An Equilibrium Sorting Approach to Evaluating the Employment Effects of Environmental Regulations

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This paper demonstrates the potential of equilibrium sorting models to inform debates about the employment effects of environment regulations. Sorting models are capable of modeling households' joint decisions of where to live and work, rather than just where to work. To demonstrate the potential of such models we consider how job loss and unemployment would affect different workers in Northern California. Our stylized simulations produce earnings losses that are consistent with the stylized facts from existing studies. They also produce two new insights. First, we find that earnings losses are sensitive to business cycle conditions. Second, we find that earnings losses may substantially understate true welfare losses once we account for the fact that households may have to commute further or live in a less desirable community after losing a job.

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Introduction

How important are the employment effects of federal regulations? Some regulatory evaluations estimate the number of jobs that will be created or destroyed, but there is no widely accepted framework for monetizing these effects. Five consecutive years of high unemployment have motivated policymakers to look for ways to integrate employment effects into benefit-cost analyses (OMB 2012). Most of the discussion to date has focused on ideas for adjusting measures of lost earnings to anticipate the duration of unemployment (Masur and Posner 2012). In this paper, we extend the literature to begin to consider how to develop a welfare-consistent measure of adjustment costs.

The majority of job searches are inherently spatial.[1] A worker's job location limits where he can live, and his house location limits where he can work. These constraints link the housing and labor markets in ways that influence the spatial mobility of the labor force. For example, according to the American Housing Survey, "new job or job transfer" is the second most frequently cited reason for moving out of a former dwelling. Likewise, "convenient to job" is the most frequently cited reason for selecting a new neighborhood. These statistics reinforce the need to consider the implications of layoffs for spatial mobility. If an unemployed worker's best job offer is far from his house, then he may decide to move. If he perceives the quality of life in his new neighborhood to be lower (higher) than his old neighborhood, then he may experience a significant welfare loss (gain) in addition to any change in earnings. Equilibrium sorting models of household participation in the housing and labor markets offer the potential to develop welfare-consistent measures of adjustment costs of unemployment that account for both changes in earnings and changes in the quality of life.

[1] Approximately 75% of U.S. workers report that they spend no time telecommuting (Noonan and Glass, 2012).

Equilibrium models of residential sorting are often used to predict the welfare effects of policies that influence the quality of life by altering the spatial distribution of public goods. While most applications assume the policy has no effect on wages or employment, a few recent studies have begun to model links between workers' participation in the housing and labor markets (Kuminoff 2010, Bishop 2011, Mangum 2012). In this paper, we extend Kuminoff's model to develop a framework for evaluating the welfare effects of a prospective regulation that would improve environmental quality while simultaneously generating layoffs.

Our analysis is based on a model of how people decide where to live and work. Households are assumed to differ in their job skills and in their preferences for local public goods, housing, and a composite private good. Different job locations offer different (wage, commuting) options. House locations differ in the public goods they provide, and in the price of housing. Each household is assumed to weigh its options before choosing the job-house combination that maximizes its utility.

When a worker in our model loses his job, he experiences a temporary unemployment spell. Its duration may vary with the worker's skills and with the state of the broader economy (e.g. recession versus expansion). At the end of the unemployment spell, the worker finds a new job. We force the worker to move to his best available job in a different metro area, holding the worker's occupation fixed but allowing him to change industries. Thus, unemployment is treated as a constraint on the worker's labor market mobility. Forcing unemployed workers to migrate allows us to evaluate the *potential* for labor market migration to influence the welfare effects of layoffs. A key feature of our model is its ability to capture the richness of commuting options in a major urban area.

In order to demonstrate the potential importance of labor market migration for the welfare effects of layoffs, we build a "layoff simulator" for Northern California's eight major metropolitan areas. The model predicts that the average North-

ern California worker's annual earnings would decline by $5,547 if he were to suddenly lose his job during a "normal" state of the economy and relocate to a new job in one of the seven other metro areas. Approximately 70% of this reduction is due to a loss of job-specific human capital. The other 30% comes from wages lost during his unemployment spell. Our layoff simulator predicts that earnings losses account for only 76% of the change in welfare. The remaining welfare losses come from a novel margin: even after workers find new jobs, they often face a tradeoff between moving to a less desirable community with, for example, lower air quality or remaining in their current community and driving a longer commute. Our model also predicts that the relative importance of lost earnings and changed housing-commuting options varies systematically across workers according to their age, experience, occupation, industry, job skill, preferences, and geographic location. Thus, our findings suggest that spatial migration has the potential to be of first order importance for evaluating the welfare effects of layoffs. We also find that the state of the economy is important for adjustment costs. Expected earnings losses are approximately 7% lower during an expansion and 16% higher during a recession.

Our paper occupies a middle ground between the partial equilibrium (Bartik) and general equilibrium (Rogerson) papers presented in this symposium. We define static welfare-consistent adjustment cost measures at the household level, while recognizing that the size of the household's income shock associated with temporary unemployment depends on broader macroeconomic conditions. Our measure of adjustment costs recognizes that some unemployed workers make spatial adjustments that affect their cost of living and quality of life. These adjustments feed back into welfare measures. Unlike the fully general equilibrium approach of the Rogerson paper, we do not model working households as forward-looking dynamic decision-makers. Nor do we model impacts on firms, adjustments to equilibrium prices or wages, or the welfare costs of collecting public

funds through taxation to pay for unemployment insurance. Our description of the household adjustment process is simple relative to some papers in the empirical sorting literature (Kuminoff, Smith, and Timmins 2013) in that we consider a hypothetical policy that is small enough that it will not induce feedback effects of the magnitude that make the general equilibrium features of Rogerson's model important. For some policies, this may be a fair approximation of reality. For others, it will clearly be insufficient. For example, extremely high unemployment could cause housing prices to fall. This might benefit renters, while reducing homeowners' assets and increasing their probability of foreclosure. Accounting for the differences between owners and renters, and the ways in which the owned and rented housing markets interact, are among the most important considerations for future research in the empirical sorting literature.

Our paper is related to Bartik's in that we both consider costs associated with transitioning from job loss to new employment. Our focus is on the spatial component of this process, whereas Bartik's is on factors that reduce the value of non-work time. Both papers consider worker-specific factors that might affect the duration of unemployment such as industry, occupation, income, age, and house location. This introduces an important source of heterogeneity that is more difficult to address in a dynamic general equilibrium setting.

