Undocumented Workers' Employment Across US Business Cycles

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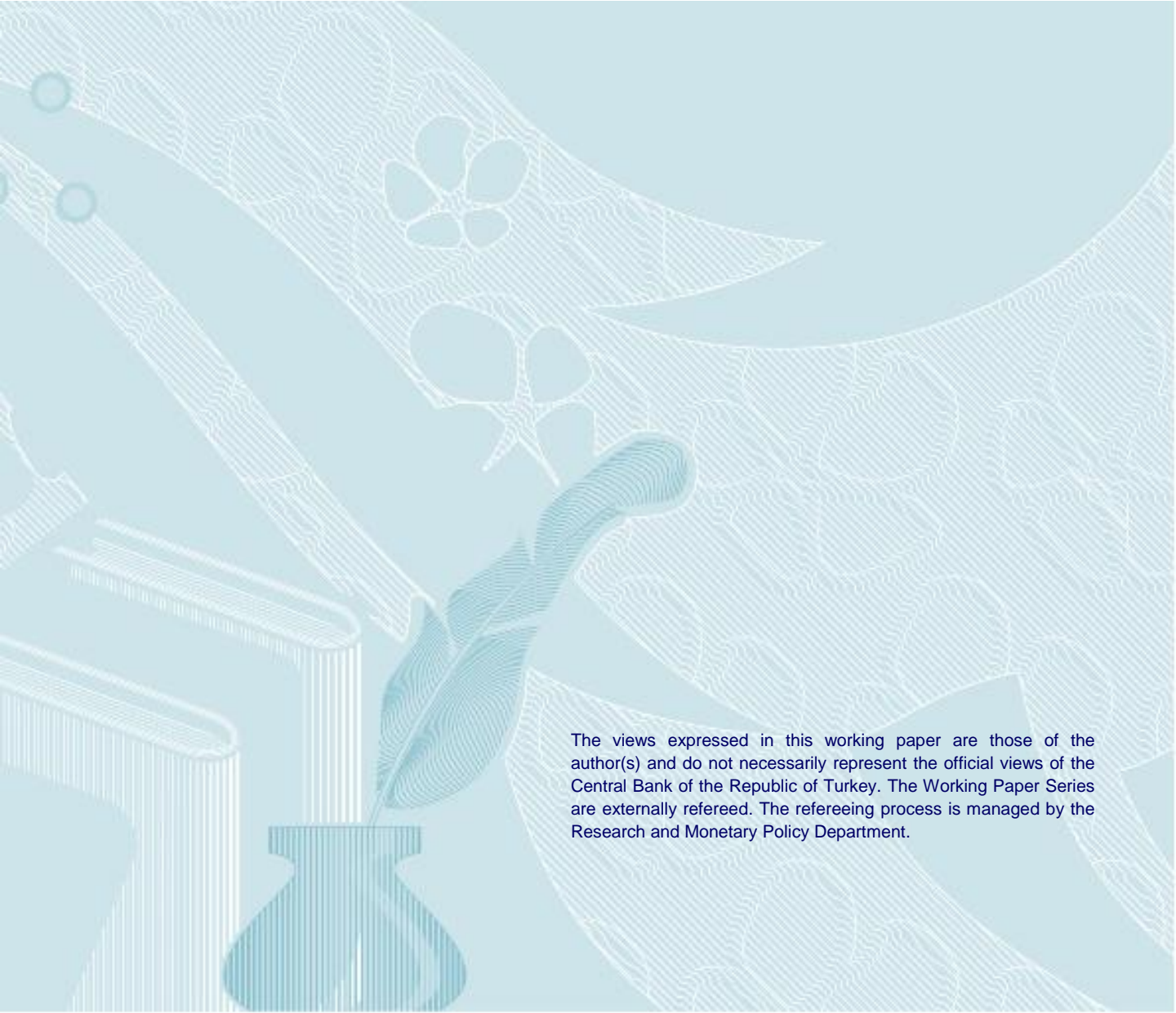
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Abstract

Using matched employer-employee data from the state of Georgia, this paper investigates how employment of undocumented workers varies along the business cycle and how it differs from the adjustment in employment of documented workers. The cyclical component of undocumented employment is found to be significantly more volatile than the cyclical component of documented employment. Simulation results indicate that complementarities between documented workers and capital account for almost 90 percent of the difference in measured volatility between documented and undocumented employment.

Undocumented Workers' Employment across U.S. Business Cycles

1. Introduction and Background

The objective of this paper is to analyze the differences in the variation in the

employment of undocumented and documented workers across business cycles in the U.S.

between 1990 and 2008. The changes in the adjustment of employment of undocumented

workers during economic booms and recessions could have important policy implications; labor

market regulations and restrictions that differ across workers will affect the relative cost of these

workers and will likely affect employers' hiring behavior. In addition, any policies that increase

the cost of labor adjustment will reduce labor allocation efficiency and, thus, reduce productivity

(Hsieh and Klenow 2009). If employers face greater flexibility (less restriction) in their

employment of undocumented workers, these workers might end up serving as a buffer in the

labor market. In other words, undocumented workers might represent a *cushion* or a *latent*

group of workers that provide employers lower labor adjustment costs with variation in product

demand. If this is the case, immigration reform that restricts the number, or affects the status, of

undocumented workers might also increase labor adjustment costs, reducing allocative efficiency

and productivity. The better quantified are the differences in employment variability between

documented and undocumented workers, the better our understanding of the impact on

employers restricting access to a source of flexible labor might be.[1]

Jerome's (1926) book on migration and the business cycle is one of the first studies on

the responsiveness of migrants to economic conditions in the receiving country. He argues that

increased labor costs moderate the business cycle, and that movement of immigrants into the

labor market impedes this moderating influence. About the adjustment of migration and

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[1]Other political and social implications of immigration reform will not be addressed in this paper.

employment, Jerome writes:

> "Frequently the turns in the migration movement lag behind the corresponding change in employment, indicating that the passage of some time is required before the full effect of a change in employment is felt upon migration. The extent of this lag varies in different cycles, and is also frequently found to vary on the downturn and the upturn of the same cycle" (p.241).

On the other hand, Kuznets and Rubin (1954) conclude, "under conditions of a free in- and outflow, one might therefore regard foreign labor supply as a sort of stabilizing reservoir" (p.5). It remains an open question what influence immigration, let alone unauthorized immigration, has on the dynamics of the business cycle or on the employment experience of natives across the cycle.

There appear to be no studies examining the employment of undocumented immigrants over the business cycle.[2] However, if we consider that more than 62 percent of undocumented workers come from Mexico and 47 percent of unauthorized workers between 25-64 years old have less than high school education, we can draw some inferences from specific studies on the adjustment of low-skilled and immigrant workers relative to higher-skilled and native workers over economic fluctuations.[3] Hoynes (2000) examines the relative impact of economic cycles on the employment, earnings, and income of individuals across different skill groups. Her findings show that the labor market outcomes of less-skilled workers exhibit more variability over business cycles than those of higher-skilled groups. She also concludes that nonwhites and those with lower education levels are more affected by changes in economic conditions.

Using Census data, Orrenius and Zavodny (2010) analyze the impact of recessions on

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[2] Fan and Pena (2012), however, do investigate the experience of immigrant agricultural labor during the Great Recession of 2008-2009. They find that wages increased less and hours increased more among undocumented agricultural workers relative to changes among documented agricultural workers.

[3] Hoefer, *et al.* (2010) and Passel and Cohn (2009) contain characteristics of unauthorized immigrants in the U.S.

Mexican immigrants. Their results indicate that low-education Mexican immigrants'

employment and unemployment are more responsive to business cycle fluctuations than are

Hispanic and white non-Hispanic U.S. natives. In addition, Dustmann, Glitz, and Vogel (2010)

study the differences in the cyclical pattern of employment and wages of immigrants and natives

for Germany and the United Kingdom. They find significantly larger responses to economic

shocks for immigrants relative to natives within the same skill group, and for low-skilled

workers relative to high-skilled workers.

Bratsberg, Raaum, and Roed (2010) study the life cycle employment of minority labor

migrants who entered Norway in the early 1970s. They find that when immigrants leave

employment, their prospects for reentry deteriorate more rapidly than those for natives, and

immigrants require longer tenure in a new employment spell to attain job security. They also find

that immigrant movements out of and back into employment are particularly sensitive to

business cycle fluctuations. Finally, they show that migrants disproportionately hold jobs in

industries and occupations in which even natives experience relatively short employment careers.

Further evidence of the dramatic cyclical variability of employment among immigrants is

found in Mandelman and Zlate (2010). They document a great deal of cyclical variability in

remittances originating in the U.S. Variation in employment outcomes will necessarily affect the

availability of funds to send home.

From these previous studies, it might be expected that undocumented workers would be

more exposed to business cycle fluctuations than documented workers. Due to their lower skill

levels, including the high probability of not being able to speak English well, employers may

dismiss undocumented workers before anyone else during an economic downturn, as they

attempt to preserve productivity levels while cutting costs. In addition, employers informally

3

hiring undocumented workers would likely face lower fixed costs of hiring and dismissing undocumented workers. Further, employment of undocumented workers is concentrated in certain industries and occupations that might be more sensitive to economic fluctuations.

