Jobs and Environmental Regulation

Marc A. C. Hafstead[a]

Roberton C. Williams III[a, b, c, d]

July 2019

[a] Resources for the Future
[b] University of Maryland
[c] Climate Leadership Council
[d] National Bureau of Economic Research

Email: hafstead@rff.org and roberton@umd.edu

This paper was written for the National Bureau of Economic Research's first annual Conference on Environmental and Energy Policy and the Economy (EEPE). We thank the conference organizers and participants at the EEPE Conference for helpful comments and suggestions. We thank Resources for the Future's (RFF) Carbon Pricing Initiative for financial support. Portions of the work were also supported by the USDA National Institute of Food and Agriculture (Hatch project 1009838). The views expressed herein are those of the authors and do not necessarily reflect the views of RFF, the University of Maryland, the Climate Leadership Council, the National Bureau of Economic Research, or the USDA.

Abstract

Political debates around environmental regulation often center around the effect of policy on jobs. Opponents decry the “job-killing” EPA and proponents point to “green jobs” as a positive policy outcome. And beyond the political debates, Congress requires the EPA to evaluate “potential losses or shifts of employment” that regulations under the Clean Air Act may cause. Yet there is a sharp disconnect between the political importance of the jobs question and the limited research on job effects of policy and general skepticism in the academic literature about the importance of those job effects for the costs and benefits of environmental regulation.

In this paper, we discuss how the existing research on jobs and environmental regulations often falls short in evaluating these questions and consider recent new work that has attempted to address these problems. We provide an intuitive discussion of key questions for how job effects should enter into economic analysis of regulations. And, using an economic model from Hafstead, Williams, and Chen (2018), we evaluate a range of environmental regulations in both the short and long-run to develop a set of key stylized facts related to jobs and environmental regulations and to identify the key questions that current models can’t yet answer well.

Key Words: jobs, unemployment, environmental regulation, performance standard, emissions pricing

JEL Classification Numbers: Q58, Q52, H23, E24, J64

1. Introduction

Effects on jobs carry great weight in political debates, especially for environmental policy. Opponents of regulation decry the "job-killing" EPA, while proponents argue regulation will create "green jobs". And that emphasis goes deeper than just sound bites: for example, the Clean Air Act requires the EPA to evaluate "potential loss or shifts of employment" that regulations may cause. But academic research has paid much less attention to these issues, reflecting a fundamental disconnect between policymakers and academic economists about the importance of effects on jobs.

How large are the job losses or gains caused by environmental regulation? To what extent are there aggregate job losses versus reallocation (i.e., job losses in some sectors offset by job gains elsewhere)? How should cost-benefit analysis of regulations treat these effects on jobs? How important are they for distributional analysis of policy? The political focus alone makes these questions important, but they're also worth considering because of the potential for substantial economic effects.

In this paper, we attempt to address those questions, drawing both on our own recent work and on the broader economic literature. In some cases, the answers are relatively clear. In others, further research is necessary, and in those cases, we try to outline the key issues and identify key effects that will determine the answers.

We argue that economic modeling of these questions must include two key aspects of the situation. First, it requires general-equilibrium analysis. Effects of regulation on jobs extend well beyond the industries directly targeted by regulation. Potential spillover effects could be negative (e.g., effects on the steel industry from regulation-induced increases in the price of electricity) or positive (e.g., increases in demand for output from unregulated firms as consumers substitute away from the output of regulated firms), and could be relatively large, making the total effect of the policy potentially quite different from the effect on regulated firms. Second, it needs to consider that the labor market isn't as simple as an Econ-101-level supply-and-demand analysis might assume. Workers have heterogeneous skills, and a range of frictions slow the movement of workers between jobs. As a result, a worker who loses his job won't immediately find a new job at the same wage, but instead will likely spend a significant amount of time searching for work, and might well need to accept a lower wage in the new job. Recognizing those issues is essential for evaluating and measuring the distributional effects of job losses and gains, and for understanding why those losses or gains might influence aggregate social costs, rather than being purely distributional.

The next section of this paper provides a brief overview of the recent literature on job effects of environmental policy. Section 3 discusses a broad range of key questions for how job effects should enter into economic analysis of regulations, with an intuitive discussion of these questions. Section 4 briefly outlines a general-equilibrium model of environmental policy with unemployment resulting from search frictions. Sections 5 and 6 present key findings from the general equilibrium analysis of steady state and transitional labor dynamics in that model, respectively. The final section summarizes and presents conclusions.

2. Existing Literature on Jobs and Environmental Regulation

The existing literature on jobs and environmental regulation can generally be split into three distinct categories: reduced-form empirical studies, full-employment general-equilibrium modeling, and search-friction models.

There is a robust literature that uses reduced-form empirical methods to evaluate the impact of existing regulations on employment levels in regulated industries. Berman and Bui (2001) compare Los Angeles refineries to other US refineries and find no evidence of changes in employment from increased regulation in LA refineries. Morgenstern et al. (2002) examine the link between environmental spending and employment across four energy-intensive industries (pulp and paper mills, plastic manufacturing, petroleum refining, and iron and steel mills) and find that increased environmental spending is associated with a small increase in employment. Greenstone (2002) evaluated the impacts of the Clean Air Act on manufacturing employment and found that nonattainment counties (subject to more strict regulations) lost 590,000 jobs between 1972 and 1987 relative to counties no subject to the Clean Air Act regulations. Curtis (2018) evaluated the NOx Budget Trading Program and found that manufacturing employment fell by 1.3 percent in regions that participated in the program.

With the exception of Morgenstern et al. (2002), each of these studies used a set of unregulated yet similar firms in different regions as a control group and (implicitly or explicitly) assumed that the policy had no effect on these firms. To the extent that the regulations cause a shift from the firms in the regulated region to firms in the unregulated regions[1], estimates of job losses in the treatment group would be biased upward.[2]

Second, these studies all implicitly assume that the effect of regulation on other industries (within the same region or other regions) is zero, ignoring the possibility of general-equilibrium spillover effects, which could be negative (such as effects on downstream industries that use output from regulated firms as inputs) or positive (such as substitution toward output from other industries). To the extent that regulation causes these general-equilibrium shifts in employment in industries outside the scope of analysis in these partial equilibrium studies, then even if the studies accurately identify the effect on the regulated industry, the overall effect of the policy will still differ from the effect on regulated industries. These issues imply a need for general-equilibrium analysis.

Computable general equilibrium (CGE) models have been widely used to project the ex-ante impacts of various regulations, including environmental policy, but the vast majority of that analysis uses models that assume full employment: that is, they assume that the labor market clears fully, with the wage adjusting such that the demand for labor equals the supply, with no unemployment. Such models clearly can't directly analyze effects on unemployment. To be able to provide an answer to questions about job losses, some CGE practitioners have followed a method of converting changes in labor supply from full-employment CGE models into "full-time equivalent" (FTE) jobs to report the "jobs" impact of a given regulation or policy. This approach has serious limitations – most notably that it only models voluntary changes in labor supply, whereas policymakers' primary interest in job gains or losses stems from concerns about involuntary unemployment – but is frequently used nonetheless. Indeed, this exact methodology

[1] For example, such a shift would occur if regulation raises costs for firms in the regulated region, leading those firms to raise output prices, and consumers respond by substituting toward output from firms in the unregulated region.

[2] More broadly, general-equilibrium spillover effects will pose a serious challenge for any causal estimation. Spillover effects violate the stable unit treatment value assumption (SUTVA), which requires that the observation for one unit doesn't depend on the treatment status of other units. In our context, for example, SUTVA would require that employment at one firm doesn't depend on whether other firms are subject to regulation. Spillover effects across firms violate that assumption, and thus will imply biased estimates of the effect of regulation. And this isn't just a result of the difference-in-difference approach, or of quasi-experimental methods in general: SUTVA is necessary even for a randomized experiment (the intuition here is simple: even if firms were randomly assigned to be regulated or unregulated, if regulation has spillover effects on unregulated firms then the difference between outcomes for regulated and unregulated firms won't correctly measure the causal effect of regulation).

was used in a prominent report, Bernstein et al. (2017), that was cited by President Trump in a speech announcing the exit of the United States from the Paris Agreement.