In the remainder of this paper we provide an overview of the equilibrium sorting model and demonstrate how it could be used, drawing on data for Northern California's working households. This is followed by some discussion of caveats and suggested directions for future research.

Overview of the Model

Consider a prospective regulation that is expected to improve environmental quality at the cost of inducing layoffs for workers in a particular industry and geo-

graphic area. For example, a proposed regulation might target the manufacturing sector in counties designated as severe nonattainment areas for federal air quality standards. How would such a regulation affect consumer welfare? The equilibrium sorting approach to answering this question proceeds in four steps. The first step is to characterize the microeconomic process that originally led the affected households to choose their current jobs and houses. The second step is to use information on macroeconomic conditions to predict the expected durations of unemployment spells for workers who lose their jobs. The third step is to predict where the unemployed workers will eventually relocate. The last step is to calculate the change in consumer welfare implied by the wages lost during unemployment and the adjustment costs associated with relocation. The remainder of this section provides an intuitive description of each of the four steps. A technical exposition of the model can be found in Kuminoff, Schoellman, and Timmins (2013).

Step 1: Characterizing Workers' Baseline Job and House Choices

Most Americans live in urbanized regions with diverse opportunities for employment and housing (e.g. Northern California, the Los Angeles metro area, and the city of New York). Equilibrium sorting models typically focus on a single region. The modeling process begins by dividing the region into housing communities and job locations. Communities are often defined as public school districts. These areas are sufficiently large to have noticeable differences in the price of housing and access to local public goods. Public goods may include services produced from tax revenue, such as public school quality, as well as environmental amenities influenced by regulatory activity, such as air quality. Job locations are often defined as metropolitan areas (e.g. San Jose, Oakland, San Francisco). Conditional on skill, a worker may be compensated differently in different job

locations due to spatial variation in regulation, tax rates, local cost-of-living adjustments, unionization, and other factors that affect the local demand for labor.

Working households are assumed to have perfect information about the spatial landscape.[2] They evaluate the feasible job-house locations and select the particular one that maximizes their utility. A household's utility depends on its consumption of private goods (including housing), its access to local public goods in its home community, and the amount of time the household's primary earner must spend commuting. We follow one of the main branches of the literature in using a parametric model for utility that assumes a constant elasticity of substitution (CES) between public and private goods (e.g. Epple and Sieg 1999, Sieg et al. 2004, Smith et al. 2004, Kuminoff 2010, Kuminoff, Schoellman, and Timmins 2013). We observe the house prices and local public goods in different communities; the wages workers earn in their chosen jobs; and the commute times between communities and job locations. Our econometric model estimates the preferences of households for private consumption and public goods and the skills of workers that rationalize these observed choices and prices as equilibrium outcomes in the market. This process involves characterizing each worker's job opportunities.

The primary earner of each household is assumed to possess idiosyncratic skills that determine the wages he would earn in each job location. Some dimensions of skill can be observed from Census micro data, such as a worker's age, education, and occupation. This information can be used to predict what the worker would earn in each job location. The difference between this prediction and the worker's actual wage at his chosen job is used to define a measure of the worker's latent job skill. Similarly, information on housing prices, household income, and access to local public goods is used to infer the strength of a household's idiosyncratic preferences for public and private goods. For example, all

[2] While the model allows some households to be retired, they do not play a direct role in our analysis. Retired households are assumed to ignore the labor market. They select a community, which determines their housing expenditures and their consumption of public goods.

else constant, a household that chooses to sacrifice a larger fraction of its income in order to live in a community with good air quality is revealed to have relatively strong preferences for air quality.

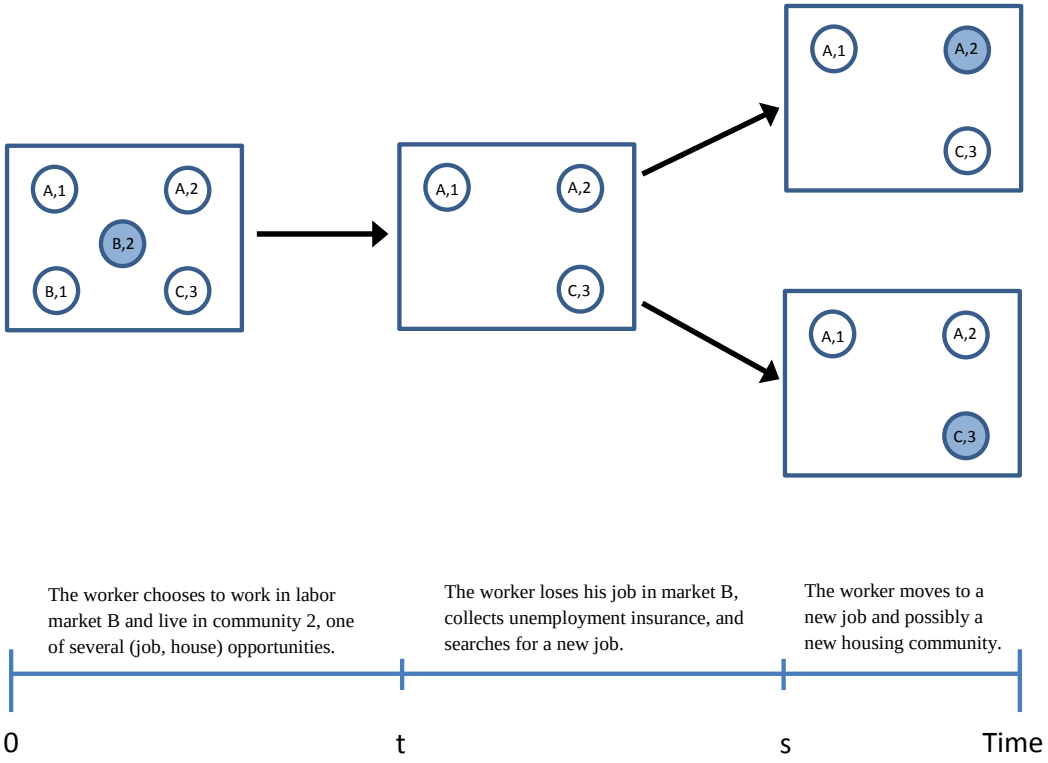


Figure 1: A Schematic of the Sorting Model's Key Components

The leftmost box in figure 1 provides a stylized representation of the choice process the model seeks to explain. There are three metro areas (A, B, and C) and three housing communities (1, 2, and 3). The circles represent the feasible job-house combinations. Metro areas A and B are both within commuting distance of communities 1 and 2. In contrast, metro area C is too far from communities 1 and 2 for commuting between them to be feasible. Hence, moving to a job in C would require moving to a house in community 3. The darkened circle (B,2) represents

the location where we observe a particular household in the baseline period. The econometric model solves for measures of the household's latent preferences and job skills that make (B,2) the location that maximizes the CES utility function for that household. In other words, the equilibrium sorting model calibrates a particular CES utility function to explain the housing and labor market choices that we observe each household making.[3]