Undocumented workers' employment could appear to be more sensitive to business cycle fluctuations if undocumented workers experience higher levels of separation overall. Hotchkiss and Quispe-Agnoli (2012) find that during the expansionary period of 1997-2000, the average quarterly separation rate was roughly 17 percent for documented workers and 36 percent for undocumented workers. On average, undocumented workers are likely to have been on their current job a shorter amount of time, have less labor market experience, and reflect greater separation behavior (not holding anything else constant). In addition, undocumented workers appear to be concentrated among employers that experience a greater degree of churning of the workforce, suggesting a need for workforce flexibility in its production process (see Brown, et al., forthcoming; and Morales, 1983).

Another candidate for explaining larger adjustments in employment outcomes among undocumented workers than among documented workers across the business cycle is found in the difference in the elasticity of substitution between capital and these two groups of workers. In an economy where capital is fixed in the short-run, if undocumented workers are less complementary (or more substitutable with) capital than documented workers, then firms will make adjustments to production levels in response to economic variation in product demand by adjusting employment levels of undocumented workers.[4] After presenting some stylized facts illustrating the greater variability in employment among undocumented workers, we will focus

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[4] As long as undocumented workers and capital are not perfect substitutes, this adjustment could occur, in the face of an economic downturn, after an immediate-term attempt to cut costs by initially dismissing documented workers. Eventually, however, employment adjustments would have to be born by the factor *less* complementary with capital -- undocumented workers.

on the higher degree of substitution between capital and undocumented labor (or higher degree of complementarity between documented labor and capital) as a potential explanatory factor for that greater volatility. With a production technology where documented labor is more complementary to capital, we can explain almost 90 percent of the difference in volatility between documented and undocumented workers. This is the first paper that we are aware of that analyzes the impact of the complementarity in a production process between capital and documented workers and its impact on the adjustment of the employment of undocumented workers across the business cycle.

2. Data

The primary data used for the analyses in this paper are the Employer File and the Individual Wage File, compiled by the Georgia Department of Labor for the purposes of administering the state's Unemployment Insurance (UI) program. These data are highly confidential and strictly limited in their distribution. The data are available from the first quarter of 1990 through the fourth quarter of 2008. The Employer File provides an almost complete census of firms, covering approximately 99.7 percent of all wage and salary workers (Committee on Ways and Means 2004).[5] The establishment-level information includes the number of employees, the total wage bill, and the NAICS classification of each establishment. The Individual Wage File links individual workers to their employer. The data also contain a 6-digit NAICS industry code and the county of location, allowing us to construct or merge in industry- and county-level indicators, such as county unemployment rate. Regrettably, the data set contains no information about workers' demographics or, more importantly, immigration status.

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[5] Certain jobs in agriculture, domestic services, and non-profit organizations are excluded from UI coverage (see U.S. Department of Labor 2008).

A. Using Social Security Numbers (SSN) to Identify Undocumented Workers

Details of how the SSN is used to identify undocumented workers are contained in Appendix A. The abbreviated version is that there are some easily identifiable ways in which a SSN is determined to be invalid. We conclude that some of those reasons are either errors or the result of incomplete record keeping by the firm. We restrict our identification of undocumented workers to invalid SSNs that are more likely to have been generated by the worker -- numbers that look valid, but are not. Workers with invalid SSNs for any other reason are considered neither undocumented nor documented and, thus, are excluded from the analysis; this will clearly undercount the actual number of undocumented workers. The inability to directly identify a worker's immigration or legal status necessitates using merely a sample to represent the presence and number of undocumented workers in the labor market. Details about the success of this identification process are contained in Appendix A.

A robustness analysis includes all workers with invalid SSNs as undocumented (not just those we've identified as "worker-generated"), with no appreciable difference in conclusions. The actual employment levels of undocumented workers are not used in estimation of the structural model, but just for comparison of the volatility in the predicted level of undocumented worker employment with the actual volatility in the sample of undocumented workers. As long as we are confident of the representativeness of the cyclical employment patterns of the sample, this comparison will be valid.

B. Sample Means

The period of our study is between 1990 and 2008 inclusive for the state of Georgia.

Table 1 presents some means for this sample of workers. Undocumented workers, on average, earn roughly half of the average documented worker wages (quarterly earnings, unconditional means). Some of this wage differential is likely because of the concentration of undocumented workers in lower-paying industries or occupations, undocumented workers working fewer hours, or the upward push in the occupational chain of documented workers with the arrival of lower-skilled undocumented workers (Pedace 2006). As can be seen toward the bottom of the table, the undocumented wage gap increases as workers move up the wage distribution. Among low-earnings workers, undocumented workers earn approximately 93% of documented workers, whereas among high earnings workers, the undocumented earn only 63% of what is earned by documented workers, on average (unconditional).

[Table 1 here]

There are also some noticeable differences in the distribution of workers across industry skill intensity and NAICS classification.[6] Most notably, undocumented workers are more concentrated in agriculture, construction, and leisure and hospitality. In addition, while similar shares of documented and undocumented workers are found in industries classified as medium-skill, there is a much greater (less) concentration of undocumented workers in low- (high-) skill industries. Note that the distribution of documented workers across industries in Georgia matches the U.S. distribution (in parentheses) fairly closely.

3. Stylized Facts: Differences in Employment Volatility

Quantifying differences in the variation of employment of documented and undocumented workers across the business cycle is accomplished in this section by analyzing a

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[6]Appendix B defines the sector classifications and Appendix C describes the construction of skill and labor intensity classifications.

series of stylized facts. The analysis begins with Figure 1, which shows the log of the cyclical

components of documented and undocumented employment along with Georgia's personal

income (subtracting transfers).[7] It is immediately apparent from this figure that undocumented

worker employment is much more volatile than documented worker employment. Even slight

economic downturns, as was seen in 1997, is accompanied by dramatic swings in undocumented

worker employment.

[Figure1here]

Confirmation of these visual conclusions can be found in Table 2, which reports the

standard deviation of the cyclical components of logged employment series for undocumented

and documented workers as a measure of the volatility. Over the entire period of analysis,

volatility of undocumented worker employment (0.07 log points) is more than three times higher

than the volatility of documented worker employment (0.02 log points). In addition, while the

volatility of documented worker employment has remained constant over the entire period,

volatility of undocumented worker employment has dropped from 0.08 between 1990 and 1999

to 0.06 for the last eight years of study (2000 to 2008). Rolling standard deviations for eight

quarters (shown in Figure 2) further illustrates these two observations; greater volatility of

employment of undocumented workers and a clear decline in that volatility over time.[8]

[Table 2 and Figure 2 here]

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[7]Georgia's Gross State Product series is annual, so we use Georgia's Personal Income
(subtracting transfers) quarterly series as a proxy. See Appendix D.
[8]Tests of significance of the average values of rolling standard deviations of the cyclical
component of employment between the early (1990-1999) and later (2000-2008) time periods
indicate that the reduction in variation among undocumented workers is statistically significant at
the 99 percent confidence level and not significantly different among documented workers.
Excluding 1990 from the earlier time period reduces the t-values, but does not appreciably
change the statistical significance.

A. Consistency in Relative Volatility Across Characteristics.

As can be seen in Table 2, the pattern of greater, but moderating volatility of undocumented worker employment relative to documented worker employment is consistent across worker characteristics and across characteristics of the workers' firm; for every sector, skill intensity, labor intensity, and worker earnings level, undocumented worker employment volatility exceeds that of documented workers. The implication is that the volatility pattern differences observed between documented and undocumented workers overall is not merely a function of their industry concentration, production process characteristics, or earnings levels.[9]

Not all sectors experienced the same moderation in volatility among undocumented worker employment from the 1990s to the 2000s. Volatility ranged from 2.3 times higher in the 1990s in Agriculture to an actual increase from the 1990s to the 2000s (in Retail Trade, Information, and Education and Health). In addition, among documented workers, employment became significantly less volatile between the two time periods in Education and Health and in Other Services. Nonetheless, while not perfectly consistent, the pattern of greater moderation in volatility of undocumented worker employment holds across most sectors. The same reduction in volatility is seen among low-earner and high-earner undocumented employment.

Looking more closely across skill and labor intensity of the firm's sector, some intriguing differences arise. As we would expect from the literature, documented employment in low-skilled sectors has a higher volatility (0.028) than documented employment in high-skilled sectors (0.014). However, this pattern is the opposite among undocumented workers; undocumented employment in high-skill sectors displays a higher volatility (0.159) than

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[9]The volatility of cyclical components of documented and undocumented employment by earnings levels across industry and skill and labor intensities are available upon request. The results are consistent across earnings levels.

undocumented employment in low-skill sectors (0.059). This may suggest that undocumented workers perform very different types of jobs in these two types of sectors. For example, undocumented workers may hold jobs such as janitor and, thus, be among the most expendable in high-skill sectors, but hold more essential positions, such as front-line production, in low-skilled sectors.

In addition, undocumented employment in low- and medium-skill sectors becomes less volatile in the 2000s, relative to the 1990s, whereas undocumented employment in high-skill sectors becomes more volatile. This increased volatility among undocumented workers employed in high-skill industries may reflect increased monitoring of SSN validity in firms in these industries.

