from the original motivation of the modeling effort, our agricultural labor market data are somewhat different. Nonetheless, we can still recover parameters that provide the same information as the structural model derived above. Namely, we observe durations of employment, and unemployment, and the wage received when employed. From our theoretical model, the parameters we estimate are $\delta, \lambda_0, \lambda_1$,and p, while the remaining elements of (8) - (10) are data. We extend the base model of Van den Berg and Ridder (1998) to incorporate both observed and unobserved worker-heterogeneity, and demonstrate how we use this model to test for evidence of farm labor shortages.

We begin with a base-model (Model 1) in which we assume no heterogeneity among workers. In general, the empirical model is a duration model, where the durations comprise the time spent unemployed (τ_{i0}) and employed (τ_{i1}). In the NAWS data, these durations are measured by the variable NWWEEKS (non-work weeks), and the sum of FWWEEKS (farm-work-weeks) and NFWWEEKS (non-farm work-weeks), respectively. The likelihood-contribution for each individual i is, therefore, the density of the distribution of the unemployment duration, weighted by the proportion of time spent unemployed, multiplied by the density of the distribution of the employment duration, weighted by the proportion of time spent employed. While the arrival rate when unemployed is assumed to be exogenous, the arrival rate when employed depends on a random draw from the distribution of wage offers, $F(w)$, and the density of the earnings distribution, $g(w)$. As is most usually the case with duration models (Cameron and Trivedi 2005), we assume the duration is exponentially distributed. With this assumption, the likelihood function for our sample of I NAWS respondents, therefore, is written as:

$$\mathcal{L}(x, \tau_1, \tau_0, w|\delta, \lambda_0, \lambda_1, b) =$$
$$= \prod_{i=1}^{I} \left(\frac{1}{\lambda_0 + \delta} \right) (\delta \lambda_0^{d_{i2}} \exp(-\lambda_0 \tau_{i0}))^{d_{i1}} (\lambda_0 g(w_i)(\lambda_1(1-F(w_i)))^{d_{i2}} \exp(\delta + \lambda_1(1-F(w_i))\tau_{i1}))^{(1-d_{i1})},$$

where $g(w)$ is the earned-wage density associated with $G(w)$, d_1 is a variable measuring the proportion of time spent in unemployment, τ_{i0} is the duration of unemployment, τ_{i1} is the duration of employment, d_{i2} is a binary variable that equals 0 if the observation is right-censored (the duration spell is equal to 52.25 weeks in the data), and the other parameters and variables are a defined above.[7]

In our first extension to the base model (Model 2), we correct the likelihood function for censoring due to the fact that our data are from a retrospective survey, and not a longitudinal panel. Approximately 15% of survey respondents experienced a duration of either unemployment or employment that was constrained by the 52.25 week limit placed on the data.

A natural extension to the base model (Model 3) considers observed heterogeneity in productivity, similar to the reduced-form wage equations in table 2. In fact, Van den Berg and Ridder (1998) consider observed heterogeneity in each of the $\lambda_0, \lambda_1, \delta$ and p parameters. With our more limited data, however, we restrict attention to heterogeneity in the marginal productivity parameter, p, which determines the wage that the firm is able to, if not willing to, pay in equilibrium and the δ parameter, or the rate of job-destruction.

Recall that the marginal-value product of labor is defined by equation (8) above. As such, the value of p represents the equilibrium "willingness-to-pay" from the employer's

[7] Note that because the duration model implies an exponential distribution of employment-spells, our likelihood function represents a right-censored exponential distribution.

perspective, given their uncertainty regarding individual reservation-wages, and the wages that other firms are offering to induce workers to take jobs. In our empirical model, we infer the value of p from observed wages, and the times spent either employed, or unemployed. It is reasonable expect that the perceived marginal-value product for each worker varies according to attributes that reflect not only investments in human capital (e.g., education and years of experience) but also attributes that may reflect employer perceptions, biases, or expectations of risk. In this latter class, age, gender, and immigration status are expected to be prominent. Therefore, we allow the productivity parameter in (8) to be a function of the crop in which the worker is employed ($S_c,\ c = 1, 2, ..., C$), the nature of the job carried out by the worker ($O_j,\ j = 1, 2, ..., J$), and a vector of $k = 1, 2, ..., K$ exogenous attributes, $\mathbf{Z}$, such that:

$$p_i(\mathbf{S}, \mathbf{O}, \mathbf{Z}|\boldsymbol{\alpha}, \boldsymbol{\phi}, \boldsymbol{\psi}) = \beta_0 + \sum_{c=1}^{C} \alpha_c S_{ic} + \sum_{j=1}^{J} \phi_j O_{ij} + \sum_{k=1}^{K} \psi_k Z_{ik} + \sigma_p \mu_i, \tag{13}$$

where the attribute-vector $\mathbf{Z}$ consists of:

$FLC = 1$ if the respondent is employed by a FLC;

$TR =$ a linear, annual trend measuring the increment in average wages;

$AGE =$ respondent age, in years, and age-squared;

$GND = 1$ if the respondent gender is female;

$ED =$ years of education, reported by the respondent;

$YRS =$ years of farm work of any type reported by the respondent;

$ENG = 1$ if the respondent considers him / herself proficient in English;

$BEN = 1$ if the respondent receives either free healthcare or housing;

$PC = 1$ if the respondent is paid by piece-rate instead of hourly;

$SAL = 1$ if the respondent is paid on a fixed annual salary;

$STATUS = 1$ if the respondent is not a citizen, nor holds a valid work visa;

$\mu =$ an iid normal error term with scale parameter σ_p,

and the crop and job descriptors are as provided in table 1.

For each worker-attribute, the estimated structural coefficient is interpreted as the change in the equilibrium productivity value for a one-unit change in the variable of interest. As equilibrium effects, the estimated parameters capture not just changes in marginal productivity associated with a worker or job-attribute, but the steady-state outcome of firms competing for the same pool of workers, and creating pressures for the productivity of the last worker hired to rise over time. For example, the trend variable is more likely to capture changes in the competitive environment than any exogenous change in technology. Given the general increase in wage inflation over the period, we expect the trend coefficient to be positive, yet small. Although agriculture is imperfectly correlated with the general economy, there is likely to be sufficient cross-over between agricultural and non-agricultural workers so that equilibrium wage demands, which should reflect a general tightening of the labor market over the sample period, will cause observed wages to rise. Further, because our sample includes periods of much higher inflation than experienced in the 2010s, wages are likely to reflect some nominal wage inflation from the general economy.

Similar reasoning guides our expectations as to the marginals associated with each of the other attribute variables. Namely, we expect worker-age to have a quadratic effect on wages, rising with a perception of accumulated learning (controlling for job-specific experience), but only up to a certain point, after which perceived productivity is likely to fall. Further, if empirical research on gender wage-equality in other sectors holds true for agriculture, we expect the coefficient on the GND variable to be negative, reflecting either a discriminatory expectation of lower productivity, or a response to the uncertainty that female workers may exit employment due to childbirth. Fourth, despite the generally-unskilled nature of most farm work, we nonetheless expect to find a positive return to education. Some of the occupational categories captured by the NAWS survey are managerial in nature, so respondents with more education are likely to be compensated consistent with their managerial skills and not necessarily their productivity in manual tasks. Fifth, controlling for age, we expect agriculture-specific experience to have a positive effect on wages as more experienced workers at each age level are likely to be more productive. Sixth, we expect English-speakers to earn more than those who cannot read or write the language as employers are more likely to place a higher value on workers they can communicate directly with. Seventh, payment by piece-rate, and by annual salary, are expected to both have positive effects on the hourly wage-rate. Workers paid by piece-rate tend to have greater incentive to work not only harder, but more efficiently. Most farm-labor environments are structured so that piece-rate workers are able to earn relatively high hourly wages if they choose to do so. Workers on annual salaries, on the other hand, tend to be more managerial in nature, so are compensated more for the tertiary skills they bring to the job, rather than raw productivity. Consequently, we expect equivalent-hourly wages for workers on salary to be higher than would otherwise be the case.

The NAWS data is somewhat unique in that it is an employer-based survey in the sense that firms provide the sampling frame, but survey respondents are workers themselves. Therefore, the survey contains measures of immigration status that may be otherwise unknown to employers. Specifically, respondents are asked to report whether they are US citizens, hold a valid US work visa, or are otherwise undocumented ($STATUS$). With this question, the NAWS data provide an opportunity to examine how a lack of legal status effects equilibrium labor-market outcomes. Because these estimates are assumed to reflect employer perceptions of risk, we expect to find a negative marginal value associated with undocumented status as workers without permission to work in the US could leave anytime, whether of their own volition, or due to arrest and deportation.

With respect to heterogeneity in the δ parameter, we allow the mean estimate to vary by the vector of occupation dummies introduced above, so that δ varies by individual such that: $\delta_i = \sum_{j=1}^{J} \delta_{ij} O_j + \sigma_\delta \nu_i$, where ν_i is an iid normal variate, and σ_δ is the associated scale parameter, and each of the mean δ_j estimates reflect occupation-specific rates of job destruction. We interpret a negative value of δ_i as a negative rate of job destruction, so that the steady-state, job-specific rate of unemployment is: $u_j/m = \delta_j/(\delta_j + \lambda_0)$. Logically, a negative unemployment rate is interpreted as an excess-demand for the occupation in question, or a shortage. With the 6 different job-classifications available in the data (pre-harvest, harvest, post-harvest, semi-skilled, supervisory and other) we expect to find a negative value of δ_j for harvest workers, but positive estimates for the others.