Step 2: Predicting the Expected Duration of Unemployment Spells

We mimic the experience of losing a job by removing the primary earner's current job location from his set of feasible locations. This is depicted in the middle box in figure 1, which represents the worker's period of unemployment. Forcing unemployed workers to work in a new metropolitan region allows us to evaluate the *potential* for spatial migration in the labor market to influence the welfare effects of layoffs. During the interim when a worker is looking for work we assume the worker collects unemployment insurance, consistent with current U.S. policy.

The transition to a new job takes time. The worker must prepare a resume, search for vacancies, and go through interviews. If a prospective job is located far away, the worker may choose to search for housing simultaneously. The probability that a newly unemployed worker will find a job within a given amount of time can be modeled using the actual job-finding experiences of recently unemployed workers in the same industry as reported in the Current Population Survey. Of course, the duration of unemployment may also vary with macroeconomic conditions. It will tend to be shorter during an economic expansion and longer during a recession.

Step 3: Predicting the Worker's New Job and House Choices

[3] While any parametric assumption for utility is inherently arbitrary, it is worth noting that the CES specification used here is more flexible than most of the alternatives in the literature.

After removing a worker's current job location from his set of feasible locations, we use his calibrated utility function to predict which of the remaining job-house locations would maximize his household's utility. Then we assign the worker to the corresponding metro area. The worker's new job may be in a different industry, but his occupation is assumed to be unchanged. This allows us to match each worker to the wages paid to other workers with similar training.[4] Whether the worker's wage rises or falls at his new job also depends on the latent component of his idiosyncratic skill recovered in step 1. After moving to a new job location, the worker may choose to remain in the same community, as shown in the top right box of figure 1. If, however, the necessary commute time induces the worker to move to a different community, as shown in the bottom right box in the schematic, then his change in utility will also depend on his household's idiosyncratic tastes for local public goods in relation to the public goods provided by the new community. A household may prefer the public goods provided by the new community and the household's income may rise at the primary earner's new job, but both cannot occur simultaneously. Utility must decline when a household's preferred location is removed from its choice set.

There are three caveats to our predictions. First, the model focuses exclusively on the primary earner's contribution to household income. All other sources of income are assumed to be fixed, including any changes in wages that would be experienced by secondary earners in a household.[5] Second, we do not allow unemployed workers to move to lower-skill jobs in the same metro area (e.g. a machinist working as a cashier).[6] The estimator does not identify skill parameters that would enable us to consistently model this possibility. However, we can con-

[4] In practice, we define occupations using 5-digit codes from the Standard Occupational Classification system. For example, the 5-digit SOC codes distinguish between five types of social scientists: economists, market and survey researchers, psychologists, sociologists, and urban and regional planners.
[5] In order to consistently predict how the incomes of secondary earners would adjust, the model would need to be extended to depict bargaining within the household. We return to this idea later as a potential area for future research.
[6] This could be particularly important for the issue of owners v. renters. Owners may face bigger moving costs and might be willing to accept a worse job to not have to leave their home.

sider a "best-case" scenario for the worker where he ultimately finds a new job at the same wage as his old job in the same metro area as his old job. This best-case scenario and our "new job location" scenario define upper and lower bounds on the welfare consequences of moving to a lower-skill lower-pay job in the same metro area as the old job. Finally, since a household's heterogeneous preference and skill parameters are estimated in step 1, rather than observed directly, we must acknowledge that the model's prediction for a particular household's new job and house locations reflect some uncertainty. For this reason, we report welfare effects as averages for particular types of households and workers.

Step 4: Calculating the Change in Consumer Welfare

For simplicity, we assume that layoffs and any changes in environmental quality are sufficiently small to leave housing prices and wages unaffected.[7] The change in consumer welfare can then be measured using a partial equilibrium concept of equivalent variation (EV). We define EV as the amount of annual income one would have to give (or take from) a household before the regulation to make them as well off as they are after the regulation, given the duration of the primary earner's unemployment spell, the wage at his new job, and any adjustments to the household's quality of life.

Because the model is inherently static, it assumes that each worker's next job is his second-best choice, without accounting for any intervening or temporary jobs. Likewise, it assumes that workers earn their long-run salaries immediately, without accounting for any initial period of lower salary or higher salary growth. The lack of dynamics also complicates the treatment of unemployment spells. As

[7] In the case of a regulation that produces a "large" shock to the housing and labor markets, a sorting model such as this one can be used to simulate ex post equilibria, taking into account changes in housing prices, wage rates, and commuting patterns. However, fairly strong restrictions on preferences are required to guarantee the equilibrium is unique. Current research is focused on evaluating the external validity of these models. See Kuminoff, Smith, and Timmins (2013) for a discussion.

a matter of convenience, we convert the wages lost during the worker's unemployment spell into an annuity, using the worker's expected lifespan and an interest rate set to match the cost of a borrowing on a 30-year fixed rate mortgage. Intuitively, we are assuming the household finances its consumption during the unemployment spell by borrowing against their house, spreading the temporary wage shock across the worker's expected lifespan.

Some workers who find new jobs may be underemployed. Underemployment is modeled here at the extensive margin. That is, the worker's occupation and hours worked are assumed to be fixed, but his second-best job option may be in an industry that does not allow him to fully utilize his occupational skills.[8] The loss of industry-specific or job-specific human capital may cause the worker's wage to decline.