In terms of labor intensity, we again see a different pattern over the whole time period for documented and undocumented worker employment volatility. Employment of undocumented workers in industries with the highest level of labor intensity is more volatile than in industries with the lowest labor intensity (0.096 versus 0.080); this makes sense, as the higher labor intensity likely results in greater flexibility for adjusting employment to meet changing demand over the business cycle. However, except in the last time period, the opposite is observed among documented workers; employment of documented workers by firms in industries with lower labor intensity is more volatile during the 1990-1998 period (and on average overall).

The volatility differences between undocumented and documented worker employment identified within industry, earnings level, and sector labor and skill intensity, suggest that employment volatility differences exist with documentation status regardless of other worker and firm characteristics.   In other words, the differences in volatility observed between documented and undocumented workers are not solely the consequence of the type of industry or job

documented and undocumented workers are employed in. This does not mean that the

differences in volatility of employment between documented and undocumented workers is

unlike those differences found between skilled and unskilled workers, for example. However,

there is a difference in employment patterns that holds even within those classifications.

     B. <u>Delineating Early and Later Time Periods</u>

     The time periods over which employment volatility is compared in Table 2 (1990-1999

and 2000-2008) are arguably arbitrary. We repeated the exercise using complete business cycles

for the two time periods, instead of decades.[10] The periods of comparison were 1990Q3 -

2000Q4 and 2001Q1-2007Q3. The conclusions were essentially same: employment volatility

among undocumented workers is consistently greater than that among documented workers,

however volatility moderated among both undocumented workers and documented workers, but

more significantly among undocumented workers.

     Of course, this begs the question of what could be driving the moderation in volatility

over time. As we will see later, it likely has more to do with changing behavior or characteristics

of undocumented workers, rather than a change in the way in which firms are utilizing

undocumented workers (i.e., substitutability with capital). For example, as undocumented

workers become more established and as employment networks develop over time, their

elasticity of labor supply may increase, making them more sensitive to wage changes and more

likely to respond similarly to documented workers.

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[10] Note that this split in the time period is irrelevant for the quantitative analysis below, as the
full series is utilized.

4. Theoretical Framework and Quantitative Analysis

From many different angles, the stylized facts presented in the previous section confirm that employment of undocumented workers is more volatile than employment of documented workers across the business cycle. This greater volatility holds consistently across industries, sector characteristics, and the worker earnings distribution, suggesting the result is truly a documented vs. undocumented phenomenon, rather than a reflection of concentration of the two types of workers within sectors or on one end of the earnings distribution or the other. Although not a foregone conclusion, this greater volatility of undocumented worker employment was not unexpected. Undocumented workers are known to be much younger, on average, than the population of documented workers (Passel and Cohn 2009), and Jaimovich, et al. (2009) has found that employment among young workers is generally more volatile across the business cycle than employment among older workers.

One of the reasons theorized to lead to these differences in volatility is the degree to which documented and undocumented workers are complementary to capital in the production process. Documented workers, typically in possession of higher skills than undocumented workers, are expected to be employed in jobs that require more intensive use of capital (Dustmann et al.2010). Lower complementarity with capital, and the fact that capital inputs are fixed in the short run, will lead to greater variability in employment of factors non-complementary to capital as the firm adjusts its production across the business cycle. In addition, Peri and Sparber (2008) present evidence that immigrants are employed in tasks, which require less skill and use less capital, and natives are employed in more quantitative tasks. In the context of this paper, the greater volatility of undocumented worker employment suggests that it is the undocumented worker that is less complementary (more substitutable) with capital than the

documented worker.

The next subsection discusses a production technology where undocumented labor is more substitutable with physical capital than documented labor. The subsequent subsections evaluate the performance of this production function in explaining the differences in the volatility of documented and undocumented employment at business cycle frequency.

A. The Production Technology

The elasticities of substitution between capital and different types of labor have been examined by numerous other studies. These studies primarily focus on differences in education across workers. Griliches (1969) was the first to document the complementarity between skilled labor and physical capital. Berndt and Christensen (1974), Fallon and Layard (1975), Denny and Fuss (1977), and Brown and Christensen (1981) also report evidence that unskilled labor is more substitutable with capital than skilled labor. A more recent study by Krusell, Ohanian, Rios-Rull and Violante (henceforth KORV) (2000) estimate the elasticity of substitution between unskilled labor, skilled labor, and capital equipment. They use a CES production technology with two types of capital and find that skilled labor is complementary to capital. Their estimate for the elasticity of substitution between unskilled labor and capital suggests a higher degree of substitutability between these two factors than the Cobb-Douglas case.

In our quantitative analysis, we adapt the production technology used in KORV (2000) and express the output produced in Georgia as follows:

$$Y_t = A_t \left[\mu (U_t)^{\theta} + (1 - \mu) \{ \lambda (K_t)^{\rho} + (1 - \lambda)(D_t)^{\rho} \}^{\frac{\theta}{\rho}} \right]^{\frac{1}{\theta}}. \tag{1}$$

Here U_t denotes undocumented workers, and D_t denotes documented workers. A_t is a neutral technology shock, which can be described by the following stochastic process:

$$A_t = \exp(z_t), \text{ where} \tag{2}$$

$$z_t = \phi z_{t-1} + \varepsilon_t, \tag{3}$$

and $E(\varepsilon_t) = 0, var(\varepsilon_t) = \sigma_\varepsilon^2.$

The elasticity of substitution between undocumented workers and capital-documented labor composite is equal to $(1/1 - \theta)$, so is captured in equation (1) through the presence of θ. Similarly, the elasticity of substitution between documented workers and physical capital given by $(1/1 - \rho)$, which is captured in equation (1) through the presence of ρ. In this framework, $\theta > \rho$ implies that documented workers are more complementary to capital than undocumented workers.

The factor returns implied by the production technology are:

$$w_t^D = A_t(1 - \lambda)(1 - \mu)(Y_t)^{1-\theta}\{\lambda(K_t)^\rho + (1 - \lambda)(D_t)^\rho\}^{\frac{\theta}{\rho}-1}D_t^{\rho-1}, \tag{4}$$

$$w_t^U = A_t\mu(Y_t)^{1-\theta}U_t^{\theta-1}, \text{ and} \tag{5}$$

$$r_t = A_t\lambda(1 - \mu)(Y_t)^{1-\theta}\{\lambda(K_t)^\rho + (1 - \lambda)(A_tD_t)^\rho\}^{\frac{\theta}{\rho}-1}K_t^{\rho-1}. \tag{6}$$

Using equations (4) and (5), we get the following wage ratio between documented and undocumented labor:

$$\frac{w_t^D}{w_t^U} = \frac{(1-\lambda)(1-\mu)\{\lambda(K_t)^\rho + (1-\lambda)(D_t)^\rho\}^{\frac{\theta}{\rho}-1}D_t^{\rho-1}}{\mu U_t^{\theta-1}}. \tag{7}$$

B. Parameterization

The first step in the quantitative analysis is to pin down the parameters of the model. There are four parameters in equation (1) that need to be specified: share parameters μ and λ, and the elasticity parameters θ and ρ. In order to specify λ and ρ, we use our data on documented employment and capital stock and their relative income shares and estimate these two parameters

from the following equation:[11]

$$\log\left(\frac{D_t w_t^D}{K_t r_t}\right) = \log\frac{(1-\lambda)}{\lambda} + \rho\log\left(\frac{D_t}{K_t}\right) + \varepsilon_t. \tag{9}$$

Estimation of equation (9) produces an estimate of the constant term of -1.28 (standard error

0.45) and an estimate of ρ of 0.14 (standard error 0.05). Using the value of the constant term, we

compute λ to be 0.78, where $\lambda = 1 / (e^{-1.28} + 1)$.

KORV (2000) estimate the value of θ as 0.4, which measures the degree of substitution

between unskilled labor and the ratio of skilled labor to capital in their model. We borrow the

value of θ from their study to represent the degree of substitution between undocumented

workers and the ratio of documented workers to capital.[12] Then we calibrate μ to match the

average ratio of documented to undocumented wage bills in Georgia between 1990 and 2008.

The values of all the calibrated parameters are reported in the note to Table 4.

C. Simulation Results

In this section we assess the performance of our model in explaining the difference

between the volatility of documented and undocumented employment. In other words, we

evaluate the importance of different elasticities of substitution between capital and

undocumented and documented labor to account for the higher variation of undocumented

employment over the business cycle.

Analogous to Castro and Coen-Pirani (2008), we use our parameters, the actual series for

capital stock (K_t), the number of documented workers (D_t), and the series for the relative

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[11]Details on the data used in this regression are available in Appendix E.
[12]Because we only have a sample of undocumented workers employed in Georgia, accurate
estimation of the elasticity of substitution between documented and undocumented workers is
not possible. Estimation of the rest of the parameters is possible because their estimation does
not depend on undocumented worker levels.

earnings of documented and undocumented workers (w_t^D/w_t^U) to obtain a predicted series for undocumented employment $\widehat{U}_t$.[13] Following this we extract the cyclical component of the simulated series $\widehat{U}_t^c$ and compute its standard deviation.