4 Results and Discussion

In this section, we first present the results from estimating several versions of the duration model derived above, with the intent of determining the importance of accounting for the censored nature of our duration data, observed and unobserved heterogeneity in the marginal value product function, and then heterogeneity in the rate of job destruction. In each case, the estimated parameters allow us to draw out pieces of evidence as to whether the California agricultural labor market over the period 1989 - 2014 exhibited signs of shortage, whether producers can reasonably be expected to meet their needs through higher wages, and the probable labor-market impacts of an exogenous reduction in the supply of immigrant workers.

4.1 Model Estimates

Our demand-model estimates are shown in table 3 below. The core estimates from the empirical model of labor-market equilibrium are the rate of job-arrivals if unemployed (λ_0), or employed (λ_1), the rate of job-destruction (δ), and the equilibrium marginal-value product (p). Because of search frictions in the labor market, the marginal-value product available to be paid to workers is not necessarily equal to the observed wage. We exploit this fact in deriving the implications of our estimates for the state of the labor market in general.

Model 1 in table 3 shows maximum-likelihood estimates obtained when we ignore the fact that the NAWS data provides censored observations of the likely true unemployment and employment durations. According to these estimates, the average farm worker in California is likely to experience 1 job offer approximately every year if unemployed, or about 1 every 3 years when employed. If a match is formed, it is subsequently destroyed at a rate of about 4% per year – a value that is particularly low given that it implies a typical worker is laid off once every 25 years. Further, the estimate of p implies that the equilibrium marginal-value product is about \$15.15, on average. However, these estimates ignore the fact that the data reported by workers in NAWS reflects only their prior 52 weeks of employment history, so any duration of employment, or unemployment, is censored at 52.25 weeks.

[table 3 in here]

We account for the censoring of the employment and unemployment durations in Model 2 by modifying the likelihood function accordingly (Cameron and Trivedi 2005). Because very few unemployment-durations are censored in our data, we expect that the effect of accounting for censoring will have a greater impact on our estimates of the rate of job-creation while employed, and less effect on the estimated rate of exiting unemployment. In fact, the estimates from Table 2 confirm this as the rate of job-offers while employed falls below the offer-rate while unemployed, but the point estimates are much closer to each other in this case. This finding is also expected based on prior results from longitudinal surveys of workers in the general economy (Van den Berg and Ridder 1998) and the fact that job-search is likely to be more intensive while unemployed than employed. Accounting for censoring of employment durations, the average worker can expect to receive a job offer about once every 5 years if currently employed. Removing this source of bias also causes the estimated marginal-value product to rise slightly, to \$15.23 per hour. As in any model of labor-market outcomes, however, averages tend to mask the importance of heterogeneity, due to either observed attributes that are likely to be associated with revealed productivity, or employers' perception of it.

In Model 3, we account for observed heterogeneity by allowing workers' marginal-value product to vary with the same set of attributes as shown in table 2 above. Accounting for observed heterogeneity leads to a higher point estimate for λ_0, but the estimate of λ_1 is roughly the same as that reported for Model 2. The estimated rate of job-destruction, however, is over twice as high, while the estimated marginal value product is substantially lower. More importantly, with this model we are able to comment on how worker attributes are associated with different values of the equilibrium marginal value product. Consistent with the summary findings in table 2, the estimates from this model show that there is a significant discount associated with FLC employment and gender, but age does not have the hypothesized quadratic effect on perceived marginal-value product. English-speakers, those who earn health or housing benefits, workers who are paid by piece-rate, or on a fixed salary, are perceived to be worth more to the firm than others, substantially so in the case of salaried workers. We also find a significant discounted associated with undocumented status, with a point estimate over double that reported in table 2.[8] These estimates, however, do not account for the fact that many important worker-attributes are likely to be unobserved by the survey-administrator, but apparent to the employer.

[8]This large negative value associated with undocumented status is in sharp contrast to Devadoss and Luckstead (2008), who argue that the marginal value of an immigrant worker is large, due partly to the complementary effect with non-immigrant workers.