The main implication of this framework for policy analysis is that analysts should be wary of interpreting changes in workers' earnings as welfare effects of layoffs or newly created jobs. Specifically, the change in earnings fails to account for the welfare implications of: (i) changes in commute time; (ii) changes in housing expenditures on housing; and (iii) changes in access to local public goods. As an extreme case, consider a worker who, prior to the regulation, chose to work at a low paying job in order to live in a desirable community. If the worker loses his job, his next best alternative may be to move to a less desirable community near a higher paying job. If the worker's unemployment spell is brief, his annualized income could *increase* despite the fact that he is clearly worse off from the move. Our point is that changes in earnings may understate or overstate welfare effects. The direction of the bias depends on whether the displaced workers move to neighborhoods with housing options, commuting options, and bundles of local public goods that they perceive to be more or less desirable.

[8] We may understate the potential for underemployment by not allowing workers to change occupations. It would be interesting to know how many workers who lose their job because of regulation actually do change occupations. We return to this issue in our discussion of future research.

Differences from a Conventional General Equilibrium Model

Compared to a conventional general equilibrium (GE) model of the economy, our sorting framework puts more emphasis on understanding the distribution of wage effects and welfare effects experienced by workers, and less emphasis on placing these effects within the context of social welfare. This allows us to approach the problem at a high level of resolution. For example, we can investigate the extent to which wage effects and welfare effects vary across working households according to demographic characteristics we can observe (e.g. income, occupation, industry) and according to estimated parameters representing unobserved features of their human capital and preferences for public goods. The sorting model also allows us to consider the role of space, recognizing that adjustments to earnings and public goods may be conveyed to households through spatial adjustment. In contrast, most GE models lack a spatial dimension.

The flexibility allowed by our sorting model also comes at a cost. While it depicts interrelated behavior in multiple markets, it is a static framework that abstracts from general equilibrium feedback mechanisms. Unlike most GE models, the prices of private goods are assumed to be unaffected by shocks to the housing and labor markets. Furthermore, the lack of an explicit model of the firm or government means that we cannot construct measures of producer surplus, social welfare, or the deadweight loss from unemployment insurance schemes. Finally, unlike the broad class of dynamic stochastic GE models used in macroeconomics, our sorting framework does not allow us to predict the adjustment path to a new equilibrium. Rogerson's paper in this symposium explains how macroeconomic models can address these caveats. Overall, these caveats suggest that the equilibrium sorting framework is most appropriate for evaluating regulations that affect a small share of workers in a particular industry and study region.

Building a "Layoff Simulator" for Northern California

In order to demonstrate how the model could be used, we construct a "layoff simulator", drawing on Kuminoff's (2010) previous calibration of the model to baseline data on working households in Northern California. Then we adapt the calibrated model to predict the wage effects and welfare effects of layoffs. We do not consider any particular regulation or model changes in environmental quality. This helps to concentrate our focus on modeling the effects of layoffs.

Calibrating the Model to Working Households in Northern California

The model is calibrated to Northern California's two main population centers—the San Francisco and Sacramento consolidated metropolitan statistical areas.[9] Housing communities are defined by dividing the region into 122 unified school districts; job locations are defined by the region's 8 primary metropolitan statistical areas (PMSA), shown in figure 2. The population is concentrated around the San Francisco Bay and the city of Sacramento, as seen by the density of census tracts in the map on the left. The set of possible location choices is defined by 268 community-PMSA combinations that, together, account for 99% of the working population.[10]

Housing prices were calculated from micro data on housing sales recorded by county assessors between 1995 and 2005. These data were used to calculate an index of community-specific housing prices using a procedure described in Seig et al. (2002). The index ranges from 1.00 to 6.51. Its distribution is consistent with the conventional wisdom that housing is particularly expensive in the San Francisco Bay Area.

[9] This region contains approximately 9 million people, or 3% of the U.S. population.
[10] The criterion used to select job/housing location combinations is that they must account for at least 500 working households (0.02% of the working population). This effectively excluded multiple-hour commutes between distant locations.

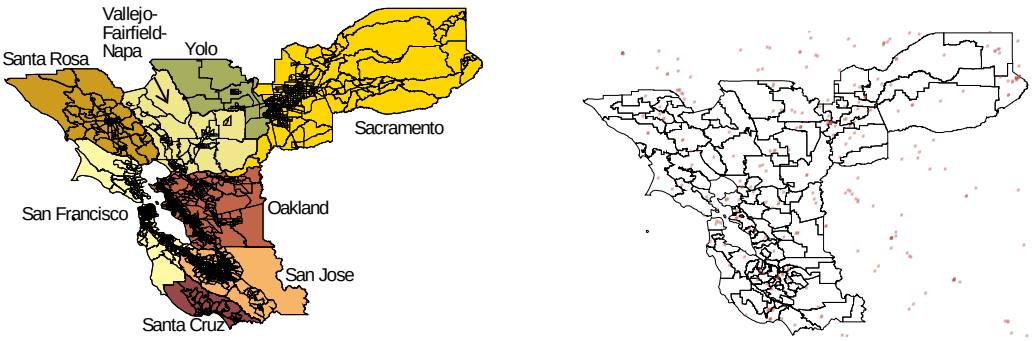


Figure 2: San Francisco and Sacramento Consolidated Metro Areas

Notes: The map on the left illustrates census tracts overlaid on the eight primary metro areas in the study region. The map on the right illustrates the locations of air quality monitoring stations overlaid on public school districts.

Air quality is measured using concentrations of ground level ozone. The right-side map in figure 2 shows the locations of 210 monitoring stations in school districts. Community-specific measures were constructed by first assigning to each house the ozone measure recorded at the nearest monitoring station, and then taking an average over all the houses in the community.[11] This process was repeated for 1999, 2000, and 2001, and the results averaged. The final measure ranges from 0.031 (parts per million) in the highest air quality community to 0.106 in the lowest.

School quality is defined using California's Academic Performance Index (API), a composite index of standardized test scores, weighted across all subjects and grade levels. For each community, a three-year average API was constructed by weighting the score of each school in the community by its number of students from 1999-2001. The resulting measure ranges from 528 to 941. A set of community-specific fixed effects are used to capture the composite effect of all other localized amenities on household location choices.