Only recently has the academic literature attempted to address these issues with general equilibrium models by introducing search-frictions to environmental CGE models. In these search-friction models, rather than having the labor market clear perfectly, unemployed workers must match with employers looking to hire. That matching friction provides a tractable way of incorporating a number of key features of real-world labor markets, including involuntary employment even in the long-run steady state. Three of our recent papers (Hafstead and Williams, 2018, Hafstead *et al.*, 2018, and Hafstead and Williams (2019)) take this approach, as do a small handful of others, including Aubert and Chiroleu-Assouline (2019) and Fernandez Intriago (2019).

Hafstead and Williams (2018) uses a highly stylized two-sector model to show that the effect of environmental taxation is largely a reallocation of jobs (from more-polluting to less-polluting industries), with very little net job loss. Among other implications, this suggests that prior difference-in-difference studies have substantially overestimated job losses in regulated industries, and overestimated net job losses by even more.

Hafstead *et al.* (2018) extends that model along several dimensions, including disaggregating production into 23 industries (government plus 22 private sectors) and introducing intermediate inputs in production. Those extensions make the model much less stylized and more realistic, and allow it to examine a wider range of spillovers across industries (including effects on upstream and downstream firms). By comparing results from that model to those from an otherwise identical full-employment model, it shows that explicitly modeling employment frictions yields much smaller estimates of job losses than prior CGE work that used full-employment CGE models to estimate effects on jobs.

Neither Hafstead and Williams (2018) nor Hafstead *et al.* (2018), however, attempt to address a different aspect of reallocation – what types of workers lose jobs and what types of workers gain jobs – which has important distributional implications. Three new papers have attempted, in different ways, to fill this gap. Aubert and Chiroleu-Assouline (2019) introduce a search-friction model with unskilled and skilled workers, but restrict the search-friction to unskilled workers only and focus almost entirely on the impacts of environmental tax reform on the income distribution. Fernandez Intriago (2019) introduces sectoral human capital accumulation and erosion into a model of energy- and non-energy-intensive manufacturing industries and finds that reallocation among manufacturing industries is likely to benefit low-skilled workers at the expense of high-skilled workers. However, further research here is needed to analyze the distributional implications of reallocation in the non-manufacturing sectors of the economy. Hafstead and Williams (2019) addresses the distributional effects of environmental policy on jobs by extending the Hafstead et al. (2018) model and classifying workers by their industry at the time of policy implementation ("initial industry"), finding significant differences in short-run labor-market effects (as measured by changes in unemployment rates, earnings, and unemployment durations) across a range of policies aimed at reducing energy-related carbon dioxide emissions across initial industry worker groups. However, additional research is required to determine the distribution of labor-market effects *within* initial industry groups.

3. A Broader Range of Questions about Jobs and Policy Analysis

This section discusses a broad range of key questions for how job effects should enter into economic analysis of government policy, and provides an intuitive discussion of these questions. Our primary focus in this paper is on environmental policy, but many of the issues discussed here apply far more broadly to any policy that has an effect on jobs, and the discussion in this section reflects that to some extent.

3.1 Separations versus Reductions in New Hires

Consider two situations in which an industry loses a given number of jobs: in one case, those job losses happen via an increase in job separations (such as layoffs or plant closings), and in the other they happen via a reduction in the rate of hiring new employees. Holding constant hiring and separation in other industries, the effect on unemployment would be the same (in one case, you're increasing the rate at which workers are entering unemployment and in the other you're decreasing the rate at which they're leaving unemployment, but the effect on the number of unemployed is the same). But the political and economic implications vary substantially between the two situations.

Some of these differences matter largely for political reasons, but don't have much direct economic importance. For example, it's far easier to identify the workers affected by an increase in separations than by a reduction in hiring (we can observe which workers lost jobs, and while attributing those losses to policy isn't straightforward, it's still far easier than identifying which unemployed workers would have found jobs if not for a reduction in hiring rates).

Other differences, however, matter along both political and economic dimensions. For example, if workers accumulate firm-specific human capital, then separations destroy that human capital in way that reduced hiring does not.[3] And, more generally, increased separations are more disruptive in a variety of ways than reduced hiring. This is particularly true for plant or mine closures, which concentrate job losses in a specific geographic area. That obviously matters for the geographic distribution of the effects, but also potentially increases the cost for individual workers (who may well need to move to find a new job, rather than finding a new job near where they already live).

Thus, it's important to consider what form the job losses take. In general, the US labor market is quite dynamic, with substantial ongoing job churn (hires and separations in a typical year vary between 18 percent and 73 percent by sector, with total hires and separations of roughly 40% across all sectors). This makes it possible to accommodate substantial job shifts via changes in hiring alone (an industry that typically replaces 40% of its workers each year could shrink by 20% in a single year – a far more drastic job shift than policy is typically projected to produce – simply by cutting its hiring rate by half, with no increase in separations). Once one understands that, it's not especially surprising that both simulation modeling (such as Hafstead and Williams, 2018 and Hafstead *et al.* 2018) and empirical research (e.g., Curtis 2018 in the context of the NOx budget program) find that employment drops in regulated industries come primarily or exclusively through reduced hiring.

Of course, simply looking at the industry level might not capture important heterogeneity: even if the policy-induced job losses in an industry are small relative to industry employment, they could still exceed what reduced hiring could accommodate if they are concentrated in a particular subsector or geographic area. And if an industry is already contracting for other reasons and policy accelerates that shift (e.g., imposing carbon pricing in an environment where the coal industry is already shrinking due to competition from low-priced natural gas) then the combined effect is harder to accommodate via reductions in hiring alone.

[3] The comparison is more complex and less stark in the case of industry- or occupation-specific human capital, because laid-off workers might find jobs in the same industry or occupation and because reduced hiring in an industry raises the probability that an unemployed worker from that industry will need to take a job in a different industry or occupation. But some difference still persists.

3.2 Job Losses as Social Costs?

To many people, job creation is an important benefit of policy and any job destruction is a cost. The standard economist's response is "jobs are a cost, not a benefit." In large part, that response is correct: labor is a scarce and valuable resource, and to the extent that a policy creates relatively unproductive jobs, it's pulling that resource away from some other more productive use. That's a cost, and conversely, job losses in unproductive firms are reductions in costs.

Where the issue gets tricky, though, is in measuring that cost. For cost-benefit analysis, the theoretically correct measure of the cost of a resource is its opportunity cost: the value of what that resource would have been used for in the absence of the policy in question. To illustrate this, consider a worker in a job created by a new policy. If, without the policy, that worker would have been employed in a different job, then the cost of that worker's labor is what he would've produced in that alternative job. If he would've been unemployed, then the cost is his reservation wage (the value to him of what he would've done with that time: leisure, home production, etc.).

In practice, however, cost-benefit analysis typically assumes (either explicitly or implicitly) that the opportunity cost of labor equals the wage[4]. In a simple model with a perfectly competitive frictionless labor market, this assumption is correct: in such a model, labor is paid its marginal product, every worker who wants a job has one, and workers are indifferent across jobs, implying that the wage is equal to opportunity cost. But in a more complex model of the labor market, the wage won't necessarily be a good measure of opportunity cost. If a worker would otherwise have been involuntarily unemployed, for example, then having that job makes the worker better off (the wage he earns exceeds his reservation wage, perhaps by a substantial margin).[5] This still wouldn't imply that jobs created by a policy represent benefits, but it does imply that a typical cost-benefit analysis would overstate the cost of a policy that creates jobs for workers who would otherwise have been involuntarily unemployed.

Note that a key to this line of reasoning is the counterfactual: what the worker would have been doing in the absence of the policy. If "job creation" from a policy is merely pulling workers out of other jobs, that has different implications than if those workers would otherwise

---

[4] We use "wages" here as a shorthand for labor compensation (wages plus benefits).