In Model 4, we extend the model to take into account the expectation that unobserved heterogeneity, likely due to inherent ability or personality attributes that are not reflected in the data, may affect search behavior, job-loss, and perceived productivity. We model unobserved heterogeneity using a random parameters approach, assuming each of the 4 core parameters is randomly distributed (normal) over individuals with a constant mean, and scale parameter estimated from the data. Allowing each of these parameters to vary randomly across survey-respondents produces not only a substantial improvement in model fit, but reduces some of the parameter-bias associated with miss-attributing ability to observed wage and duration data. By accounting for unobserved heterogeneity, we find results generally consistent with those reported in Model 3, but the significant negative marginal value attributed to female workers is now much smaller, there is a much larger premium associated with English-speaking workers, and a greater discount for undocumented workers. After controlling for both observed and unobserved heterogeneity, the point-estimate for the mean marginal-value product falls to nearly \$14.28. Accounting for unobserved heterogeneity appears to remove some of the perceived productivity that was previously associated with unobserved factors.

The estimates in Model 4, however, assume that the rate of job destruction is constant across occupations. Therefore, Model 5 introduces observed heterogeneity in the δ function as suggested by Van den Berg and Ridder (1998).[9] By allowing for heterogeneity in the rate of match-destruction, specifically by job-description, we can pick out aggregate discrepancies between the number of workers willing to do particular jobs, and the demand for them. According to the summary data in table 1, the most numerous job-classification is "semi-skilled" laborer, followed closely by workers who are hired only to "harvest." Given the anecdotal data reported in the media of growers unable to find workers to pick crops at specific times of the year, we expect to observe a negative value of δ_j for harvest workers, but not necessarily for the others. In fact, the estimates reported in table 3 support this hypothesis as the estimate of δ_j for "harvest" is significantly different from zero, and negative. We interpret this finding as implying that there is a shortage of harvest workers, on average,

[9] Note that the value of the LLF for Model 5 is not directly comparable to the others because the other models are not nested within this more general specification.

over the sample period, roughly of the order of magnitude of 7.5% of the workforce. As an average, however, this estimate does not mean there was a shortage during each year of the sample period, nor even in the most current year, but that arguments for a shortage of labor do have some statistical support in an average sense. By introducing heterogeneity in the δ function, the remaining estimates are qualitatively consistent with the estimates in the other specifications, except that the trend rate of productivity is now much lower than in the previous models, and that reflected in the wage trends of table 2.[10]

While these estimates are of some inherent interest, they are of little direct interest to the important policy questions concerning whether labor markets are indeed in shortage, whether any shortage can be quickly addressed through higher wages, or the implications of a dramatic reduction in the supply of immigrant workers. Given the prior results from Kostandini et al. (2014) and Ifft and Jodlowski (2016), and the fact that fully 48% of our sample were undocumented, we expect that any further restrictions on labor supply will have a substantial effect on the labor market. We address these issues in the next section.

4.2 Policy Simulations and Model Implications

Despite the simplicity of the model developed above, the estimated parameters provide a number of important insights into outcomes that have real importance to agricultural employers. In this section, we describe three counter-factual simulations that provide different perspectives on the state of the agricultural labor market, and potential impacts on wage and employment outcomes. Each of these simulations use the structural estimates shown in table 3 above, and are calibrated using the most recent NAWS data available, from 2014.

In the first simulation, we answer a purely hypothetical question, but one that is at the core of the debate regarding how to resolve any perceived labor shortages. That is, if there is a shortage of farm labor, then how much of a wage increase would be necessary to eliminate it? To answer this question, we calculated the amount of labor supply using equation (6) at each point of the equilibrium wage distribution. Based on media reports of interviews with growers, the perceived labor shortages are at the bottom end of the distribution, or attributed

[10] Estimated productivity values may also vary by policy regime. We tested this hypothesis by allowing productivity to differ between the base regime (pre-2001), the Bush administration (2001 - 2008), and the Obama administration (after 2008). None of the fixed-regime indicators were statistically significant.

to those earning near the lower support of the wage distribution. We then calculated the elasticity of labor supply at this point of the distribution, calibrated using 2014 data, and estimated how much of a wage increase would be required to bring forth a hypothetical 10% increase in the number of workers.[11] At the lower support of the wage distribution, the elasticity of labor supply is a surprisingly-large 1.181,which likely provides a conservative estimate of the required wage increase necessary to raise the supply of workers sufficient to close any existing shortage.[12] At the assumed 10%-increase level, we find that the wage support would have to rise from \$8.00 to \$8.68 in order to attract an additional $43,000$ workers. This seems reasonable, and growers could possibly absorb a 8.5% increase in wages if they are able to pass them through to packers and retailers.