Finally, micro data on households and their location choices were drawn from

[11] The exact ozone measure used is the average of the top 30 1-hour daily maximum readings recorded at each monitoring station during the course of a year.

the 5% micro data sample of the 2000 Census of Population and Housing. Key variables include house location, household income, and the primary earner's job location, occupation, industry, wage income, commute time, gender, age, race, and years of education.[12] If a worker were to move to a different job-house location, his counterfactual commute time is assumed to be the average commute time observed for that location. See Kuminoff (2010) for additional detail on the data and an explanation of the econometric methods used to estimate parameters representing the latent components of households' idiosyncratic preferences and skills.

Defining the Macroeconomic Conditions

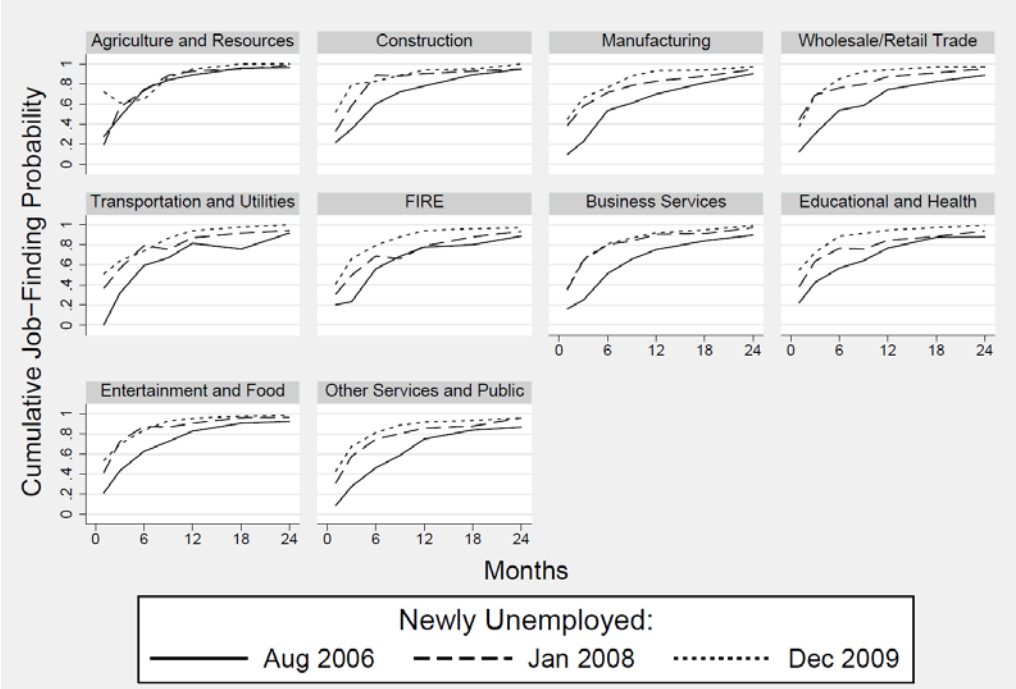
We calibrate the model to reflect the duration of unemployment spells observed in the Current Population Survey (CPS) at different stages of the business cycle. The primary goal of the CPS is to provide monthly data on the labor market status of a sample of approximately 60,000 Americans. We construct from these files the subsample of unemployed workers age 16 or older between January 2002 and February 2012. We focus on this time period because the industry classifications were consistent over time, enabling us to construct industry-specific job finding rates. The CPS asks each unemployed worker how long they have been unemployed. Given the total number of workers unemployed at date *t*, u_t, and the number unemployed for more than *s* weeks at date *t*+*s*, u_{t+s}^{s}, we can construct an approximation to the job finding rate at various durations as:

$$\omega_{s,t} = 1 - u_{t+s}^{s}/u_t \ . \tag{1}$$

[12] Occupation is defined using the Standard Occupational Classification system. Industry is defined using the North American Industrial Classification System. Job and house locations are defined in the Census data as public use microdata areas (PUMA). In most cases, there is an exact mapping from PUMAs to PMSAs and unified school districts. In cases where PUMA boundaries overlap school district boundaries, we assigned households to communities based on the assumption that people are uniformly distributed across PUMAs.

The job finding rate ($\omega_{s,t}$) provides a measure for the share of workers who were unemployed at date *t* but found work within *s* weeks of that date. This technique follows Shimer (2005, 2012).

Figure 3: Cumulative Job Finding Probability, by Industry and Business Cycle



Note: These graphs display national cumulative job finding probabilities, by NAICS industry, for workers who were newly unemployed during expansion (Aug 2006), recession (Dec 2009), and normal (Jan 2008) periods. Job finding probabilities were estimated from data on unemployed workers in monthly CPS. In 1.6% of industry/month combinations, the estimated marginal job finding probability is negative due to sampling error. In these cases we use linear interpolation to restrict the job finding probability to be positive. Some 2-digit industries were aggregated to reduce sampling error. Specifically, Agriculture and Natural Resources = 11, 21; Manufacturing = 31-33; Wholesale/Retail Trade = 42, 44, 45; Transportation and Utilities = 22, 48, 49; FIRE = Finance and Insurance (52) and Real Estate and Rental and Leasing (53); Business Services = 54-56; Education and Health = 61-62; Entertainment and Food = 71-72; and Other Services = 51, 81, 92.

We calculate $\omega_{s,t}$ by industry nationwide for a few key time periods. We abstract from geographic variation because job-finding rates for unemployed workers in the San Francisco-Sacramento area are very similar to those for the nation as a whole. On the other hand, there are modestly larger differences by industry. Both of these differences are, however, dominated by the variation over the course of the business cycle. The graphs in figure 3 show job-finding rates by

industry for workers who became initially unemployed in August 2006, January 2008, and December 2009. These months had the highest, median, and lowest job-finding rates in the first month in our CPS sample. One can see immediately that the differences in job-finding rates over the business cycle are much larger than the differences by industry, and that they persist strongly for at least two years.[13] Our findings are consistent with the prior work of Hall (2006) and Shimer (2012), who document that variation in the job-finding rate over the business cycle explains most of unemployment fluctuations; and with the work of Şahin et al. (2012), who document that little of aggregate unemployment can be explained by variation in the vacancy-unemployment rate across geographic regions or industries/occupations.