[5] Note that this point is in no way unique to labor: it applies anytime a resource is priced above its opportunity cost (i.e., the policy increases economic surplus for the owner of that resource). But it may well matter more for labor than for other resources, because of the importance of frictions in the labor market.

have been unemployed. This will depend on a wide variety of factors, but perhaps the most important factor is overall macroeconomic conditions: during a deep recession, it's far more likely that workers would otherwise be unemployed than it would be during an economic boom. This is one of the key arguments for public investment programs during economic downturns: during a recession, it's more likely that a worker employed by such a program would otherwise be unemployed, and thus the cost of those investments is lower during a recession than during an expansion.

This point emphasizes the need for general-equilibrium analysis. Looking just at jobs directly created or destroyed by a policy could be quite misleading. If the direct job effects are purely reallocation – e.g., if job losses in a regulated industry are exactly offset by gains in other industries – then the implications are quite different than if they are net job losses (or if there is a multiplier effect, with additional job losses outside the regulated industry). Thus, it's important to look at effects outside the directly affected industries.

It's also important to think carefully about why wages differ from the opportunity cost of labor: i.e., to think carefully about the frictions in the labor market that create that differential. Consider the basic Mortensen-Pissarides search-friction model, in which unemployed workers can't instantly find a job, but instead must match with employers who are looking to hire. In such a model, the marginal product of labor is above a worker's opportunity cost of time, producing significant surplus from a successful job match, and that surplus gets divided between the worker and the employer, making both better off. In a frictionless model, that gap couldn't persist – workers would be hired up to the point where the marginal product of labor equals the opportunity cost for the marginal worker – but the search friction limits that, so some gap remains.

One might think this implies that in such a model, a policy-induced reduction in unemployment would necessarily produce an efficiency gain. But that's not necessarily the case. If one could reduce or eliminate the search friction (e.g., if a new technology were created that makes it easier for workers and employers to find a good match), then that would generate an efficiency gain. But to the extent that the job-matching process remains the same, and policy changes the incentives for workers or employers then lower unemployment necessarily implies more search effort. Whether that produces an efficiency gain or not will depend on the existing incentives for those workers and employers to search for a match.

This is captured in the Hosios (1990) condition, which compares the match elasticity (the effect of additional search effort on the number of job matches) to the share of the surplus from a match that goes to the party doing the searching. The intuition for this condition is that the former determines the marginal increase in match surplus from additional search effort (i.e., the marginal social value of search effort) and the latter determines the benefit to the searcher (the private return to that effort). If the two are equal, then private incentives for search are already efficient, implying that the level of unemployment is constrained-efficient (i.e., efficient given the constraint imposed by the search friction). In such a case, policy-induced changes in unemployment have no effect on efficiency at the margin (the increased surplus to workers and employers from reduced unemployment is exactly offset by increased the increased search costs necessary to lower the unemployment rate). If the match elasticity is higher than the surplus share, then the social returns to search exceed the private returns, and policy-induced reductions in unemployment will yield an efficiency gain. But if the match elasticity is lower, then reducing unemployment will actually reduce efficiency (because the cost of additional effort needed to lower the unemployment rate will exceed the gains from the additional employed workers).[6] There exists a range of estimates of these key parameters in the Hosios condition from the original macro-labor search literature, but there is little consensus on the parameters of a single-sector model and almost no estimates, so it is difficult to evaluate what this condition implies in practice.

3.3 Social Costs of Labor Reallocation

Setting aside the issue of the level of unemployment, there could be social costs from reallocation as well. Davis and von Wachter (2011) find that workers who lose their jobs in mass-layoff events suffer not just a spell of unemployment, but also have persistently lower earnings for a long period even after finding a new job.[7] This is clearly bad for those workers even if there's no change in overall unemployment, but it's less clear whether it represents a net

[6] This condition implicitly reflects externalities that operate through the matching process itself (e.g., if one employer searches harder for workers, that makes it harder for other employers to find workers, but easier for workers to find jobs), but assumes no other externalities for unemployment or job search. To the extent that there are other externalities – for example, if unemployed workers are more likely to commit crimes – then this would provide an additional source of potential efficiency gains from lower unemployment.

[7] Mass-layoff events are not common, even during recessions, and it's not clear how much we should apply this analysis to the analysis of regulation-induced changes in employment.

social cost, or – if it is a net social cost – whether that cost is captured elsewhere in a cost-benefit analysis.

The first question to address is whether the loss to those workers is offset by gains to employers or to other workers. If these job losses come from reallocation – with those job losses offset by job gains in other industries – then it's not unreasonable to think that there will be gains to workers and firms in those other industries. Those gains are often much harder to see and measure, but that doesn't mean they don't exist. And even answering this question with theory or simulation modeling is challenging, because (as Davis and von Wachter point out) existing search-and-matching models do a poor job of matching the long-term earnings losses due to job loss (predicting much smaller losses than what Davis and von Wachter find empirically). If a model can't adequately match those losses, there's no reason to think it would tell us anything useful about whether they're offset by gains elsewhere. Thus, there's a clear need for further research in this area.

The second key question is whether this cost (if it is a net social cost) is captured elsewhere in a cost-benefit analysis. For example, consider the cost of reducing pollution emissions in response to an emissions price (such as an emissions tax). In a model with no other distortions, the marginal cost of emissions reductions is the emissions price – and that's true even in a complex model with a range of potential margins for reducing emissions. In that setting, one doesn't need to go through and add up a variety of different costs to estimate marginal abatement cost: one can just look at the emissions price, and that will capture the whole relevant set of costs (potentially including the costs associated with job losses and job transitions). For example, Shimer (2013), shows that even if search frictions make it costly for workers to move from a polluting sector to a nonpolluting sector, the optimal tax on a polluting good still equals marginal damage (the same result as in a model without search frictions).[8] This result implies that if one takes a "top-down" approach to measuring costs under an emissions price (or some similar policy), that approach will already incorporate any job transition costs.[9]

---

[8] This general principle applies to transition costs more broadly: such costs generally will not affect the optimal emissions price. For example, Williams (2012) shows a similar result for capital adjustment costs. Note, though, that because such transition costs slow the response to a given emissions price, transition costs do affect the optimal path for the quantity of emissions (as shown in Williams (2012) for capital adjustment costs and Shimer (2013) for labor search costs).

[9] This point applies equally well if the policy leads to permanent job loss, not just reallocation. Such costs would also be captured in a "top-down" approach (again, as long as there are no other distortions).

The key to that result, though, is that employers fully internalize the labor transition costs in their decision making. That doesn't require that employers bear the full cost; for example, if wages are set through an efficient bargaining process, then employers don't bear the full transition cost, but still fully internalize it in making production decisions. But if not, then there's an additional externality – firms don't fully consider that their production decisions affect employees' welfare. With this additional distortion, the emissions price no longer necessarily measures the social marginal cost of abatement.[10]

Moreover, even if employers are fully internalizing the costs, a "bottom-up" approach to measuring costs – individually measuring and adding up various elements of the cost of firms' responses to regulation – wouldn't necessarily capture labor transition costs.

3.4 Distributional Effects

Even if job losses aren't social costs, they could still have substantial distributional implications. As mentioned in the previous section, there appear to be substantial, persistent effects on workers who lose their jobs. Even if policy-induced job losses occur entirely through a reduced rate of hiring, rather than increased separations, that reduction in hiring can still disproportionately affect some groups of workers relative to others. And, similarly, even if the job effects are entirely reallocation – fewer jobs in some industries offset by more jobs in other industries – again, that can have important distributional implications.

The key to these effects – especially in the latter two cases – is the extent to which workers are constrained in moving across sectors or occupations. If that movement is costless, distributional effects will be small: if hiring is reduced in one industry, workers can simply flow to other industries instead (especially if the policy induces positive spillovers, in which hiring increases in those other sectors). But if that movement is very costly, then there could be substantial differences in effects across workers, with welfare gains to workers in sectors that gained jobs and losses in sectors that lost jobs.