By estimating an equilibrium model of the farm labor market, however, we need not rely on perceptions of whether wage increases are likely to be absorbed. Rather, our model provides further insight as to whether the additional \$0.68 can be internalized by producers by comparing the incremental wage requirement with the amount of "friction" in the labor market, measured by the gap between the marginal-value product and the observed wage, or $(p - w)$. Whether friction is attributable to workers' equilibrium search costs or the amount of monopsony power possessed by employers (Wolinsky 1987) is immaterial for empirical purposes as we interpret the gap as simply the amount of value that could be returned to workers if the labor market were sufficiently tight. Calibrated using 2014 data, we find that the equilibrium margin is approximately \$0.21, as the estimated value of $p = \$15.02$ while the calculated value of $w = \$14.81$, which would not be enough to achieve the 10% labor-force increase cited above. However, if employers were to give up all of their transaction surplus to attract new workers, the estimated parameters imply that they could hire an additional $13,447$ employees. Adding this many workers would likely help the situation, but would require a level of competitiveness in the labor market that would be likely unachieveable in practice.

[11] Note that the qualitative outcome is the same whether we use a 1% increase, 10% increase, or 20% increase. We chose 10% as illustrative of the magnitude of the perceived shortages as the calculations are very simple to make using the equations in the text.

[12] Buccola, Li, and Reimer (2012) also find the elasticity of farm-labor supply to be very high elastic, or wages to be "...rather inflexible..." in their terminology (p.1).

Further, the theoretical model implies that the flow into and out of unemployment must be balanced, so we can infer the rate of unemployment in the steady-state using the estimated parameters of the model, or $u/m = \delta/(\delta + \lambda_0)$. With the heterogeneity estimates in Model 5 of table 3, we recognize that unemployment rates are likely to differ according to specific occupations: Media reports of labor shortages do not refer to supervisory or semi-skilled laborers, but nearly always refer to shortages at harvest time (Brat 2015; Blanco 2016). Using these estimates in table 3, we report these occupation-specific unemployment rates in table 4. Some occupations, such as the most-numerous "semi-skilled" worker category, and the most highly-paid "supervisory" workers, have 2014 unemployment rates of over 8.3% and 13.3%, respectively, suggesting that jobs are destroyed often, and are not replaced. On the other hand, the unemployment rate for "harvest" workers is -8.8%, which we interpret as indicating a shortage of workers specifically for the harvest. In other words, jobs are destroyed at a negative rate for this specific task as there is insufficient supply to meet the demand from firms, even in the steady-state equilibrium. This finding mirrors industry concerns that, given the general and historic dysfunction in US immigrant-worker law, labor shortages are chronic and not merely a feature of our current policy environment.

[table 4 in here]

Finally, we consider the potential effects of applying existing immigration law with varying levels of rigor. That is, we consider a policy that eliminates all undocumented workers (48% of the sample workforce), half of the undocumented workers (24%) and only a relative few that may have prior criminal, or other legal, histories that may put them at risk of deportation (10%).[13] In this case, our simulation involves shifting the labor-supply curve back at each wage, and calculating the new equilibrium wage using the estimated parameters in table 3. This exercise involves calculating the entire wage distribution using equation (8), and then calculating the associated steady-state labor force using equation (6). However, we recognize that the impacts are not likely to be felt at the upper-support of the wage distribution, so consider changes at the lower end, and calculate the new equilibrium wage

[13] We acknowledge that equilibrium forecasts of 50% and 100% labor-force reductions are extreme, and have relatively large errors, but these are reasonable estimates in light of the stated policies of the current administration.

that would be required to call forth the minimum supply of labor at the lower-support of the wage distribution.

Using this approach, we find that a 10% reduction in the number of undocumented workers would cause the equilibrium lower-support wage to rise from \$8.00 to \$8.70. As suggested in the first simulation above, a roughly \$0.70 wage increase could, plausibly, be absorbed by growers. However, a 24% reduction in the workforce would cause the lower-support wage to rise to \$9.76, which would cause a substantial rise in labor costs, and likely create incentives for growers to search for new ways to mechanize the harvest. Ultimately, an increase in cost of this magnitude would likely drive more of the industry to other low-wage regions, such as Mexico or South America.

In the extreme event that Immigration and Customs Enforcement (ICE) is successful in removing all undocumented workers, we find that the lower-support wage would rise to \$11.36, fully 42.0% higher than in the 2014 base-case. A wage increase of this magnitude would almost certainly cause growers to move to less labor-intensive crops, and would have consequential effects on the ability of California to produce its current portfolio of high-value commodities. Machine-harvesting would be a near-certainty, yet a wage increase of this magnitude may be sufficient to call forth at least some supply of domestic workers.