Since variation over the business cycle and industry of prior employment seem to be the most important channels, we focus on these. In particular, we use the actual job-finding probabilities that prevailed in August 2006, January 2008, and December 2009, which replicate "expansion", "normal", and "severe recession" labor markets. Doing so allows us to address whether aggregate economic conditions are important for the implied welfare costs of job loss from environment regulations.

Summary of Results

Table 1 presents our aggregate results on the wage effects and welfare effects of layoffs. All figures in the table are based on iteratively "firing", one at a time, individuals drawn from a random 1-in-10 sample of Northern California households using the Census Bureau's household weights. Panel A summarizes the wages lost due to temporary unemployment. Wages lost per worker during the

[13] Although the CPS documentation indicates that workers should be able to report almost arbitrarily long unemployment spells, we find that almost no workers report spells longer than two years, and that the maximum duration is 124 weeks. We truncate unemployment duration at two years.

unemployment spell ranges from an average of $15,224 in our expansion scenario to an average of $30,821 in our recession scenario. We convert these figures to annuities using the number of expected life years remaining for the worker and an interest rate of 0.07.[14] The annualized wage loss from temporary unemployment ranges from $1,231 to $2,493.

Table 1: Annual Wage and Welfare Effects of Simulated Layoffs, per Household

A. TEMPORARY UNEMPLOYMENT

	expansion	normal	recession
Mean unemployment duration (months)	4.60	6.14	9.41
Net wages lost during unemployment period (mean per worker)	-15,224	-19,978	-30,821
Annualized net wage loss (mean per worker)	-1,231	-1,618	-2,493

B. CHANGE IN ANNUAL SALARY

Assumption about New Job	expansion	normal	recession
Rehired at identical job in original location	0	0	0
Move to 2nd best (job, house) location	-3,929	-3,929	-3,929

C. EXPECTED EQUIVALENT VARIATION

Assumption about New Job	expansion	normal	recession
Rehired at identical job in original location	-1,231	-1,618	-2,493
Move to 2nd best (job, house) location	-6,986	-7,287	-7,936

Notes: The first row of panel A summarizes the mean unemployment duration for the three scenarios shown in figure 3. The second row reports the wages foregone during the unemployment period for the average worker, net of unemployment insurance. Workers are assumed to collect unemployment insurance at 36% of the old wages. Row 3 converts the total loss to an annuity, using the worker's expected life years remaining and an interest rate of 7%. Row 2 of Panel B reports the mean change in wage from moving to the worker's second best job. Panel C reports the expected equivalent variation, taking into account the unemployment spell along with changes in wage and job-house location.

Panel B reports the average difference in annual salary between workers' new utility maximizing jobs and their old jobs. We consider two scenarios for how layoffs affect employment opportunities. In the first row, we depict the best out-

[14] Expected life years remaining is set based on Center for Disease Control life tables for the year 2000, and the interest rate is set to match the 1995-2005 average interest rate on a fixed rate 30-year home loan.

come for workers, in which being fired does not diminish their job opportunities. At the end of a worker's unemployment spell, he is simply rehired at his old job (or hired at an identical job in the same location). Thus, there is no change in the worker's salary. The second row reports the change in wages when all workers are forced to move to their second-best job locations. Annual wages decrease by nearly four thousand dollars in this case.

Finally, Panel C reports the expected equivalent variation.[15] In the normal scenario, for example, the range of predictions for expected EV per household per year ranges from -$1,618 under the scenario where the worker is rehired at an identical job to -$7,287 in the scenario where the worker has to move to their second best job location. In the first case, the state of the business cycle is very important for welfare measurement, with a 100% difference in EV between the recession and expansion scenarios. In contrast, the state of the business cycle is relatively less important when workers have to relocate. In that case, our measures of EV are driven by changes in salary at workers' new jobs and by changes in utility from moving to different housing communities and different commuting options.

Table 2 disaggregates the results by demographic group. For brevity, we just report results for "normal" business cycle conditions. Our qualitative predictions for the changes in earnings are consistent with the stylized facts about demographic variation in the income effects of layoffs. For example, consistent with Masur and Posner's (2012) summary of the evidence from ex post models of the earnings effects of layoffs, we observe that earnings losses tend to be (i) larger for men relative to women, (ii) increasing in experience, and (iii) increasing in age. Since our intra-urban sorting model is not constrained to reproduce any of these results, the fact that it does provides some preliminary support for the model's

[15] As a reminder, EV is the annual payment we would have to make to a group of workers each year for the rest of their life to compensate them for the loss of their most preferred and initially chosen job-house pair. Expected EV is calculated by integrating over the distribution of unemployment spells for each business cycle scenario.

validity. The model also predicts that earnings losses will tend to increase in the level of education and will tend to be larger for homeowners relative to renters.

Table 2: Wage and Welfare Effects of Layoffs, by Demographic Group

	(1) Annual adjustment for temporary unemployment	(2) Change in annual salary	(3) Expected change in real wages	(4) Expected equivalent variation
Population	-1,618	-3,929	-5,547	-7,287
Gender				
women	-1,288	-2,418	-3,706	-5,570
men	-1,815	-4,833	-6,649	-8,313
Age				
under 40	-1,309	-2,828	-4,137	-5,956
40-60	-1,846	-4,892	-6,739	-8,401
over 60	-2,089	-4,431	-6,521	-8,278
Education				
less than 13 years	-980	-2,295	-3,275	-4,609
13-16 years	-1,306	-2,757	-4,063	-5,705
more than 16 years	-2,161	-5,594	-7,755	-9,764
Experience				
less than 10 years	-1,110	-1,698	-2,808	-4,863
10-20 years	-1,610	-4,165	-5,775	-7,489
more than 20 years	-1,795	-4,554	-6,349	-7,995
Homeownership				
renters	-1,167	-1,979	-3,147	-5,023
owners	-1,910	-5,192	-7,102	-8,752

Note: Column 1 reports the wage loss from temporary unemployment, converted to an annuity using each worker's age and life-year tables for the year 2000 from the Center for Disease Control. The annualized loss reflects an expectation over the distribution of unemployment durations corresponding to the job finding probability distribution during "normal" labor market conditions. Column 2 reports the mean change in annual salary when workers move to their second best job locations. Column 3 is the sum of columns 1 and 2. Finally, Column 4 reports the expected equivalent variation.