Measuring and modeling those costs of movement is difficult, and existing models don't even do a good job of capturing differentials that we can observe in the data. As noted earlier,

[10] One way to think about this issue is to ask whether a tax on layoffs would improve welfare; if employers aren't internalizing labor transition costs, then a layoff tax would function as a Pigouvian tax, correcting that externality.

standard search-friction models have a hard time matching the substantial and persistent earnings effects that Davis and von Wachter (2011) found from mass layoffs.

Moreover, based on job flow data, it appears that it's relatively easy for workers to move across sectors: if one aggregates job transition data up to 20 industries (similar to the number of industries in the model we present later in this paper), roughly one-third of workers find new jobs in the same industry they left.[11] That's substantially higher than what one would observe if there were no costs or frictions associated with switching industries, but nonetheless relatively low. Together with the high rate of job churn in the US economy, this suggests that flows of workers across sectors can easily accommodate substantial reallocation without persistent distributional effects (as noted earlier, in the average year, hires and separations are each roughly 40% of the labor force, and if roughly two-thirds of those new hires are in a different industry, that implies that more than 25% of the labor force switches industries in a typical year). Again, this is hard to reconcile with the empirical evidence of substantial, persistent earnings effects from mass layoff events (such as those found by Davis and von Wachter, 2011). This could imply that simple models will have difficulty capturing these distributional effects or that industry-to-industry transitions aren't really the relevant measure of the switching frictions that drive distributional differences. Or perhaps it just indicates that mass layoff events have fundamentally different effects from other job losses.

Reduced-form empirical work may be much more useful for measuring distributional effects than it is for measuring overall employment effects. Even if there are general-equilibrium effects on the control group, and thus a simple treatment-control design (using workers in firms subject to a new regulation as the treatment group and workers in other firms as the control) will yield biased estimates of the aggregate effect of the policy, such a design would still provide an unbiased estimate of the differential effect between the two groups, and thus provide useful information about distributional effects.

3.5 Geographic Effects

Distributional effects of environmental regulation across geographic locations seem particularly interesting and potentially important, for two reasons. First, geographically concentrated effects on jobs could have substantial local multiplier effects (e.g., when a coal

[11] See the appendix for further discussion of job transition data and how we use it in this paper.

mine closes, it could affect not just the coal miners, but also have negative spillover effects on local firms where those miners spend their earnings). And second, geographic mobility in the US is much lower than job mobility (only about 1.5% of Americans move to a different state in a typical year) and has dropped substantially over time (in the early 1990s, that rate was roughly 3%). Moreover, even if workers could easily move away to find new jobs, the capitalized effect on local real estate could still be substantial. This suggests that if policy has a localized effect on jobs, that could easily have important differential effects across geography.[12]

Again, this is an area where general-equilibrium modeling will be difficult (albeit potentially important). In many cases, the data necessary to calibrate such models is not available at a sufficiently disaggregated level (or, when it is, the assumptions behind the disaggregation are questionable). And, just as with other distributional effects, being able to specify the constraints on mobility is both important and difficult. And again, reduced form empirical work can provide useful insights about differential effects across geography, even if general-equilibrium effects imply biased estimates of the aggregate effects.[13]

3.6 Job Quality

A common argument against regulation is not just that the policy causes job losses, but that the jobs that are lost are disproportionately "good jobs" and, at least implicitly, that any offsetting job gains in other sectors are disproportionately not "good jobs".[14] This argument is perhaps most common in the context of trade policy, but also comes up frequently in discussions of environmental policy. Exactly what constitutes a "good job" is often left unsaid, rigorous definitions are rare, and even informal definitions vary significantly. But in general, a "good job" in this context is typically a job that pays relatively well and requires relatively little formal education, especially those in blue-collar, disproportionately male occupations, such as those in

---

[12] Interestingly, though, Molloy *et al* (2014) argues that the reduction in mobility observed over the last few decades is driven primarily by a reduction in the benefit to workers of switching jobs. If so, then that directly contradicts the idea that there are large geographic differentials in labor markets.

[13] A notable example is Autor, Dorn, and Hanson (2013) and follow-on papers in the "China shock" literature on the job-market effects in local labor markets of rising competition from Chinese imports. General-equilibrium spillovers are likely to imply SUTVA violations which will cause empirical estimates in this literature to be biased (for similar reasons to the arguments we made earlier in this paper, in section 2). But even in that case, such estimates could still provide valuable information about the differential effects across local labor markets.

[14] For example, a coal mining job may be a "good job", while service-sector jobs available to a former coal miner might not be "good jobs".

the mining and manufacturing industries. These industries are often targeted by environmental regulation, and even when they're not directly targeted, they can be subject to spillover effects (e.g., if regulation raises energy or materials costs, those increased costs significantly affect manufacturing).[15]

A key question here is why these types of jobs pay well. This is important both for measuring the extent to which losing these jobs will harm workers, and for modeling how policy will affect them. In a simple, frictionless model, it's impossible for some jobs to be genuinely better than others; if that were the case, then there would be a surplus of workers for good jobs and a shortage of workers for bad jobs, and wages would adjust to equilibrate the market. In that kind of model, any wage differential must be the result of some other difference, rather than having some jobs be genuinely better than others.

One possible explanation is that jobs in mining and manufacturing are typically more dangerous and more physically demanding than jobs in other sectors. To the extent that the higher wages simply reflect compensating differentials – that these jobs pay more only because higher wages are necessary to compensate workers for doing dirty, dangerous, demanding work – then workers might well be no worse off if those jobs went away and were replaced by jobs that pay somewhat less but are safer, cleaner, and easier. But anecdotal evidence indicates that these jobs are seen as desirable, despite their demands and risks. And research suggests that the higher wages reflect more than just compensating differentials.[16]

Similarly, what if the higher observed wages in these jobs are caused not by characteristics of the jobs themselves, but of the workers who take those jobs (e.g., if those workers are more skilled)? This again would mean that job losses in those industries wouldn't necessarily make those workers substantially worse off; they would likely earn relatively high

[15] Popular perceptions of the extent to which policy is driving loss of these jobs may be greatly overstated. Over time, the fraction of the labor force employed in these industries has dropped substantially, and many observers are inclined to blame policy changes for these shifts. But much of that change would likely have happened anyway, due to technological progress in these sectors that has made them much less labor-intensive. For example, coal mining production (tons of coal mined) increased by a factor of 2.4 between 1949 and 2008 (peak year of production) while the labor input into coal mining (total hours worked) fell by over 70 percent, primarily due to a shift toward mechanized surface mining (source: EIA Annual Coal Report 2017, Tables ES1 and ES2).

[16] Studies of inter-industry wage differentials suggest that work conditions explain very little of the estimated differentials across industries. See, for example, Krueger and Summers (1988), which finds that industries such as construction, manufacturing, and transportation still show substantial wage premia even after controlling for working conditions.

wages in other jobs as well. To the extent that the differences across workers can be measured, one can adjust for them, but there might well be differences that are unobservable in the data (e.g., differences in work ethic). Again, though, research suggests that differences across workers can't fully explain wage differentials across jobs.[17]

Thus, it appears that genuine "good jobs" exist: jobs that pay significantly more, even after accounting for differences in other job conditions and differences across workers.[18] Consequently, economists need to take this issue seriously. There are a variety of possible explanations for why these genuine wage differentials can persist, including unionization, efficiency wages, or a variety of search and matching frictions. But under any of these explanations, losing a good job represents a larger welfare loss for the individual worker (and potentially for society as well) than losing an average job, and thus job effects in industries with a greater share of good jobs could matter more.[19]

Modeling how policy will affect good jobs is difficult, however, as is measuring the magnitude of the welfare loss from losing a good job, and thus there is relatively little solid evidence to evaluate how important these issues are. We are unaware of any work in the environmental context that attempts to model the effect of regulation on job quality, though there is a limited amount of work in other contexts. For example, Davis and Harrigan (2011) combine a Melitz (2003) trade model with a Shapiro-Stiglitz (1984) model of efficiency wages to produce a model of trade liberalization in which identical workers get paid more in some jobs than in others. They find that trade liberalization could cause substantial losses of good jobs (in one experiment, they find that up to a quarter of above-average-wage jobs are destroyed). But that finding doesn't shift the conclusions about the aggregate welfare effects: they still find substantial aggregate gains from trade liberalization. And their model is highly stylized, so it is hard to draw clear quantitative conclusions.