Figure 3 presents the cyclical component of undocumented employment from the benchmark model compared to its data counterpart. Table 3 reports the cyclical properties of the simulated undocumented employment series. In particular, we report the volatility measured by the standard deviation of the cyclical component of undocumented employment produced by our model. The co-movement in Table 3 refers to the contemporaneous correlation of the cyclical component of the data series (documented employment and actual and simulated undocumented employment) with that of the output series we use for Georgia.

[Figure 3 and Table 3 here]

The model produces a standard deviation of 0.08 for the whole period, which is a slight over-prediction of the volatility observed in the data for the same period. Looking at the 1990Q1-1999Q4 and 2000Q1-2008Q4 periods separately, we observe that the model does well in matching the volatility of the undocumented employment for both sub periods. In particular, for the second sub period covering the quarters between 2000 and 2008, our model generates an undocumented employment series with a standard deviation of 0.05. The standard deviation of the cyclical component of the undocumented employment is measured as 0.06 in the data for the same period, implying that our model can explain about 85% of the cyclical variation of undocumented employment after 1999. For the 1990-1999 period, the volatility of the model-simulated undocumented employment is 0.1, which is approximately 20% higher than the actual standard deviation of 0.08 in the data.

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[13]Georgia capital stock was obtained from Peri (2009).

Since capital and output are available only at the aggregate Georgia level, the model cannot be estimated separately by sector or by firm or worker characteristics. Hence, it is always possible that the results we are attributing to differences in the elasticities of substitution between capital and documented and undocumented workers is really the result of differences in the elasticities of substitution between capital and, say, skilled and unskilled workers or the concentration of documented and undocumented workers in certain sectors. However, recall that the difference in employment volatility between documented and undocumented workers was remarkably stable across sectors and worker and firm characteristics (see Table 2). Consequently, we believe these results suggesting an important role for differences in elasticities of substitution between capital and documented and undocumented workers would hold if it were possible to estimate the model by sector or by different worker characteristics.

The model also captures the decline in undocumented employment volatility over time observed in the data. The model's prediction for the volatility of the undocumented employment series is slightly higher for the 1990-1999 period, which results in a larger standard deviation for the whole period. This result is entirely data driven, as the parameters of the model are held constant for both time periods. This is confirmed by the standard deviations of the data series used to estimate the model, found in Table 4. The volatility of the wage ratio data series moderates from 0.053 to 0.016 whereas the volatility of capital stock actually increases slightly over this time period, from 0.009 to o.014.

[Table 4 here]

The moderation in volatility deriving from the data, rather than from the model, indicates that it is not the result of any change in substitutability of undocumented workers with capital over the time period (which is dictated by the parameters), but is generated by something outside

17

of the model, such as behavioral or characteristic changes among undocumented workers. One

possible explanation is that undocumented worker employment networks have grown over time,

improving the mobility and employment opportunities during the later time period relative to the

earlier time period (Yueh 2008 documents the importance of networks in determining

employment outcomes). This hypothesis is consistent with the observed moderation in volatility

of wages paid to undocumented workers, relative to documented workers. Further evidence of

improved opportunities for undocumented workers over time comes from the wage ratio itself,

which rises over the period of 1990-2000, then declines, indicating the relative improvement in

employment outcomes among undocumented workers, relative to documented workers.

Recall that the volatility prediction for undocumented workers is being compared to the

actual volatility of a relatively conservative sample of undocumented workers in the state of

Georgia (see Appendix A). The conclusions are nearly identical when using a more broadly

defined sample of undocumented workers. Appendix F compares the results for the narrow and

broad samples of undocumented workers.

5. Conclusions and Policy Implications

The sensitivity of different types of workers' employment to business cycle fluctuations

has received a fair amount of attention in recent years (for example, see Hoynes 2000; Orrenius

and Zavodny 2010; and Dustmann, Glitz, and Vogel 2010). The existing studies have examined

how the employment of skilled vs. unskilled, young vs. old, and native vs. immigrant workers

behave differently from each other over the course of the business cycle. This paper investigates

the same question, but for documented vs. undocumented workers. Using quarterly data on

employment of documented and undocumented workers in Georgia between 1990 and 2008, we

18

have shown that the employment of undocumented workers is more volatile than documented worker employment. This greater volatility among undocumented workers holds within industry, within sector characteristics, and within different portions of the earnings distribution. We explore differences in the elasticity of substitution between capital and the two types of labor as one potential explanation for this observation. We use a simple production technology where firms use capital, documented and undocumented labor, and the undocumented labor is more substitutable with capital. The results from our quantitative analysis show that with this production technology we can explain a significant amount of the greater volatility of undocumented worker employment across the business cycles in Georgia.

The consistency of these results with those found by others when comparing the employment volatility of unskilled, young, and immigrant workers, compared with employment volatility of skilled, older, and native workers, respectively, is not surprising; undocumented workers are typically low skilled, young, and are, by definition, immigrants. Although undocumented workers make up a much smaller group of workers than the low-skilled, young, or immigrants, this role of providing additional production flexibility means that immigration reform that restricts the number, or affects the status of undocumented workers would also curtail the flexibility in labor markets that employers currently have, increasing labor adjustment costs, such as minimum notice for separation, mandatory severance payments, and minimum wages. An economy with lower labor adjustment costs enjoys a more efficient allocation of labor and, thus, higher productivity (see Hsieh and Klenow 2009). Given this, calls to tighten immigration enforcement during economic downturns may be unwarranted.

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Figure 1. Documented and Undocumented Employment during the U.S. Business Cycle: 1990-2008 (cyclical component)
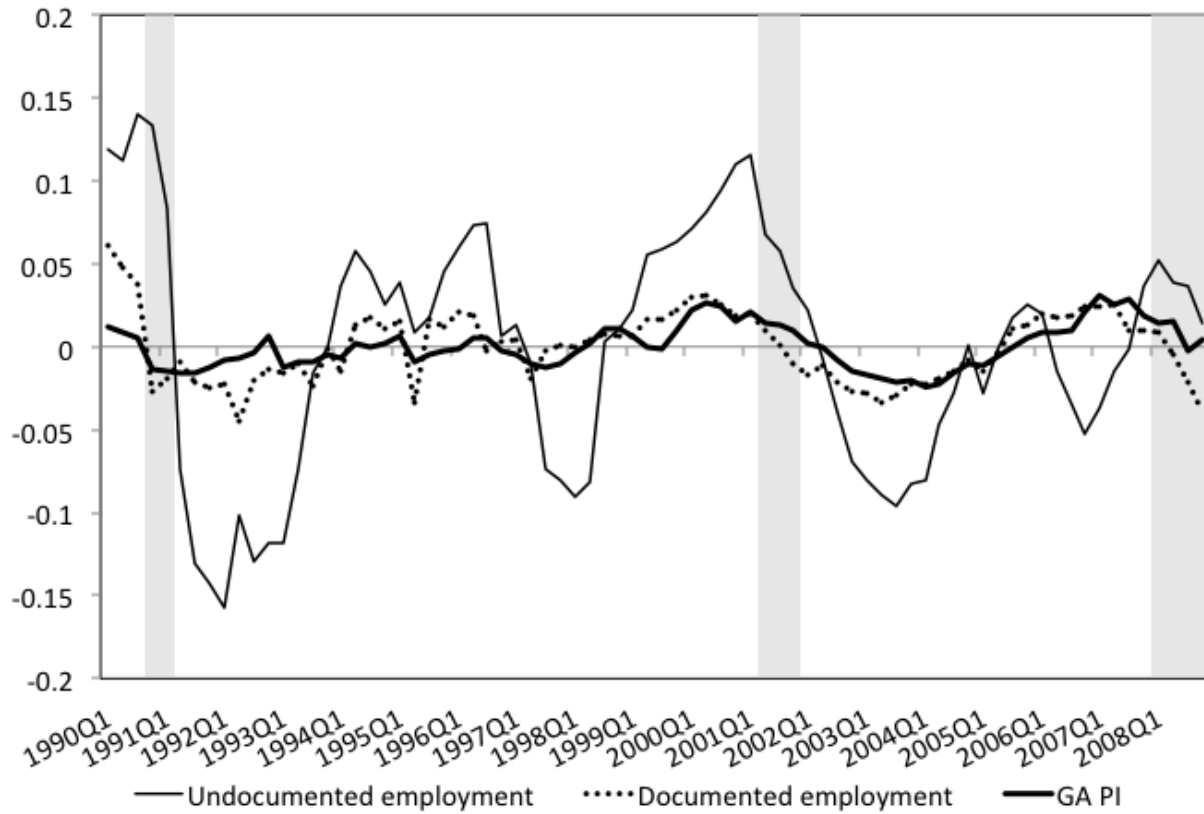
Note: The plot shows the log of the cyclical component of undocumented and documented employment, seasonally adjusted. GA PI is the cyclical component of the log of Georgia's Personal Income minus transfers. The shaded bars reflect NBER-dated recessionary periods. Plots showing these series separately by sector and worker characteristics are available upon request.