Comparing columns 3 and 4 reveals that lost earnings are responsible for about three-fourths of the loss in welfare on average. The remainder is due to the fact that when the average worker makes a job switch, he either chooses a longer commute or moves to a community with a combination of house prices and local

public goods that he finds less desirable. The relative importance of the latter effect varies across demographic groups due to differences in their initially chosen locations, preferences, skills, and job opportunities.

Table 3: Wage and Welfare Effects of Layoffs, by Original Job Location

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Share experiencing an increase in:				
Job Location in 2000	Expected change in real wages	Expected equivalent variation	Share moving to different community	housing price	air quality	school quality	commute time	other public goods
Northern California	-5,547	-7,287	0.94	0.27	0.42	0.55	0.59	0.26
Oakland	-5,452	-6,728	0.94	0.22	0.31	0.59	0.57	0.24
Sacramento	-2,604	-7,443	0.91	0.68	0.83	0.28	0.78	0.66
San Francisco	-6,603	-7,659	0.94	0.12	0.20	0.63	0.47	0.15
San Jose	-7,237	-8,117	0.96	0.13	0.46	0.58	0.52	0.08
Santa Cruz	-6,703	-5,624	1.00	0.16	0.61	0.80	0.78	0.11
Santa Rosa	-5,621	-5,781	1.00	0.26	0.30	0.68	0.73	0.27
Vallejo	-3,347	-5,770	0.93	0.34	0.31	0.48	0.79	0.37
Yolo	-3,125	-5,983	0.90	0.55	0.72	0.58	0.79	0.44

Note: Columns 1 and 2 report the same measures of the expected changes in real wages and EV as in table 4. Column 3 reports the share of workers who are predicted to move to a different housing community after finding a new job in a different PMSA. Columns 4 through 8 report the share of households experiencing increases in housing prices, air quality, school quality, unobserved public goods, and commute times after moving to their new locations.

Table 3 reports the earnings losses and welfare losses for households that lose jobs in each of the eight possible job locations. It also reports the fraction of households that move and the characteristics of the new communities chosen by migrants. The goal of this table is to illustrate why earnings losses generally understate welfare losses (as they do here for seven of the eight job locations). The starkest illustration of this effect is workers who lose jobs in Sacramento. Sacramento is a relatively low-wage area, so workers who lose jobs there experience relatively modest earnings losses when they relocate. However, these earnings losses represent just one-third of their total welfare loss. The remaining large gap is accounted for by the change in living conditions. Sacramento offers a distinct combination of relatively low house prices and low amenities as compared to the

rest of the Bay Area. Households who lived there revealed that they had preferred these types of communities (that is, that they put a lower weight on public goods and a higher weight on private consumption). When they find new employment elsewhere in the Bay Area they face either a very long commute or a move to a different community with higher amenities and housing prices, either of which lowers their welfare significantly. This specific example illustrates a more general implication of the sorting model. The workers who chose to live in "dirty" areas based on relatively weak preferences for environmental quality may experience disproportionate welfare losses if they are effectively forced by a regulation to move to "clean" areas where housing prices and amenities are both higher. This is especially important for policies establishing minimum standards on environmental quality, since these policies effectively target the dirtiest areas.

In contrast, earnings losses tend to closely approximate welfare losses for workers who initially worked in the high-wage areas of San Francisco and San Jose. The reason is that these workers tend to move to areas where they trade-off lower air quality and amenities for lower house prices; although they generally preferred their former communities, the average cost of this move is smaller.

Finally, it is worth noting that our layoff simulator can be used to investigate the implications of job losses for any subgroup of the population that can be identified on the basis of worker and/or household characteristics reported in the Census PUMS data. Potential subgroups of interest might include the worker's specific industry and occupation, the household's income, house location, and the presence of children in the household. Table 4 provides an example of this by summarizing the expected EV for households where the primary earner works in the manufacturing sector, by the worker's age and original work location. In future evaluations of specific regulations, our simulator could be used to focus on a small subset of workers in the particular industries, occupations, and metro areas that are targeted by those regulations.

Table 4: Wage and Welfare Effects of Layoffs in the Manufacturing Sector

		Expected change in real wages	Expected equivalent variation	Share of manufacturing workers
All Manufacturing		-7,674	-8,800	1.00
Job Location in 2000	Age			
Oakland	under 40	-4,882	-6,082	0.09
	over 40	-7,900	-8,915	0.12
Sacramento	under 40	-3,075	-8,451	0.05
	over 40	-5,741	-11,761	0.05
San Francisco	under 40	-5,005	-6,653	0.06
	over 40	-7,899	-8,791	0.06
San Jose	under 40	-6,981	-7,947	0.21
	over 40	-11,676	-11,337	0.25
Santa Cruz	under 40	-7,368	-5,994	0.01
	over 40	-7,689	-6,157	0.01
Santa Rosa	under 40	-4,081	-4,326	0.02
	over 40	-8,031	-7,981	0.02
Vallejo	under 40	-2,727	-4,617	0.01
	over 40	-7,184	-8,623	0.02
Yolo	under 40	-1,618	-4,401	0.01
	over 40	-4,996	-8,145	0.01

Note: The table reports expected changes in real wages and equivalent variation for workers in the manufacturing sector (NAICS 31-33) broken out by the worker's age and original job location. See the text and notes to tables 1-3 for definitions of the variables in each column.

Discussion

Our results suggest that the net reduction in earnings experienced by a worker who loses his job may significantly understate the reduction in welfare experienced by that worker's household. In our simulations, the workers who remain in the same houses after losing their jobs tend to experience longer commutes after they relocate to new jobs. Moreover, the workers who move to new housing

communities, closer to their new jobs, tend to consume (housing, amenity) bundles that they perceive to be inferior to the bundles at their original locations.

The sorting model also predicted that workers who move to new jobs in different metro areas will tend to be paid less due to a loss of job-specific or industry-specific human capital. This prediction is consistent with evidence from ex post studies of mass layoffs in general (Couch and Placzek 2010) and ex post studies of layoffs caused by environmental regulation in particular (Walker 2012). However, we did not allow workers to adjust the number of hours they work, or to look for jobs outside of their SOC 5-digit broad occupation (e.g. education administrator, detective and criminal investigator, cook). Because we ignore these potential dimensions of underemployment, our predictions for earnings losses and welfare losses may be attenuated.