[17] See, for example, Blackburn and Neumark (1992) and Gibbons and Katz (1992).

[18] Note, however, that one still needs to take account of these differences when measuring the value of a good job. Simply comparing wages will mis-measure that value.

[19] It's not necessarily the case that the loss of high-quality jobs implies a loss of efficiency. For example, Mangin and Julien (2018) show that in a search-friction model where extra search effort can produce not just more matches but also higher-quality matches (i.e., matches with higher labor productivity for a given worker), a generalized version of the Hosios condition holds. As with the standard version of the Hosios condition (discussed previously), this means that an increase in search effort (which here could take the form of more high-quality jobs) could be efficiency-reducing, depending on the values of the parameters in that generalized Hosios condition.

We are also unaware of any research on the welfare effects of “good job” losses in this context. We can, however, draw some limited conclusions from results in Walker (2013). That paper uses linked worker-firm data to look at how job transitions induced by regulation under the 1990 Clean Air Act Amendments affect workers, including periods of nonemployment and lower future earnings. That paper finds that earnings losses are concentrated among higher-wage workers (Walker, 2013, p. 1823), though it also implies that result is driven by effects on older workers (who tend to be higher-wage), and doesn’t connect it to the “good jobs” question.

Thus, while it’s clear that there is something to the “good jobs” issue, it’s far less clear how quantitatively important the issue is. Further research is needed in this area, both empirical studies to try to estimate some of the key effects and theory/simulation research to better model how policy affects job quality and what welfare effects that will have.

4. A Model of Jobs and Environmental Regulation

To highlight how current economic modeling addresses the questions about the impact of environmental regulation on jobs discussed above, we utilize the search-CGE model from Hafstead et al. (2018) and Hafstead and Williams (2019). This multisector model extends a standard computable general equilibrium used to evaluate the impacts of environmental regulation, adding a search friction as in Pissarides (1985) and Mortensen and Pissarides (1994). This key element introduces unemployment and labor market dynamics into the model. In any given period, an endogenous fraction of unemployed workers matches with firms, the worker and firm negotiate wages and hours, and these workers begin employment in the following period. Employed workers can be allocated to production work or to recruiting new workers. An exogenous small fraction of employed workers separates from their jobs at the end of each period, becoming unemployed in the following period. These dual processes of job creation and job destruction determine the unemployment rate in each period.

In addition to the economic spillovers that occur between industries interdependent through supply chain linkages in the standard CGE model, there are two additional sources of potential spillovers in the labor market in the search-CGE model that may be especially important for analyzing environmental regulations. First, the match process, following Hafstead and Williams (2018) (a multisector generalization of the process in Shimer (2010)), is designed such that recruiter productivity (the expected number of recruits per recruiter) and the probability a worker finds a firm in each period are functions of the number of job seekers and the aggregate recruitment effort (the number of recruiters) of *ALL* firms. For example, if an environmental regulation reduces recruiting effort in the regulated industry, workers would be less likely to find a job in that industry, but firms in unregulated industries would be *more* likely to find workers, due to decreased competition in the hiring market. Second, the wage bargain in the model splits the surplus created by the match between the worker and the firm, and this surplus is a function of the worker's outside option (the value of turning down the job offer and remaining unemployed). The outside option is partially determined by how long workers expect to be unemployed. Consequently, an environmental regulation that reduces recruitment in one industry or a small subset of industries could worsen the outside option and thus ultimately reduce the wages of *ALL* workers regardless of industry; unregulated industries may therefore decide to hire more workers due to the decrease in wages.

Hafstead et al. (2018) compares the steady-state predicted labor market effects of an economy-wide carbon tax between the search-CGE model and an otherwise equivalent model that assumes full employment. Here, we apply the same search-CGE model to evaluate the labor market outcomes across a range of different environmental regulations in both the steady state and the transition to that steady state. The model is ideally suited to capture interactions across regulated and unregulated industries, labor market spillovers, and changes in job flows for the average worker. This allows us to predict gross and net job changes across the industries in our model and evaluate labor market outcomes such as the length of the average unemployment spell, changes in recruitment across industries, and the change in after-tax earnings for average workers. The ultimate goal of this analysis is to provide intuition for these results and to give readers an understanding of the key forces at work.

4.1 Brief Model Description

A complete model description is beyond the scope of this paper (see Hafstead et al. (2018) for all details), but here we provide a brief summary of the model, data, and calibration. There are 22 private industries and a government sector (representing federal/state/local government). Each industry combines labor, energy inputs, and material inputs to produce a distinct good using a standard nested constant-elasticity-of-substitution (CES) production function. Table 1 provides a complete list of industries.[20] Each private industry is classified as either an energy industry (E) or a materials industry (M). Oil&gas extraction, Coal mining, Electric power, Natural gas distribution, and Petroleum refining and coal products are all classified as energy industries, and the remaining industries, including government enterprises, are classified as materials industries. Firms (or the government) choose inputs of energy and materials to minimize the unit cost of intermediate inputs. Firms (or the government) begin each period with a stock of workers and then decide whether to allocate workers to the production process or to worker recruitment. Taking recruitment productivity as given, the firm chooses recruitment effort and the overall level of intermediate inputs to maximize the value of the firm; the public government sector chooses recruitment effort and intermediate inputs to provide a fixed level of a public good at minimum cost. Because firms lose a fixed fraction of workers each period through an exogenous separation rate,[21] firms (almost) always recruit workers and even a small change in recruitment effort could alter the number of workers employed in each period.[22]

As is standard in the search-and-matching literature, we use a representative household framework (see, for example, Merz 1995). A representative household is also standard in the full-employment CGE literature (see, for example, Goulder et al. 2016). In the search-CGE model, this framework assumes full insurance across workers such that the marginal utility of consumption is constant across workers regardless of past or current employment status. Household income is the sum of after-tax earnings across sectors plus unemployment compensation (held fixed in real terms) received by unemployed workers. Aggregate consumption is a constant elasticity of substitution (CES) composite of consumption of each industry-specific good. Households choose consumption to maximize life-time discounted utility.

---

[20] Government enterprises are considered a private industry and are separate from the public government sector. However, in Table 1 "Government (incl. enterprises)" aggregates government enterprises and the public sector together.

[21] The model holds total exogenous separations (layoffs plus voluntary quits/retirements) constant. Across the business cycle, overall separations are relatively constant; increased layoffs often lead to decreased voluntary separations; we anticipate a similar pattern in response to policy. However, this implies that our model will not be able to capture differential economic impacts of changes in the layoff/voluntary separation ratio.

[22] Firms are also allowed to increase separations (fire workers) above the exogenous separation rate if, with zero recruitment effort, the value of the firm at current employment levels is below zero. In our analysis, we find that increased separations are rare and only occur in particularly affected industries in the first month of the policy.

Finally, as in Hafstead and Williams (2018) we incorporate foreign trade through a standard Armington assumption; households/firms may choose to buy domestically produced or foreign produced goods/inputs. Trade elasticities determine the extent to which households/firms alter the patterns of trade in response to changes in relative prices. A single foreign economy represents the rest of the world (ROW). The foreign economy mirrors the domestic economy in all respects, although the scale of the ROW economy is larger.