Taken together, these simulations, along with our summary observations, show that there is evidence of substantial pressures in the California agricultural labor market. Our structural estimates show that there is an inherent negative unemployment rate for harvest-workers in California, which supports anecdotal evidence from growers, reported widely in the media, that sufficient workers are simply not available at any wage. While our theoretical model of equilibrium search suggests that sufficient workers would be available if growers would be willing to increase wages by 8% or more, our estimates also indicate that there simply may not be enough surplus in the wage-employment transaction to pay workers that much. Perhaps more importantly, an hypothetical data experiment into the possible labor-market impacts of more intensive enforcement of existing immigration laws shows that equilibrium wages could rise from 8.8% if only 1/5 of current undocumented workers leave the country, to fully 22.0% if a more reasonable estimate of 50% of workers leave. A wage effect of this magnitude would have dramatic effects on not only the fresh fruit and vegetable industry in

California, but low-skilled, labor-intensive industries throughout the US.

5 Conclusion and Implications

In this paper, we consider how tightening enforcement of immigration laws can be expected to effect the California agricultural labor market through the perspective of a equilibrium-search model of unemployment and wage-formation. While there is ample anecdotal evidence that there are persistent shortages of farm labor – shortages that have been periodically exacerbated through more intensive immigration-law enforcement policies at the state and local level – there is little empirical evidence that would support an assertion that these shortages cannot be addressed through higher wages.

An equilibrium-search approach is useful because it provides a parsimonious framework through which we can better understand the incentives workers have to join the labor force, or to move from one employer to another, consistent with the incentives employers have to offer them jobs. Because of the large volume of recent empirical work in this area by macroeconomists, we have a well-developed understanding of the empirical methods necessary to estimate structural versions of these models, and the type of data required. With the structure provided by an equilibrium-search framework, we estimate endogenous wage offers, employment and unemployment durations, as well as the marginal-value product that employers have available to pay. Most importantly, all of this information is recoverable from existing surveys of agricultural employment.

We estimate an equilibrium-duration model using data from the National Agricultural Workers Survey (NAWS) from 1989 - 2014 for workers in the state of California. Summary observations from this data show a persistent trend of rising wages, but lower pay for female and older workers in the same employment categories, in the same sub-sectors, and with the same educational and immigration background as other workers. Moreover, we show that undocumented workers are paid, on average, roughly 6% less than workers who are legally allowed to work in the US. Our structural estimates support these summary observations, in general, and provide further evidence that employers are not likely to be able to pay workers enough to address any shortage that may exist. Further, we find evidence of a persistent negative unemployment rate for harvest workers, which implies that shortages are not just anecdotal, but a feature of the survey data. Finally, we show that a complete exclusion of undocumented workers is likely to result in a 42.0% increase in wages for the lowest-skilled workers. While this hypothetical outcome would seem to be a good thing from the workers' perspective, in all likelihood it would not be forthcoming from employers (who have only 2% surplus to spend) so would result in a fundamental realignment of the agricultural industry in California, from labor-intensive to labor-extensive crops, and would accelerate the search for mechanized solutions to many more tasks now carried out by humans.

Our findings are likely to have broader implications beyond the California agricultural industry. With an aggregate unemployment rate below 5.0%, the US economy is arguably near full employment, so many sub-sectors of the economy have more job openings than there are workers available to fill them (Moore 2015). Attempting to address worker shortages by offering higher wages may fail in other industries for reasons similar to that encountered by agricultural employers – there are simply no workers available that are either willing, or able, to do the work. For industries that draw on the same labor pool as farmers, including hotels, fast-food restaurants, and even construction firms, tighter immigration restrictions will mean dramatically higher wages and, somewhat counter to the goals of the program, greater incentives for illegal border crossing. Ultimately, without other goods-market distortions, imports of labor-intensive goods will rise as labor will be less expensive abroad.

Any study of agricultural labor markets is subject to a number of important limitations. Despite the quality of the NAWS data, it remains less suited to the type of structural duration model implied by equilibrium search theory than more typical, longitudinal data sets available to researchers in macroeconomics. Second, the survey relies on self-reported labor histories, which are always subject to limited recall and the potential for strategic responses on the part of survey subjects. Finally, the theory upon which our model is based depends on a number of assumptions regarding labor market equilibrium that may simply not hold in the real world for any one of a number of reasons. We cannot control for the failure of theory to describe reality, but the fact that the qualitative conclusions from our empirical model are consistent with reduced-form, and even model-free observations, helps allay most of these fears.