As with all revealed preference models of housing and labor market outcomes, our specific predictions for the welfare costs of job losses depend on assumptions about unobserved sources of heterogeneity in preferences and skills among workers and households. There are, of course, several other limitations of our analysis that serve as caveats to our results and define potential avenues for future research. First, we have ignored moving costs, forward-looking behavior, and dynamics. While focusing on a small geographic area at least mitigates the potential bias from ignoring moving costs, emerging research suggests that these issues are likely to be collectively important for welfare measurement in the sorting literature (e.g. Bishop 2011; Bayer et al. 2011).

Second, we did not attempt to simulate general equilibrium effects. If a particular regulation were to induce enough people to move, their migration patterns could lead to adjustments in housing prices, wage rates, commute times, and the provision of local public goods which, in turn, would feed back into welfare measures. While it is possible to solve for a new equilibrium that embeds these adjustments, relatively little is known about the uniqueness of equilibria in such

general environments (e.g. Sieg et al. 2004, Timmins 2007). This is an area where more research is needed.

Third, our Northern California model is obviously limited in its geographic scope, covering only 3% of the U.S. population. Unfortunately, the model does not provide an easy way to predict immigration or emigration outside the study region. Moreover, the basic idea of spatial sorting suggests that unobserved heterogeneity in preferences and skills presents a fundamental problem for the standard "benefit transfer" approaches to transferring estimated welfare measures outside the geographic region of an existing study.

Fourth, our focus has been limited to considering the welfare effects experienced by working households. We have not attempted to model the costs borne by employers. Nor have we attempted to model the deadweight loss of unemployment insurance programs. Thus, our model does not allow us to comment on the implications of a regulation for social welfare.

Finally, the basic idea of using a sorting model to simulate the welfare effects of layoffs presupposes that the analyst begins with a range of values in mind for the potential layoffs that could result from a prospective regulation. That is, the current generation of sorting models does not allow us to endogenously predict how a prospective regulation will affect the demand for labor. To do this, one would need to model the demand for heterogeneous labor on the part of differentiated firms. This would be an interesting and challenging direction for future research.

Areas for Future Research

The sorting literature is an active area of research that is being pushed forward on many dimensions (Kuminoff, Smith, and Timmins 2013). Moving forward, one approach to using sorting models to systematically assess the effects of prospec-

tive regulations would be to develop more refined "regulation simulators" for several major metropolitan regions, similar to our Northern California model. Potential refinements could include tailoring the mechanisms used to describe job loss, job match, and unemployment duration to the relevant study area and time period. A second approach would be to pursue the development of a national sorting model that integrates unemployment, moving costs (physical, financial, and psychological), dynamics, imperfect information, and heterogeneous skills and preferences for amenities, extending the recent work of Bayer, Kahn, and Timmins (2011), Bayer, McMillan, Murphy, and Timmins (2011), Bieri, Kuminoff, and Pope (2012), Bishop (2011), Kennan and Walker (2011), and Mangum (2012).

On the methodological side, it would be interesting to extend the model to consider a collective household where two adults have potentially diverging economic motivations and divorce is a possibility. Gemici (2011) develops such a model, absent a housing market equilibrium. Given the possibility for job separation to result in the breakup of marriage and the social costs that may accompany that breakup, this is an important complication to consider in future applications of residential sorting to unemployment. Another interesting extension would be to model unobserved constraints that may prevent households from instantaneously adjusting to labor market shocks (e.g. moving costs, job search costs, information acquisition). Similarly, given the current level of concern about omitted variable bias in empirical microeconomics, it would be useful to conduct research on defining a set of "best practices" for dealing with unobserved amenities. Previous approaches have included the use of random effects (Gyourko and Tracy 1991), exploiting panel variation in amenities and Census data (Bayer, Keohane, and Timmins 2009), and formally testing a model's external validity (Galiani, Murphy, and Pantano 2012).

Finally, developing some direct evidence on the migration patterns and job

transitions of workers who lose their jobs could help to inform the most productive direction for future research. While aggregate migration data are widely available, it is not clear whether migration patterns are systematically different for workers who lose their jobs. Walker (2012) provides some initial evidence by tracking the *job locations* of workers who relocated within four states, reporting that more than 40% of job separators moved to new jobs in different counties. However, it is not clear how many of these workers moved to new houses. Likewise, Mangum's (2012) work on developing an "islands" model of metropolitan areas with unemployment begs the question of whether unemployed workers move to new metro areas *before* or *after* finding a job there. More generally, if the share of unemployed workers who move to new housing communities and labor markets is small, then a Roy-type model of labor market sorting might be more useful than a dual-market model of sorting across the housing and labor markets. If the share is larger but most movers stay within the same metro area, then a regional model of both markets—similar to the one is this paper—may be the most appropriate one to pursue. Lastly, if the share of workers who move cross-country is large, then advancing a national sorting model may be the most productive direction for research.

Conclusion

Over the past decade, full-employment equilibrium models of residential sorting have increasingly been used to evaluate the benefits of existing and prospective environmental regulations (Sieg et al. 2004, Smith et al. 2004, Walsh 2007, Tra 2010, and Klaiber and Phaneuf 2010). We demonstrated that the literature can potentially be extended to consider unemployment and some dimensions of underemployment. In a demonstration of the model where workers who lose their jobs were assumed to receive no benefits of improved environmental quality, we

observed that the average worker's earnings losses substantially understated their welfare losses. This wedge arises because workers who move to new jobs often move to new housing communities as well. Their new communities often provide bundles of housing, commuting options, and local public goods that the movers perceive to be less desirable. These preferences were assumed to be revealed by the movers' original location decisions. This non-wage effect on utility dominated welfare measures for workers in some Northern California metro areas and was a relatively minor component of welfare in other metro areas. Our analysis also suggests that the state of the business cycle, as reflected through the duration of unemployment spells, has the potential to be of first order importance in assessing the costs and benefits of environmental regulations from the perspective of working households.

Overall, the results from our preliminary analysis and from other recent papers in the literature cause us to be optimistic about the potential for using sorting models to evaluate the benefits and costs of environmental regulations that may result in layoffs. However, the current models should be refined and vetted before using them for "prime time policy analysis". We made several specific suggestions for further research along these lines.

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