Table 1. Separation Rates and Labor Share by Industry

Industry	Separation rate	% of total labor compensation
Oil&gas extraction	4.6	0.16
Coal mining	4.6	0.04
Other mining	4.6	0.07
Mining support services	4.6	0.52
Electric power	3.2	0.66
Natural gas distribution	3.2	0.18
Petroleum refining and coal products	2.3	0.17
Water/sewage utilities	3.2	0.03
Agriculture	4.6	0.54
Construction	4.7	5.10
Durable manufacturing	2.0	5.85
Nondurable manufacturing (excl. refining)	2.3	2.95
Wholesale trade	2.4	4.66
Retail trade	4.7	4.95
Transportation and warehousing	3.2	3.17
Information	2.8	2.79
Finance, insurance, real estate (incl. housing)	2.3	8.37
Professional business services	5.2	18.34
Education and health	2.6	12.33
Leisure and hospitality	6.1	4.70
Other services	3.6	3.84
Government (incl. enterprises)	1.5	17.63

Our model also includes two additional features beyond Hafstead et al. (2018): industry switching frictions and staggered wage bargaining.[23] To incorporate industry switching frictions,

[23] Both extensions are also included in Hafstead and Williams (2019). They affect the transition only; neither extension affects the model's steady state.

we introduce a generalized matching function as in Hafstead and Williams (2018) such that the probability a worker finds a job in any given industry is a function of the worker's previous job experience; such an assumption prevents workers from easily moving industries during the transition (from a regulated to an unregulated industry, for example). In the long run, we assume that wages are fully flexible: wages and hours are effectively renegotiated each period. As is common in the search and matching literature, we assume Nash bargaining between workers and firms. Under this bargaining assumption, hours are set to maximize the surplus created by the match (the value of the match to the employer plus the value of the match to the employee) by setting the marginal disutility of hours worked by the worker equal to the marginal benefit to the firm of an additional hour of work; wages are then set to split the surplus between the worker and firm according to the employer's bargaining power.[24] In the short run, however, wages are unlikely to be fully flexible and/or may not be renegotiated in each period. Following Hafstead and Williams (2018), we incorporate the Gertler and Trigari (2009) staggered wage bargaining model; in each period, only a fraction of firms in an industry may renegotiate wages and the average wage in each sector is a function of an optimal wage (which takes into consideration that wages may be fixed for an extended period of time) and the average wage in the previous period.[25]

The data and calibration are identical to Hafstead et al. (2018). The model is set such that one period is equal to one month and all standard CGE and search model parameters are calibrated using relatively standard assumptions. The Appendix describes our data sources and the model calibration process in more detail.

4.2 Environmental Regulations

In this analysis, we consider three types of environmental policy, varying widely in scope and stringency, representing the wide range of existing and proposed environmental policies. Comparing modeling results for these policies allows us to show which labor market effects are

[24] In our benchmark model, we assume that workers and employers have equal bargaining power and therefore they evenly split the surplus.

[25] All workers at a firm receive the same wage; if renegotiations take place, both new workers and incumbents receive the same wage. Hours are still fully flexible in this framework.

robust across widely different policies, and to identify how labor market effects vary across policies.

The first policy is meant to correspond to the vast majority of existing environmental regulations as put forth by the EPA or other agencies; the policy applies only to a single industry and takes the form of an input-cost shock (intended as a simple way to approximate typical unit-level technology mandates that would require end-of-pipe controls or process changes). Here, we apply the input-cost shock to the durable manufacturing sector. The shock is calibrated to reduce output from the sector by approximately one percent. Labor taxes are adjusted to maintain revenue-neutrality.

The second policy is a tradable performance standard in the electric power sector: the policy requires reductions in carbon dioxide emissions per megawatt hour in the overall generation fleet. This policy is similar in nature to the Clean Power Plan, which set state-specific goals for power-sector emissions intensities, but applies to all generators across all states and allows for rate credit trading across all states.[26] This case could also approximate a clean energy standard that sets minimum requirements for generation from zero or low-carbon generation technologies. Here, we model a performance standard that results in a 20 percent decrease in electricity-related carbon dioxide emissions (relative to 2015 levels).[27] As with the durable manufacturing regulation, we impose revenue-neutrality through increases in labor taxes.

Finally, our third policy is an economy-wide carbon tax, similar to the taxes considered in Hafstead et al. (2018). A number of proposals call for an economy-wide price on carbon dioxide emissions, including the Climate Leadership Council's Baker-Shultz Carbon Dividend Plan, the Whitehouse-Schatz American Opportunity Fee Act, the bipartisan Energy Innovation and Carbon Dividend Act, and the Republican MARKET CHOICE Act. These proposals indicate a growing interest in an economy-wide carbon tax, but vary widely in the starting price level and rate of change over time. Therefore, for illustrative purposes, we have chosen to model the employment impacts of a federal economy-wide carbon tax of $40 per metric ton (in $2015) on

[26] The Clean Power Plan, which has since been repealed by the Trump administration, allowed for states to set rate or mass-based policies to meet state-level emissions intensity targets. The plan also allowed states to join coalitions with trading across states. The policy here is roughly equivalent to the Clean Power Plan if all states joined a single coalition that used a rate-based policy with trading across states.

[27] The Clean Power Plan required a 32 percent reduction in power sector emissions, relative to 2005. Emissions in 2015 from the power sector were already 21 percent below 2005 levels and a further 20 percent reduction in emissions from 2015 levels is equivalent to a 37 percent reduction relative to 2005 levels.

energy-related carbon dioxide emissions only.[28] Revenue from the policy is recycled to households through lower labor income taxes.

Importantly, our analysis focuses only on the labor market implications of policies and does not consider the full set of costs and benefits. Further, we deliberately chose to model policies that vary substantially in scope and stringency, in order to show that most of the key insights from the model on jobs and environmental regulation are robust across policies. But those scope and stringency differences also mean that directly comparing the magnitude of employment effects across these policies is an apples-to-oranges comparison (one would expect a policy that is more stringent and/or covers more of the economy to have correspondingly larger effects on employment).[29]

5. Steady State Analysis

Our analysis starts by evaluating the impact of the three environmental regulations in the model's steady state. In the steady state of a dynamic model, the distribution of employment across firms is constant over time; while there are still worker flows into and out of each firm in each period, these flows balance for each firm, such that the number of employees in each firm isn't changing. The steady state analysis abstracts from the many frictions that could prevent job reallocation in the short-run (worker-job skill mismatches, inflexible wages, geographic immobility, etc.), but highlights many important aspects of the relationship between environmental regulation and the labor market.[30]

Table 2 reports the employment impacts by sector for each of the three environmental policies.[31] In Table 2, unregulated sectors are categorized as "negative spillover" if employment

[28] Many of the carbon tax proposals contain elements not modeled in this analysis. For example, the Baker-Shultz Carbon Dividend Plan includes border adjustments and a reduction in regulations, neither of which are included in this analysis. Our carbon tax is also introduced unexpectedly and without a phase-in; introducing either would change the timing and magnitude of the employment response.

[29] In Hafstead and Williams (2019), we hold emissions reductions constant across power-sector performance standards and carbon taxes to evaluate how the different types of policies affect jobs when holding scope and stringency fixed: carbon taxes cause smaller long-run overall reductions in employment than a performance standard (or could even yield long-run employment gains) but with the tradeoff of more job reallocation and larger short-run reductions in employment.

[30] We also assume that the separation rate is exogenous and independent of environmental policies in the steady state.

[31] For the carbon tax, there is some leeway in defining what is a regulated sector; here, we classify all energy sectors to be regulated and all non-energy sectors to be nonregulated.

falls in steady state (relative to no regulation) or "positive spillover" sectors if employment increases in the steady state. The change in employment is reported as a fraction of the total labor force and therefore the "All sectors" column is simply the sum of the change in employment in the regulated and unregulated (negative plus positive spillover) sectors.[32] The final column reports the difference-in-difference estimate of the jobs impact in the regulated sector, equal to change in employment in the regulated sector minus the change in employment in the unregulated sectors (negative plus positive spillover). As discussed previously, partial equilibrium studies often use unregulated sectors as the control group: the difference-in-difference estimator will only be unbiased if there is no change in employment in the unregulated sectors.