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Table 1. Summary of NAWS Data: 1989 - 2014

Variable	Units	Mean	Std. Dev.	Min.	Max.
Children	#	1.0015	1.4295	0	12
Age	Years	35.1228	12.1771	14	88
Gender	1 = Female	0.1894	0.3918	0	1
Farm Labor Contractor	1 = Yes	0.2881	0.4529	0	1
Farm Work Weeks	#	37.1236	13.6428	0.1	52.1
Migrant	1 = Yes	0.3054	0.4606	0	1
Age at Entry	Years	21.7781	8.4537	0	75
Below Min Wage	1 = Yes	0.0128	0.1124	0	1
Weeks with Current Employer	#	10.5908	12.4714	0	52.25
Status	1 = Undocumented	0.4809	0.4996	0	1
Foreign Born	1 = Yes	0.9532	0.2112	0	1
Unemployment Duration	Weeks	8.0797	9.9439	0	52
Years of Farm Work	Years	12.7679	10.6377	0	78
Hours per Week	Hours / Week	43.7933	11.3346	1	97
Education	Years	6.2828	3.5728	0	16
Wage	$ / Hr.	7.4094	2.5845	2	30
Income	$ / Week	327.3850	151.4932	13	2012.5
Field Crops	1 = Yes	0.0003	0.0183	0	1
Fruits and Nuts	1 = Yes	0.0568	0.2314	0	1
Horticulture	1 = Yes	0.6024	0.4894	0	1
Vegetables	1 = Yes	0.0904	0.2868	0	1
Miscellaneious	1 = Yes	0.2282	0.4197	0	1
Not Reported	1 = Yes	0.0219	0.1463	0	1
Pre-Harvest	1 = Yes	0.1940	0.3954	0	1
Harvest	1 = Yes	0.2963	0.4567	0	1
Post-Harvest	1 = Yes	0.0832	0.2762	0	1
Semi-Skilled	1 = Yes	0.3449	0.4753	0	1
Supervisor	1 = Yes	0.0043	0.0652	0	1
Other	1 = Yes	0.0774	0.2672	0	1

Note: N = 20,875. Note that "Field Crops" refers to non-fruit-or-vegetable crops.

Table 2. Reduced-Form Wage Equations

	Model 1		Model 2		Model 3		Model 4	
	Est.	Std. Err.	Est.	Std. Err.	Est.	Std. Err.	Est.	Std. Err.
Constant	4.2061*	0.0458	2.2047*	0.1343	2.4015*	0.1226	2.7602*	0.1280
Task 2	0.6896*	0.0425	0.6952*	0.0411	0.0959*	0.0387	0.0978*	0.0386
Task 3	0.4563*	0.0597	0.3620*	0.0585	0.2439*	0.0526	0.2299*	0.0525
Task 4	0.3997*	0.0409	0.1739*	0.0400	0.0238	0.0361	0.0135	0.0360
Task 5	2.8192*	0.2234	2.0659*	0.2165	1.6763*	0.1942	1.7114*	0.1939
Task 6	0.2593*	0.0615	0.1846*	0.0594	0.0400	0.0534	0.0522	0.0533
FLC	-0.4091*	0.0320	-0.2761*	0.0311	-0.4778*	0.0283	-0.4624*	0.0283
Trend	0.2173*	0.0021	0.2060*	0.0020	0.2028*	0.0018	0.2105*	0.0020
Age			0.0665*	0.0067	0.0610*	0.0060	0.0538*	0.0061
Age Squared			-0.0009	0.0008	-0.0008	0.0007	-0.0008	0.0007
Gender			-0.3095*	0.0370	-0.3837*	0.0333	-0.4125*	0.0334
Education			0.0417*	0.0047	0.0406*	0.0042	0.0391*	0.0042
Yrs. Work			0.0453*	0.0021	0.0381*	0.0019	0.0317*	0.0020
English			0.2154*	0.0180	0.1785*	0.0162	0.1402*	0.0167
Benefits					-0.0023	0.0069	-0.0013	0.0068
Piece Rate					1.7127*	0.0385	1.7156*	0.0384
Salary					4.9860*	0.0981	4.9734*	0.0979
Combo					0.6681*	0.0772	0.6474*	0.0771
Undocumented							-0.3142*	0.0332
R^2	0.3541		0.3993		0.5171		0.5191	
F	1,634.57		1066.69		1,313.22		1,250.5	

Note: A single asterisk indicates significance at a 5% level. Estimated with 1989 - 2014 NAWS data.