Figure 2. Rolling Standard Deviation of the Cyclical Component of Documented and Undocumented Employment, 1990Q1-2008Q4
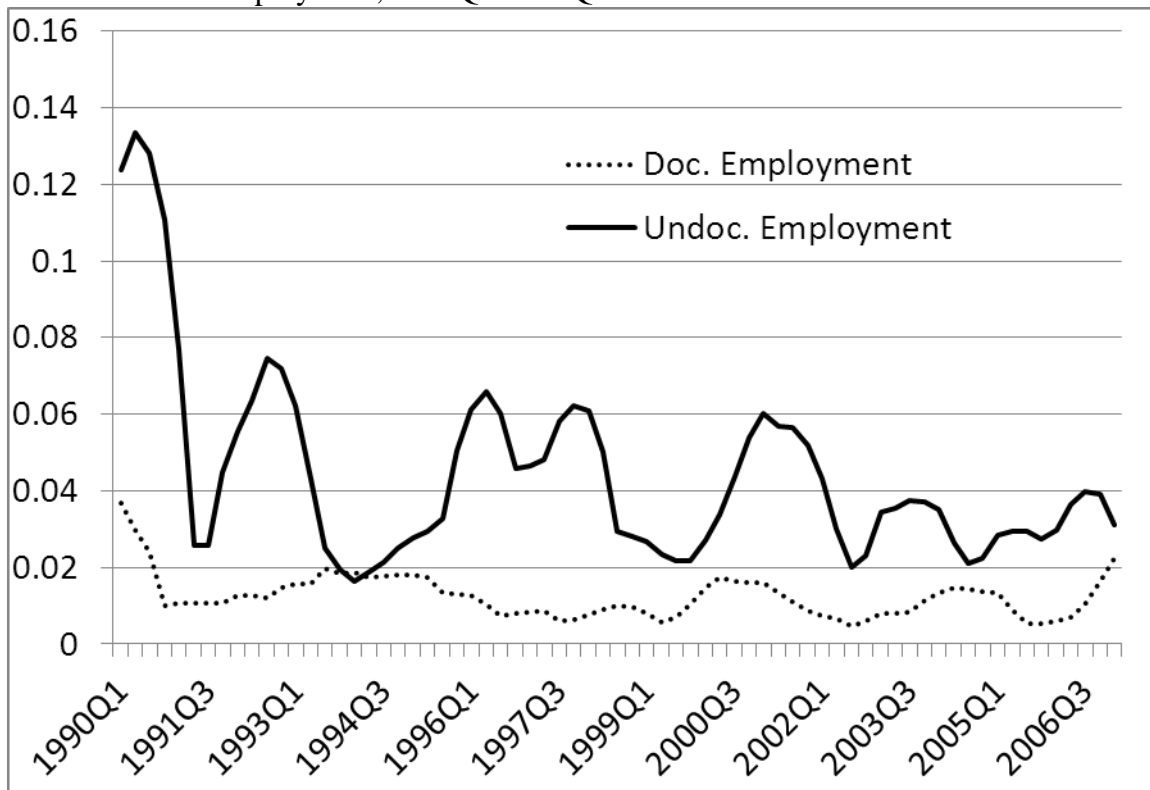
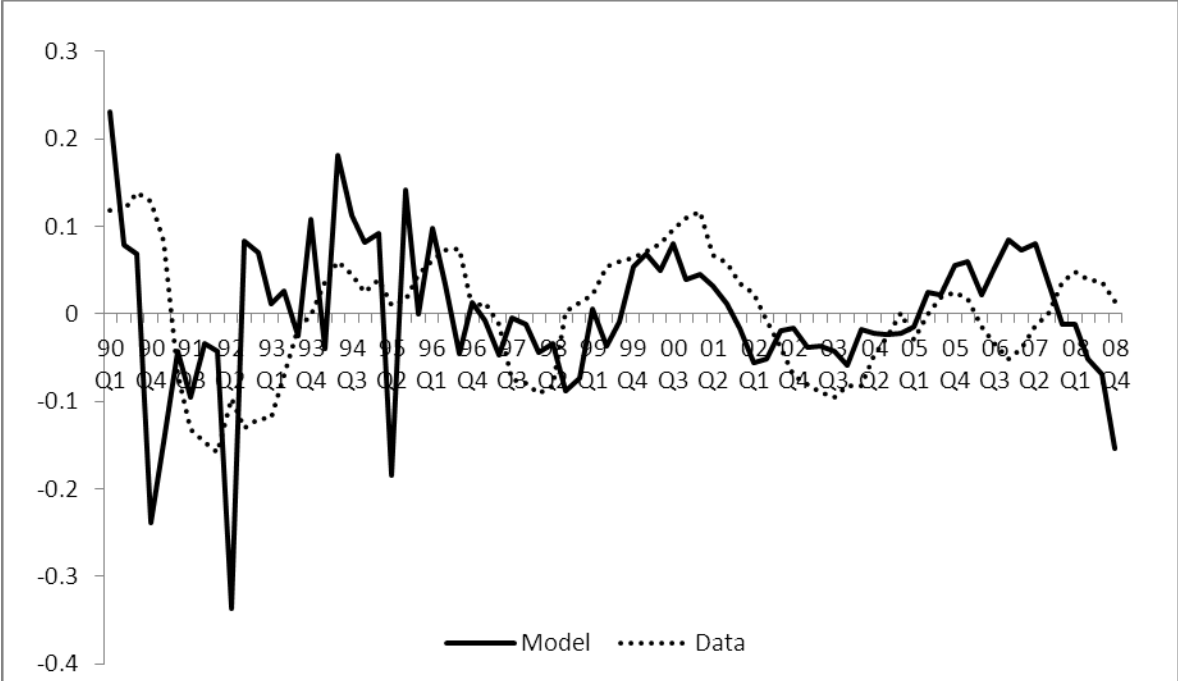Figure 3. Cyclical component of undocumented employment: Model vs. Data

Table 1. Sample means, quarterly averages, 1990Q1-2008Q4.

	Documented		Undocumented	
	Number of Workers	Real Earnings	Number of Workers	Real Earnings
Total	3,947,169	8,016	29,169	3,976
	(438766)	(785)	(17196)	(439)
Industries (National Share)				
Nat. Res & Ag. (1%)	36591	6496	1705	2109
	(2344)	(384)	(769)	(332)
	[1%]		[6%]	
Construction (6%)	207081	7988	4582	4976
	(29997)	(1095)	(3208)	(885)
	[5%]		[16%]	
Manufacturing (15%)	538248	9470	4248	4992
	(51177)	(1059)	(2219)	(609)
	[14%]		[15%]	
Trans. & Utilities (4%)	148521	9717	400	5173
	(14929)	(752)	(232)	(869)
	[4%]		[1%]	
Wholesale Trade (5%)	203735	12905	1208	5814
	(23940)	(1480)	(763)	(1201)
	[5%]		[4%]	
Retail Trade (13%)	523893	5251	1740	3576
	(55862)	(445)	(1020)	(422)
	[13%]		[6%]	
Financial Activities (7%)	213534	11495	449	6065
	(28011)	(1514)	(228)	(1399)
	[5%]		[2%]	
Information (3%)	128755	13510	143	6937
	(20673)	(1695)	(74)	(1981)
	[3%]		[0%]	
Prof. & Bus, Srvs* (17%)	584114	8216	5799	3519
	(105597)	(1017)	(3673)	(726)
	[15%]		[20%]	
Ed. & Health Services (15%)	677081	8284	842	5985
	(135030	(599)	(581)	(868)
	[17%]		[3%]	
Leisure and Hospitality (10%)	411916	3103	7102	2702
	(56906)	(276)	(4412)	(402)
	[10%]		[24%]	
Other Services** (5%)	165238	8049	105	5156
	(16202)	(573)	(23)	(697)

	[3%]		[3%]	
Earnings Level				
Low Earnings (< R$3,000/quarter)	1,258,811	$1,203	13,616	$1,118
	(110134)	(28)	(6487)	(94)
	[31%]		[47%]	
High Earnings (≥ R$3,000/quarter)	2,688,372	$11,204	15,552	$7,094
	(366892)	(824)	(10852)	(1042)
	[68%]		[53%]	
Skill Intensity				
Low	1,428,859	8,121	15,744	5,001
	(749202)	(2843)	(11732)	(1727)
	[36%]		[33%]	
Medium	1,396,478	7,590	10,217	4,461
	(762857)	(2486)	(7727)	(1609)
	[35%]		[61%]	
High	1,121,844	6,642	3,206	4,580
	(599283)	(2036)	(2395)	(2187)
	[28%]		[6%]	
Labor Intensity				
Low	165,238	8,049	5,920	4,430
	(16202)	(573)	(2965)	(553)
	[21%]		[20%]	
Medium	842,500	9,892	17,584	3,785
	(46479)	(1136)	(10991)	(485)
	[45%]		[60%]	
High	1,771,350	6,711	5,558	3,954
	(211498)	(676)	(3366)	(820)
	[30%]		[19%]	

Notes: Standard deviation in parentheses. Share of total in brackets. Wages are real quarterly earnings in 2006Q4 dollars, deflated by the chained price index for personal consumption expenditure.
[a] Source: U.S. Census County Business Patterns (http://censtats.census.gov/cbpnaic/cbpnaic.shtml), March 2000.
*Professional & Business Services includes temporary services.
** Other Services includes private household, laundry, and repair and maintenance services.