Table 2: Steady State Employment Impacts by Sector

	Change in Employment (as fraction of labor force)				Difference-in-difference estimator
	Regulated Sector(s)	Negative Spillover Sectors	Positive Spillover Sectors	All Sectors	
Durable Manufacturing Regulation	-0.019%	-0.037%	0.020%	-0.036%	-0.002%
Power Sector Performance Standard	0.041%	-0.049%	0.002%	-0.006%	0.088%
Economy-Wide Carbon Tax (Labor Tax Cuts)	-0.032%	-0.343%	0.396%	0.021%	-0.086%

There are four primary channels through which spillovers occur in response to regulation in this model. First, supply chain spillovers occur when an upstream or downstream industry is affected through changes in the demand or supply of goods from the regulated sector. Second, to the extent that the policy raises prices of final goods that use polluting inputs, consumer demand spillovers occur as consumers substitute away from those goods toward other consumer goods that are less pollution-intensive in production. Third, as discussed previously, labor market spillovers through the match and bargaining processes affect other firms. Finally, changes in tax rates required to impose revenue-neutrality may also impact hiring across unregulated industries.

Under the durable manufacturing regulation, the input cost shock reduces employment in the regulated sector due to the output effect from increased overall costs, though this is partially

[32] Because we normalized the labor force to be equal to one, the change in employment across all sectors is equal to the change in the unemployment rate times negative one. For example, the unemployment rate is predicted to increase from 5 percent to 5.036 percent under the durable manufacturing regulation.

offset by a substitution effect: firms respond to higher costs of intermediate inputs by substituting toward labor. As expected, some supply chain spillovers cause negative spillovers in industries that use a disproportional amount of durable manufacturing products (electric power and natural gas distribution, for example) but some industries increase employment and experience positive spillovers due to labor market spillovers (oil&gas extraction, other mining, and mining services, for example). Finally, some industries that are not obviously linked to manufacturing also suffer negative spillovers (education and health or leisure and hospitality), most likely due to the small labor tax increases that occur to maintain revenue-neutrality for the government.

As shown in Goulder et al. (2016), the performance standard is equivalent to a tax on power sector emissions and subsidy on electricity generation. Under this policy, the power sector actually increases employment levels: firms substitute from fossil fuels toward labor in order to reduce emissions, and the implicit output subsidy prevents any significant drop in sector output. However, there are significant supply chain spillovers: employment falls dramatically in the coal sector due to decreased demand for the most carbon-intensive fuel. The offsetting employment impacts in these two industries appear to mitigate any substantial spillovers through the labor market channels and overall the increase in the tax rate due to the revenue-neutrality assumption is small. As a result, the spillover effects (with the exception of coal mining) of the power sector performance standard are small.

Unsurprisingly given its large scope and scale, the economy-wide carbon tax (with labor tax recycling) generates the largest employment impacts in both regulated sectors (energy sectors) and unregulated sectors. Energy-intensive sectors such as durable manufacturing, nondurable manufacturing, and transportation and warehousing experience negative employment impacts while less energy-intensive sectors such as education and health, leisure and hospitality, and government (enterprises and general) experience positive employment impacts due to positive labor market, consumer demand, and tax spillovers. Overall, however, employment is projected to increase slightly under the economy-wide carbon tax with labor tax recycling as the positive spillover channels dominate the supply chain channel.[33]

---

[33] The sign of the overall effect on employment may vary with a range of different model assumptions and details of the policy. For example, if instead revenues were returned to households in lump-sum rebates instead of via labor tax cuts, the overall change in employment would be negative, an indicator of the importance of the labor tax spillover channel. But while the sign of the overall employment effect may vary, the magnitude generally quite small, especially relative to the wide scope and substantial stringency of the policy.

Despite the differences across policies, Table 2 reveals several key findings that are consistent across each of the three different policies considered. First, there are likely to be considerable spillovers, both positive and negative, in unregulated sectors. As a result, the SUTVA assumption is violated and thus difference-in-difference estimators are likely to yield substantially biased estimates of the effect on employment in the regulated sector and may even get the sign of that effect wrong. Second, our analysis suggests that changes in employment in unregulated sectors are likely to be large relative to the employment changes in the regulated sector, regardless of policy scope and scale. Finally, our modeling shows that reallocation, defined as the sum of the absolute value of employment changes across sectors, will be large relative to net employment changes. In other words, environmental policy in the long-run will shift far more workers across industries than it will push workers into unemployment.

To test whether these findings are robust across alternative assumptions, we consider alternative parameter values in Table 3. Specifically, we've focused on a set of parameters that may affect the various channels of spillovers in the model: a) employer bargaining power, b) the match elasticity, c) the elasticity of labor supply for each worker, d) the elasticity of substitution for household consumption and e) the labor-intermediate input elasticity in production. And while the quantitative magnitude of the spillovers varies across parameter values, our key findings about labor market spillovers appear robust across the alternative parameter values considered in Table 3.[34]

[34] Appendix A provides a table of calibrated parameter values in the benchmark model and the alternative values considered in the sensitivity analysis.

Table 3: Steady State Employment Impacts by Sector, Sensitivity Analysis

Durable Manufacturing Regulation

	Change in Employment (as fraction of labor force)				
	Regulated Sector(s)	Negative Spillover Sectors	Positive Spillover Sectors	All Sectors	Difference-in-difference estimator
Benchmark	-0.019%	-0.037%	0.020%	-0.036%	-0.002%
Low employer bargaining power	-0.017%	-0.022%	0.031%	-0.008%	-0.026%
High employer bargaining power	-0.026%	-0.112%	0.000%	-0.138%	0.085%
Low match elasticity	-0.020%	-0.048%	0.011%	-0.057%	0.016%
High match elasticity	-0.018%	-0.027%	0.027%	-0.017%	-0.018%
Lower labor supply (hours) elasticity	-0.020%	-0.045%	0.013%	-0.053%	0.012%
Higher labor supply (hours) elasticity	-0.018%	-0.029%	0.026%	-0.022%	-0.014%
Lower consumer elasticity of subs.	-0.015%	-0.045%	0.023%	-0.037%	0.007%
Higher consumer elasticity of subs.	-0.026%	-0.022%	0.014%	-0.034%	-0.018%
Lower labor-intermediate input elasticity	-0.028%	-0.041%	0.030%	-0.039%	-0.017%
Higher labor-intermediate input elasticity	-0.010%	-0.033%	0.009%	-0.034%	0.013%

Power Sector Performance Standard

	Change in Employment (as fraction of labor force)				
	Regulated Sector(s)	Negative Spillover Sectors	Positive Spillover Sectors	All Sectors	Difference-in-difference estimator
Benchmark	0.041%	-0.049%	0.002%	-0.006%	0.088%
Low employer bargaining power	0.041%	-0.045%	0.003%	-0.001%	0.084%
High employer bargaining power	0.041%	-0.065%	0.001%	-0.022%	0.105%
Low match elasticity	0.041%	-0.053%	0.002%	-0.009%	0.092%
High match elasticity	0.041%	-0.047%	0.003%	-0.003%	0.085%
Lower labor supply (hours) elasticity	0.041%	-0.052%	0.002%	-0.008%	0.091%
Higher labor supply (hours) elasticity	0.041%	-0.048%	0.003%	-0.003%	0.086%
Lower consumer elasticity of subs.	0.043%	-0.051%	0.003%	-0.006%	0.091%
Higher consumer elasticity of subs.	0.038%	-0.046%	0.002%	-0.006%	0.083%
Lower labor-intermediate input elasticity	0.023%	-0.038%	0.008%	-0.007%	0.052%
Higher labor-intermediate input elasticity	0.060%	-0.065%	0.000%	-0.005%	0.125%