Table 3. Structural Duration Model Estimates

	Model 1		Model 2		Model 3		Model 4		Model 5	
Parameter	Est.	SE	Est.	SE	Est.	SE	Est.	SE	Est.	SE
λ_0	0.9107*	0.0010	0.2969*	0.0010	0.8827*	0.0010	0.9194*	0.0010	0.9268*	0.0010
$\sigma(\lambda_0)$							-0.2928*	0.0032	0.0791*	0.0099
λ_1	0.3324*	0.0007	0.1866*	0.0007	0.2052*	0.0012	0.1883*	0.0011	0.2359*	0.0108
$\sigma(\lambda_1)$							-0.0204*	0.0018	0.1309*	0.0044
δ	0.0393*	0.0002	0.0260*	0.0001	0.0557*	0.0005	0.0495*	0.0004		
δ Task 1									0.0374*	0.0108
δ Task 2									-0.0747*	0.0120
δ Task 3									0.1120*	0.0102
δ Task 4									0.0839*	0.0103
δ Task 5									0.1417*	0.0121
δ Task 6									0.0701*	0.0108
$\sigma(\delta)$							0.0020*	0.0008	0.0194*	0.0045
p	15.1484*	0.0007	15.2253*	0.0058	14.6762*	0.1112	14.2844*	1.6017	15.0249*	0.4204
$\sigma(p)$							0.2625	0.1672	-0.0290	0.0806
Constant										
FLC					-0.9551*	0.07552	-1.0564*	0.1199	-0.8179*	0.0189
Trend					0.0937*	0.00722	0.0761*	0.0083	-0.1658*	0.0012
Age					0.1157*	0.02151	0.1459*	0.0089	0.1022*	0.0030
Age^2					0.0001	0.00027	-0.0012*	0.0005	-0.0025*	0.0003
Gender					-2.1594*	0.07951	-0.1688	0.1550	-0.4039*	0.0236
Education					0.0259*	0.01383	0.1066*	0.0161	0.0861*	0.0027
Years Work					-0.0655*	0.00711	-0.0951*	0.0085	0.0001	0.0012
English					0.1178*	0.04514	1.0328*	0.0708	0.1854*	0.0105
Benefits					0.1705*	0.0269	0.3095*	0.0373	-0.0464*	0.0042
Piece					3.1654*	0.14098	2.5308*	0.1670	1.5420*	0.0248
Salary					3.5866*	0.14959	2.5553*	0.2451	4.5277*	0.0717
Status					-0.6341*	0.09778	-0.8387*	0.1299	-0.4737*	0.0204
LLF	-2.8636		-2.5779		-2.5811		-2.4449		-5.4882	

Note: Crop and Task indicator estimates not shown for presentation clarity, but are available. Model 1 = No censoring, Model 2 = censoring, no heterogeneity, Model 3 = heterogeneity, Model 4 = unobserved heterogeneity Model 5 = heterogeneity in δ function. Constant term in het. models not separately identified from p parameter. A single asterisk indicates significance at a 5% level. LLF values scaled by 10^6 for presentation.

Table 4. Unemployment Rate Simulation

Job	% Sample	Workers	u/m
Pre-Harvest	19.40	83,489	3.89%
Harvest	29.63	127,554	-8.77%
Post-Harvest	8.32	35,817	10.78%
Semi-Skilled	34.49	148,441	8.31%
Supervisor	0.43	1,835	13.26%
Other	7.74	33,301	7.10%

Note: u/m is the job-specific unemployment rate.
Simulation conducted with 2014 NAWS data.

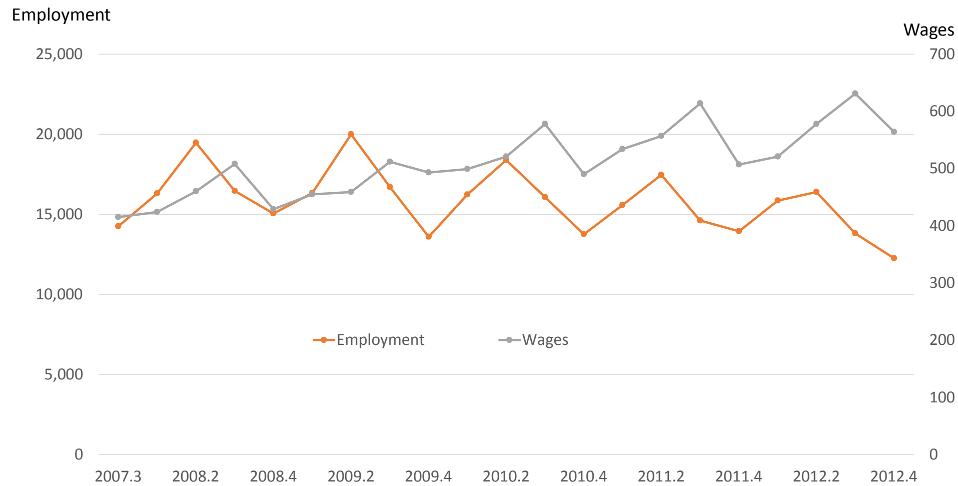

Figure 1: Fresno County: Farm Employment and Wages

Figure 2: Fresno County: Construction Employment and Wages