Table 2. Volatility of the cyclical components of undocumented and documented employment.

Time Period	1990Q1-2008Q4		1990Q1-1999Q4		2000Q1-2008Q4	
	Undoc	**Docum**	**Undoc**	**Docum**	**Undoc.**	**Docum.**
Total	0.072	0.023	0.082	0.022	0.059	0.024
Industry						
Natural Resources & Ag	0.087	0.031	0.110	0.029	0.050	0.033
Construction	0.097	0.053	0.101	0.057	0.092	0.048
Manufacturing	0.112	0.028	0.142	0.027	0.064	0.030
Trans. and Utilities	0.111	0.024	0.135	0.022	0.079	0.027
Wholesale Trade	0.084	0.028	0.090	0.026	0.076	0.031
Retail Trade	0.115	0.030	0.103	0.028	0.128	0.031
Financial Activities	0.178	0.023	0.200	0.023	0.153	0.023
Information	0.192	0.042	0.155	0.044	0.228	0.039
Prof. & Business Servs	0.101	0.037	0.117	0.031	0.080	0.044
Ed. and Health Servs	0.133	0.013	0.114	0.016	0.152	0.009
Leisure and Hospitality	0.062	0.029	0.064	0.029	0.060	0.031
Other Services	0.176	0.043	0.129	0.057	0.218	0.019
Earnings Level						
Low Earnings (< R$3,000/quarter)	0.079	0.040	0.087	0.036	0.069	0.044
High Earnings (≥ R$3,000/quarter)	0.075	0.017	0.090	0.017	0.055	0.017
Industry Skill Intensity						
Low	0.059	0.028	0.071	0.026	0.041	0.029
Medium	0.084	0.031	0.097	0.029	0.067	0.033
High	0.159	0.014	0.128	0.017	0.189	0.011
Industry Labor Intensity						
Low	0.080	0.043	0.101	0.057	0.048	0.019
Medium	0.069	0.023	0.076	0.022	0.061	0.025
High	0.096	0.029	0.105	0.027	0.087	0.030

Note: The volatility of cyclicality components of documented and undocumented employment by earnings levels across industry and skill and labor intensities are available upon request.

Table 3. Volatility of undocumented employment: Model vs. Data

		Volatility		Co-movement	
		Documented	Undocumented	Documented	Undocumented
1990Q1:2008Q4	Data	0.02	0.07	0.71	0.50
	Model		0.08		0.39
1990Q1:1999Q4	Data	0.02	0.08	0.72	0.46
	Model		0.10		0.45
2000Q1:2008Q4	Data	0.02	0.06	0.83	0.68
	Model		0.05		0.58

Note: $\lambda = 0.78$, $\rho = 0.14$, $\theta = 0.4$, $\mu = 0.001$. Co-movement refers to the contemporaneous correlation between the data series and Georgia's output (Georgia personal income minus transfers).

Table 4. Standard deviation of data series used in estimation of the model across two different time periods.

	Wage Ratio $\left(\frac{w_t^D}{w_t^U}\right)$	Capital Stock (K_t)
1990:Q1-1999:Q4	0.053	0.009
2000:Q1-2008:Q4	0.016	0.014

Appendix A: Using SSNs to Identify Undocumented Workers

Identifying Invalid Social Security Numbers

Every quarter employers must file a report with their state's Department of Labor detailing all wages paid to workers who are covered under the Social Security Act of 1935. Each worker on this report is identified by his/her social security number (SSN). There are a number of ways in which one can establish that a reported social security number is invalid. The Social Security Administration provides a service by which an employer can upload a file of SSNs for checking, but one must register as an employer to obtain this service.[14] In addition, there are several known limitations on what can be considered a valid social security number, so a simple algorithm is used to check whether each number conforms to the valid parameters.

There are three pieces to a SSN.[15] The first three numbers are referred to as the Area Number. This number is assigned based on the state in which the application for a SSN was made; it does not necessarily reflect the state of residence. The lowest Area Number possible is 001 and the highest Area Number ever issued, as of December 2006, is 772. Using information provided by the SSA, the dates at which area numbers between 691 and 772 are first assigned can be determined. Any SSN with an Area Number equal to 000, greater than 772, or which shows up before the officially assigned date, will be considered invalid.

The second piece of a SSN consists of the two-digit Group Number. The lowest group number is 01, and they are assigned in non-consecutive order. Any SSN with a Group Number equal to 00 or with a Group Number that appears in the data out of sequence with the Area

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[14]See Social Security Number Verification Service <http://www.ssa.gov/employer/ssnv.htm>.
[15]Historical information and information about valid SSNs can be found at the Social Security Administration's web sites:
<http://www.ssa.gov/history/ssn/geocard.html>,<http://www.xocialsecurity.gov/employer/statew
eb.htm>, and <http://www.socialsecurity.gov/employer/ssnvhighgroup.htm >.

Number will be considered invalid.

The last four digits of a SSN are referred to as the Serial Number. These are assigned consecutively from 0001 to 9999. Any SSN with a Serial Number equal to 0000 is invalid.

In 1996 the Internal Revenue Service (IRS) introduced the Individual Tax Identification Number (ITIN) to allow individuals who had income from the U.S. to file a tax return (the first ITIN was issued in 1997). It is simply a "tax processing number" and does not authorize an individual to work in the U.S. Employers are instructed by the IRS to "not accept an ITIN in place of a SSN for employee identification for work. An ITIN is only available to resident and nonresident aliens who are not eligible for U.S. employment and need identification for other tax purposes."[16] ITIN numbers have a "9" in the first digit of the Area Number and a "7" or "8" in the first digit of the Group Number. Anyone with this numbering scheme will be identified as having an invalid Area Number; the percent of SSNs with high area numbers that also match the ITIN numbering scheme has risen from about one percent in 1997 to over 60 percent by the end of 2006.

A series of SSNs were de-commissioned by the Social Security Administration because they had been put on fake Social Security Cards used as props to sell wallets.[17] Apparently, some people who purchased the wallets thought the fake Social Security Cards were real and started using them as their own. If any of these 21 "pocketbook" SSNs appear in the data, they are considered invalid, although their frequency is so low as to be inconsequential. In addition, a number of SSNs are exactly equal to the employer identification number. These are invalid, primarily because they have too few digits. In any instance where a SSN is used for more than

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[16]"Hiring Employees," <http://www.irs.gov/businesses/small/article/0,,id=98164,00.html>. Also see, "Individual Taxpayer Identification Number (ITIN),"
<http://www.irs.gov/individuals/article/0,,id=96287,00.html>.
[17]See U.S. Department of Housing and Urban Development (1990).

one person on a firm's UI wage report or does not have the required number of digits (including

zeros), the SSN is considered invalid.

The possibility that someone fraudulently uses a valid SSN assigned to someone else

poses a special problem. First of all, the SSN will show up multiple times across firms in one

quarter for workers with different surnames (the wage report includes the first three characters of

the workers' surnames). With this information alone, it is not possible to know which worker is

using the SSN fraudulently and who the valid owner of the number is. If one of the

SSN/surname pairs shows up in the data initially in a quarter by itself, this is the pair that is

considered valid, and all other duplicates (with different surnames) are considered invalid.

Does "Invalid" mean "Undocumented?"

Not all invalid SSNs are classified as undocumented workers; examining the patterns of

incidence of different types of invalid SSNs suggests that some types are firm generated rather

than worker generated. Figure A1 illustrates the incidence patterns across types of invalid SSNs

in construction. The percent of workers with SSNs having a high area number or out-of-

sequence group number displays the expected growth in undocumented workers (see Hoefer,

Rytina, and Campbell 2007), whereas the incidence of SSNs for other reasons exhibits a flat to

declining, highly seasonal pattern (this seasonality appears in all other sectors, as well). The

strong seasonal nature of the other invalid reasons suggests that firms are temporarily assigning

invalid SSN numbers to workers before having time to gather the information for the purpose of

record keeping/reporting. Or firms may decide to not bother obtaining a SSN for workers who

will only be employed a very short time.[18] The high degree of churning observed among

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[18]Indeed, a worker has 90 days to resolve a discrepancy that results in the receipt of a "no-match" letter from the Social Security Administration. The employee may be long gone before such a letter is even received.

workers with invalid SSNs for these other reasons is consistent with either of these practices.

[Figure A1 here]

Since there is no way to know whether a temporary assignment by the firm of an invalid SSN is to merely cover for temporary employment of an undocumented worker or to allow the firm to file its wage report before having had a chance to record the worker's valid SSN, a worker is only classified as "undocumented" if the SSN reported has an <u>area number that is too high or a group number assigned out of sequence</u>; workers with invalid SSNs for any other reason are considered neither undocumented nor documented and, thus, are excluded from the analysis. This will clearly undercount the actual number of undocumented workers.

Figure A2 plots the prevalence of undocumented workers in the seven broadly defined sectors with the highest incidences. The concentration of workers in these sectors was also identified nationally by Fortuny, Capps, and Passel (2007).[19] The pattern of growth is also consistent with Fortuny, Capps, and Passel who estimate that 72 percent of unauthorized immigrants in Georgia arrived in the last 10 years.

[Figure A2 here]

Fortuny, Capps, and Passel (2007) estimate that 4.5 percent of the workforce in Georgia was undocumented in 2004. In our sample 1.0 percent of workers are classified as undocumented in 2004, implying that the sample used for the analysis in this paper is capturing about 22 percent of all undocumented workers in the state of Georgia. Note that the identification process we use in this paper does not make any assumptions about whether the employer knows a worker is documented or undocumented. In addition, the goal of the

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[19]Fortuny, Capps, and Passel (2007) estimate that nationally in 2004 the percent of workers in leisure and hospitality and construction that was undocumented was 10 percent each, nine percent of workers in agriculture, and six percent each in manufacturing, professional and business services, and other services. Also see Pena (2010).

conservative identification process was to end up with a sample in which we can have a high degree of confidence that the sample is representative of the undocumented workforce, not to actually count the number of undocumented workers in Georgia.

Are Undocumented Workers Correctly Identified?

There are several reasons we are confident that the sample of undocumented workers is representative. First of all, the rate of growth seen in both the number and percent of undocumented workers identified in Georgia matches closely the rate of growth in the Social Security Administration's (SSA) earnings suspense file (ESF). The ESF is a repository of social security taxes paid by employers that cannot be matched to a valid name or SSN. It is widely believed that this growth in the ESF reflects growing incidence of unauthorized work in the U.S. (Bovbjerg 2006).

Figure A3 plots the number of workers (panel a) and the percent of workers (panel b) identified as undocumented along with the size of the ESF. This figure shows a remarkable consistency between the growth seen in workers identified as undocumented and the ESF.

[Figure A3 here]

As mentioned earlier, data suggest that between 40 and 60 percent of Mexicans in the U.S. are undocumented, and that 61 percent of unauthorized immigrants come from Mexico (see footnote 3). Clearly not all Hispanics are undocumented, or vice versa, however using weighted data from the Current Population Survey (CPS), we calculate the average annual growth in total workers and total number of foreign born, Hispanic workers in the U.S. and in Georgia in order to compare growth rates to those in our sample. These results are reported in Table 1. The work force in GA grew faster over the period than the U.S. work force (2.9 percent vs. 1.5 percent, respectively). In addition, the number of foreign born, Hispanic workers in the U.S. grew faster

(eight percent per year) than the overall work force; this phenomenon has been documented by others (Passel and Cohn 2009a). But most importantly for our purposes, is that the growth rate of foreign born, Hispanic workers in GA (roughly 27 percent per year), which is much larger than in the U.S. overall (also see Passel and Cohn 2009a), is similar to the growth in the number of workers in GA classified here as undocumented. We also observe a similarly large growth rate in the number of foreign born, Hispanic workers with less than a high school degree (21percent), among which we might expect a larger share of undocumented workers than among foreign born, Hispanics in general.

[Table A1 here]

The close match in growth rates in the number of workers classified as undocumented with that of the SSA ESF and with the number of foreign born, Hispanic workers in Georgia as measured by the CPS, suggests that the mechanism employed in this paper to identify undocumented workers is accurate; it's clear that not all undocumented workers are being captured in the data, but those identified as undocumented are likely to be undocumented.
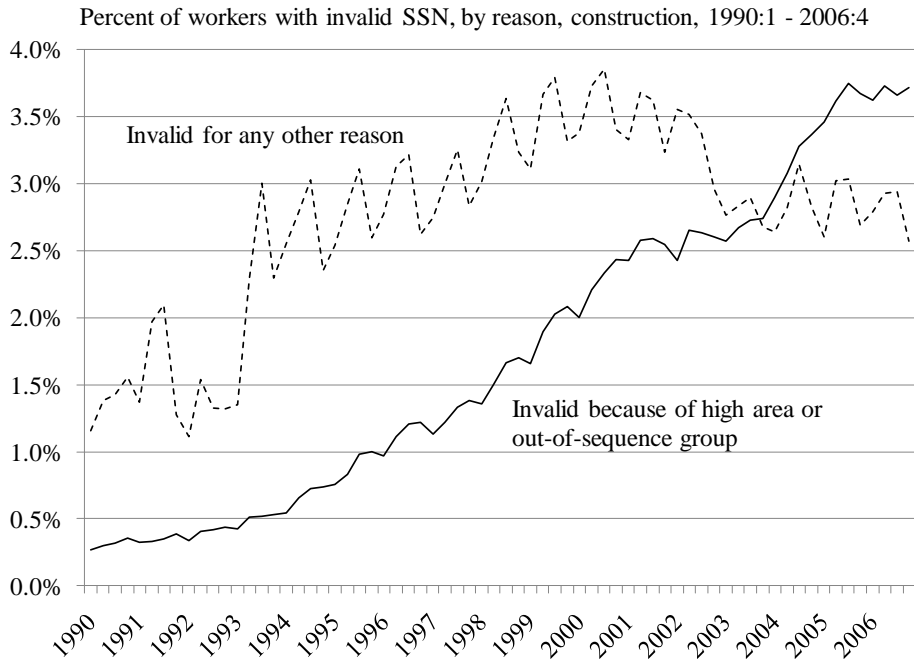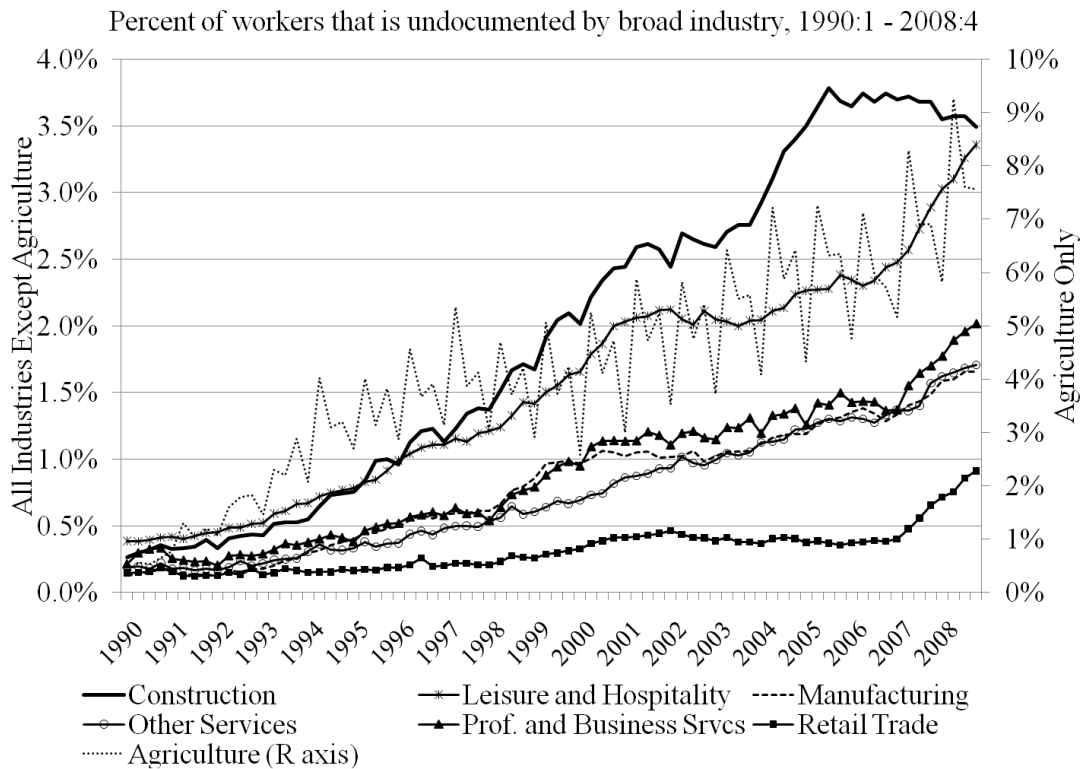
Figure A1.

Percent of workers with invalid SSN, by reason, construction, 1990:1 - 2006:4

Invalid for any other reason

Invalid because of high area or out-of-sequence group

Figure A2.

Percent of workers that is undocumented by broad industry, 1990:1 - 2008:4

Construction —— Leisure and Hospitality ——*—— Manufacturing -----
Other Services ——○—— Prof. and Business Srvcs ——▲—— Retail Trade ——■——
Agriculture (R axis) ········

Notes: See Appendix B for sector definitions.

Figure A3. Growth in the earnings suspense file and the total number and percent of workers identified as undocumented in Georgia, 1990-2006.

(a) Growth in earnings suspense file and number of undocumented workers identified in Georgia, 1990-2006.

(b) Growth in earnings suspense file and percent of workers identified as undocumented in Georgia, 1990-2006.
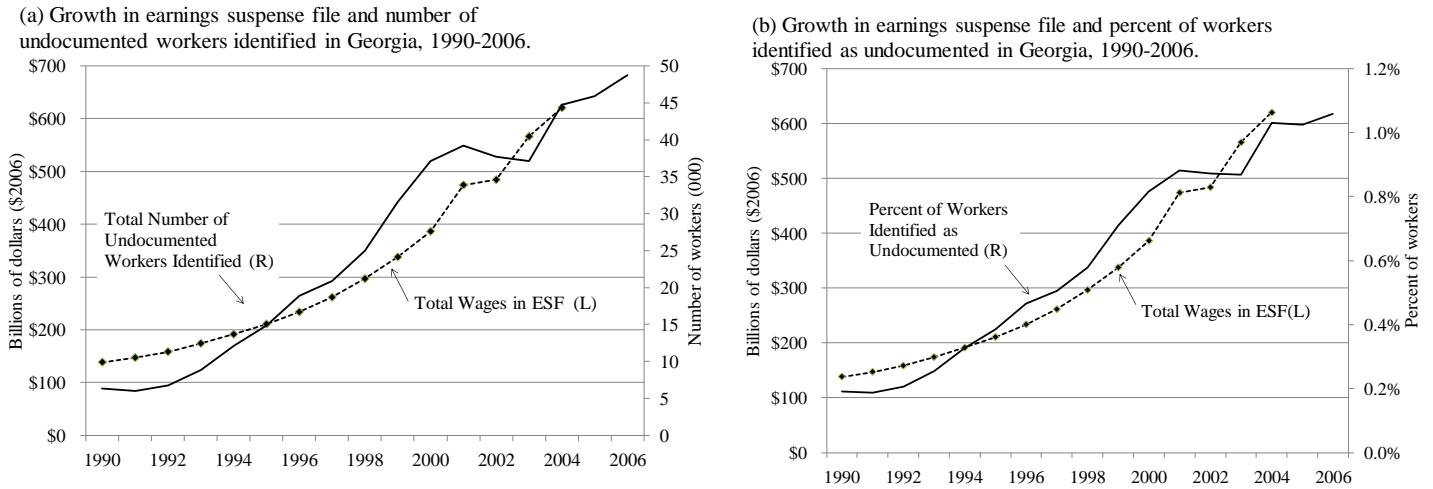
Source: Huse (2002) for estimates 1990-2000, Johnson (2007) for estimates 2001-2004, and authors' calculations. Dollar estimates reflect 2006 values, using the PCE chain-weighted deflator.

Table A1. Average annual growth, 1994-2008, in U.S. and GA employment, Hispanic workers, and workers identified as undocumented.

Average Annual Growth Rate of:	
Total number of workers in the U.S.	1.43%
Total number of foreign born, Hispanic workers in the U.S.	7.26%
Total number of workers in Georgia	2.82%
Total number of foreign born, Hispanic workers in Georgia	20.74%
Total number of workers in GA identified as undocumented	*29.65%*

Source: Current Population Survey, Basic Survey (March), 1994-2008; and authors' calculations.
Note: 1994 is used as the base year, since it is the first year the Current Population Survey has a reliable indicator of Hispanic ethnicity.

Appendix B: Definition of Sectors

Table B1: Definitions of sectors based on 2-digit NAICS classifications.

Sector	Included 2-digit NAICS
Construction	23
Manufacturing	31-33
Transportation and Utilities	22, 48-49
Wholesale Trade	42
Retail Trade	44-45
Financial Activities	52-53
Information	51
Professional and Business Services (includes temporary services)	54-56
Education and Health Services	61-62
Leisure and Hospitality	71-72
Other Services (includes private household, laundry, and repair and maintenance services)	81

<u>**Appendix C: Skill and Labor Intensity Categories**</u>

Industry Skill Classification

Each three-digit NAICS industry is assigned a skill intensity based on the weighted average of educational attainment of workers in that industry, using the Current Population Survey for 1994. This year was chosen since this is the first year in which the nativity (place of birth) of respondents is reported. For each industry, the percent of workers with less than a high school education (LTHS), a high school education (HS), some college (SCOLL), college degree (COLL), and graduate education (GRAD) is calculated. Skill intensity categories were assigned as follows:

$$LowSkill = \begin{cases} 1 \ if LTHS > HS + COLL \\ 0 \ otherwise \end{cases}$$

$$HighSkill = \begin{cases} 1 \ if SCOLL + COLL + GRAD > HS + SCOLL \\ 0 \ otherwise \end{cases}$$

$$MediumSkill = \begin{cases} 1 \ if HighSkill = 0 \ and LowSkill = 0 \\ 0 \ otherwise \end{cases}$$

About 23 percent of the industries are classified as high skill, 15 percent at low skill, and 62 percent at medium skill. Some examples of low-skill industries include agriculture, some manufacturing, and accommodation and food services. Medium-skill industries include construction, retail trade, some manufacturing, some education and health, and arts and entertainment. High skill industries include the information sector, electronic computer manufacturing, the financial sector, and some education and health.

Industry Labor Intensity Classification

Labor share for each four-digit NAICS industry is based on coefficients from the U.S. Input-Output (I-O) Benchmark Tables 2002

(http://www.bea.gov/industry/index.htm#benchmark_io). The labor share coefficient is defined as the share of compensation of employees (wage bill) in total industry output. Compensation of employees includes wages and salaries and their supplements. Total industry output is the sum of the products consumed by the industry, compensation of employees, taxes on production and imports less subsidies, and gross operating surplus.

Coefficients are calculated at the four-digit NAICS industry level and grouped in 3 levels. Level 1 includes coefficients from 0.01 to 0.29 (cost of labor accounts for from one to 29 percent of total output), level 2 includes coefficients equal to 0.30 to 0.39, and level 3 includes coefficients from 0.40 to 0.79.

Examples of industries in Level 1 are oilseed and grain farming, oil and gas extraction; petroleum refineries; automobile manufacturing; electronic computer manufacturing; real estate; snack food and breakfast cereal manufacturing; doll, toy, and game manufacturing; telecommunications; cutlery, utensil, pot, and pan manufacturing; rail transportation; and book publishers. In Level 2, we find footwear manufacturing; printing; dry-cleaning and laundry services; tire manufacturing; watch, clock, and other measuring and controlling device manufacturing; fitness and recreational sports centers; child day care services; insurance agencies; brokerages; wholesale and retail trade; and food services and drinking places. Level 3 includes cut and sew apparel contractors, custom computer programming services, scientific research and development services, elementary and secondary schools, nursing and residential care facilities, home health care services and employment service.

Appendix D: Estimating Proxies for Quarterly Georgia Gross State Product

Georgia's Gross State Product is an annual series, and to obtain a proxy for a quarterly series we look at U.S. gross domestic product, Georgia personal income and Georgia personal income less transfers. We calculated the correlations between the logs of these series and the log of Georgia's GSP, and then we estimated the series' cyclical component correlations, and we decided to use personal income less transfers. The results of these correlations are as follow:

Log series correlations	
	GA GDP
U.S. GDP	0.986
GA Personal Income	0.995
GA Personal Income-transfers	0.997

Cyclical component correlations	
	GA GDP
U.S. GDP	0.703
GA Personal Income	0.736
GA Personal Income-transfers	0.766

Source: U.S. Bureau of Economic Analysis and authors' calculations

Appendix E. Definitions of variables and source data.

For all the variables in equation (9) we use annual data between 1990 and 2008. The data are as follows:

$D_t w_t^D$ is total annual wage earnings of documented labor in constant 2005 dollars.

$K_t r_t$ is capital income, which is computed as a residual by subtracting GA labor earnings from GA PI. Labor earnings is calculated from personal income accounts of GA and is equal to:

Labor Earnings = Wages and salaries - personal contribution for social insurance + other labor earnings + adjustment for residence + some share of proprietor's earnings.

There are different views on how much of proprietors' earnings should be counted as labor earnings. The approach we take here is to apply the same ratio of unambiguous labor earnings (wages and salaries - personal contribution for social insurance + other labor income + adjustment for residence) and unambiguous capital income (dividends and interest earnings) to the division between capital and labor.

In addition, the following terms are measured as:

D = number of documented workers employed.

K = The physical capital stock in GA economy measured in constant 2005 dollars.

Appendix F. Comparison of results for narrow and broad samples of undocumented workers.

Recall from Appendix A that the stylized facts and simulation comparison make use of a narrowly-defined sample of undocumented workers for whom we are the most confident are representative of the undocumented worker population in the state of Georgia during the time period studied. The purpose of this appendix is to demonstrate that the measure of volatility and simulation comparison is robust to the use of the broader sample of undocumented workers. This broader sample is not used in the main body of the paper because we believe it is more prone to measurement error, although that measurement error does not appear to be correlated with volatility of the sample.

Table F1 compares the volatility of the narrow and broad samples of undocumented worker employment with the model estimate for that volatility, making use of KORV's (2000) 0.4 estimate for the value of θ using the estimated values of λ and ρ (which do not depend on the sample of undocumented workers), and the estimated μ, which is also reported in the table.

[Table F1 here]

First of all, volatility appears to be greater within the broad sample, relative to the narrow sample of undocumented workers. However, the differences are slight enough that the comparison to the model produces the same conclusions as those reported in the text of the paper.

Table F1. Volatility of undocumented employment: Model vs. Data, broad and narrow sample of undocumented workers.

	Narrow Sample $\mu = 0.001$		Broad Sample $\mu = 0.0027$	
	Data	Model	Data	Model
1990Q1:2008Q4	0.07	0.08	0.09	0.08
1990Q1:1999Q4	0.08	0.10	0.11	0.11
2000Q1:2008Q4	0.06	0.05	0.06	0.05

Note: $\lambda = 0.78$, $\rho = 0.14$, $\theta = 0.4$.

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