Economy-wide Carbon Tax

	Change in Employment (as fraction of labor force)				
	Regulated Sector(s)	Negative Spillover Sectors	Positive Spillover Sectors	All Sectors	Difference-in-difference estimator
Benchmark	-0.032%	-0.343%	0.396%	0.021%	-0.086%
Low employer bargaining power	-0.032%	-0.349%	0.388%	0.007%	-0.072%
High employer bargaining power	-0.032%	-0.329%	0.421%	0.060%	-0.124%
Low match elasticity	-0.032%	-0.340%	0.400%	0.028%	-0.092%
High match elasticity	-0.032%	-0.347%	0.392%	0.013%	-0.077%
Lower labor supply (hours) elasticity	-0.032%	-0.340%	0.399%	0.027%	-0.091%
Higher labor supply (hours) elasticity	-0.032%	-0.345%	0.393%	0.016%	-0.080%
Lower consumer elasticity of subs.	-0.009%	-0.272%	0.303%	0.021%	-0.040%
Higher consumer elasticity of subs.	-0.073%	-0.478%	0.571%	0.020%	-0.166%
Lower labor-intermediate input elasticity	-0.061%	-0.344%	0.416%	0.011%	-0.132%
Higher labor-intermediate input elasticity	-0.003%	-0.382%	0.415%	0.031%	-0.036%

Employer bargaining power determines how the match surplus is split between workers and firms. As explained in Hafstead and Williams (2018), it also determines how responsive the wage is to changes in the marginal product of labor. When employer bargaining power is high, the wage is relatively unresponsive to changes in the marginal product of labor and employment is relatively more responsive. In the case of our environmental policies, less employer bargaining power decreases the negative spillover and increases the positive spillovers due to more flexible wages; increased employer bargaining power does the opposite. Overall, reallocation is increasing in employer bargaining power and the bias in the difference-in-difference estimator is also increasing in the employer bargaining power.

The match elasticity determines how responsive the job-finding rate is to labor market conditions (as measured by the ratio of recruitment effort to job seekers); a higher match elasticity decreases negative spillovers and increases positive spillovers but does not change the overall pattern of reallocation relative to either regulated sector employment changes or overall net employment changes.

The labor supply elasticity determines how responsive hours per worker are to environmental regulations; more responsiveness would allow a firm to decrease its labor demand through hours worked instead of reducing the number of workers. As a result, changes in employment in both the regulated and negative spillovers sectors are decreasing in this elasticity. And because changes in hours per worker are roughly equivalent across sectors, positive spillovers are increasing in the labor supply elasticity: less hours worked per worker requires more workers to meet the same level of labor demand. Overall, spillovers seem to be weakly decreasing in this elasticity under the durable manufacturing regulation and the power sector performance standard.

Changes in the household elasticity of consumption and the producer labor-intermediate input elasticity have different effects on regulated employment changes and employment spillovers across the three different policies, but the overall pattern of spillovers is robust across these alternative parameter values.

In addition to studying the change in the total employment or the change in employment by sector caused by environmental regulation, the model can also predict changes in key labor market statistics such as the job-finding rate, the average length of unemployment spells, and the change in real household income. Table 4 displays steady-state values of these key labor market variables in the baseline (no policy) and under each of our three environmental regulations.

Table 4: Steady State Labor Market Outcomes

	Job-finding rate	Average Unemployment Spell (months)	Percent change in household income (real)
No Policy Baseline	62.44%	1.60	N/A
Durable Manufacturing Regulation	61.98%	1.61	-0.30%
Power Sector Performance Standard	62.36%	1.60	-0.05%
Economy-Wide Carbon Tax (Labor Tax Cuts)	62.69%	1.60	0.19%

The US labor market is especially dynamic: about 62.4 percent of unemployed workers find a job each month and the average worker expects to be unemployed for only about 1.6 months (or about 48.7 days) in our benchmark model calibrated to US labor market dynamics in the absence of new environmental policies. And the model further suggests that additional environmental policies will not significantly impact or disrupt this dynamism in the long run. Under the durable manufacturing and power sector regulations, our model predicts almost no changes in the job-finding rate and the corresponding average unemployment spell. In the long-run, at least, workers are not expected to spend more than an additional day looking for a job. Even under the economy-wide carbon tax (with labor tax cuts), which at $40 is expected to significantly reduce US energy-related carbon dioxide emissions and affects the most industries and workers, the job finding rate actually increases to 62.7 percent and there is no measurable change in the average unemployment spell.[35]

Environmental regulations may cause changes in employment across regulated and unregulated industries, but it could also affect the earnings of *all* workers, even those who do not change jobs. In our model, wages are perfectly flexible in the long run and depend on labor market health; because regulations are predicted to slightly reduce job-finding probabilities, these regulations will also reduce wages across all workers, regardless of industry. To measure the average change in household income, we calculate the change in real household income (equal to the sum of price-adjusted after-tax earnings across workers plus the real unemployment benefits received by unemployed workers).[36] As expected, the magnitude of the change in real household income is smallest under the power sector performance standard, which has the smallest labor market disruption. And the economy-wide carbon tax actually increases real after-tax income due to the reduction in labor taxes.

Table 5 reports the steady-state labor-market impacts for all three policies across a range of parameter values. Again, our finding that environmental policies do not significantly change job-finding rates or the corresponding average unemployment spell appears to be robust across most policies and parameter values. In particular, the pattern of changes in the job-finding rate is consistent with the pattern of changes in aggregate employment across parameters; employer bargaining power is particularly important in determining the magnitude of these changes. As discussed above, higher employer bargaining power often leads to relatively inflexible wages in response to policy and therefore larger effects on employment. On the other hand, inflexible wages may also help offset the impact of the policy on average household income.

---

[35] Under a carbon tax with lump-sum rebates, the job finding rate falls slightly, to 58.4 percent.

[36] Note that this is not a complete measure of the effects of policy on households. As discussed earlier, our analysis is focused on labor market effects and does not attempt to incorporate all the costs and benefits of each policy.

Table 5: Steady State Labor Market Impacts, Sensitivity Analysis

Durable Manufacturing Regulation

	Percent change in job-finding rate	Change in Average Unemployment Spell (Days)	Percent change in household income (real)
Benchmark	-0.75%	0.37	-0.30%
Low employer bargaining power	-0.16%	0.08	-0.27%
High employer bargaining power	-2.83%	1.42	-0.41%
Low match elasticity	-1.18%	0.58	-0.33%
High match elasticity	-0.35%	0.17	-0.27%
Lower labor supply (hours) elasticity	-1.09%	0.54	-0.32%
Higher labor supply (hours) elasticity	-0.45%	0.22	-0.29%
Lower consumer elasticity of subs.	-0.77%	0.38	-0.31%
Higher consumer elasticity of subs.	-0.70%	0.35	-0.28%
Lower labor-intermediate input elasticity	-0.79%	0.39	-0.32%
Higher labor-intermediate input elasticity	-0.70%	0.34	-0.28%

Power Sector Performance Standard

	Percent change in job-finding rate	Change in Average Unemployment Spell (Days)	Percent change in household income (real)
Benchmark	-0.13%	0.06	-0.05%
Low employer bargaining power	-0.03%	0.01	-0.05%
High employer bargaining power	-0.48%	0.23	-0.07%
Low match elasticity	-0.20%	0.10	-0.06%
High match elasticity	-0.06%	0.03	-0.05%
Lower labor supply (hours) elasticity	-0.18%	0.09	-0.05%
Higher labor supply (hours) elasticity	-0.08%	0.04	-0.05%
Lower consumer elasticity of subs.	-0.13%	0.06	-0.05%
Higher consumer elasticity of subs.	-0.13%	0.07	-0.05%
Lower labor-intermediate input elasticity	-0.15%	0.07	-0.06%
Higher labor-intermediate input elasticity	-0.11%	0.05	-0.04%

Economy-Wide Carbon Tax

	Percent change in job-finding rate	Change in Average Unemployment Spell (Days)	Percent change in household income (real)
Benchmark	0.39%	-0.19	0.19%
Low employer bargaining power	0.09%	-0.04	0.18%
High employer bargaining power	1.23%	-0.59	0.21%
Low match elasticity	0.53%	-0.26	0.18%
High match elasticity	0.21%	-0.10	0.20%
Lower labor supply (hours) elasticity	0.51%	-0.25	0.19%
Higher labor supply (hours) elasticity	0.27%	-0.13	0.20%
Lower consumer elasticity of subs.	0.40%	-0.19	0.19%
Higher consumer elasticity of subs.	0.35%	-0.17	0.17%
Lower labor-intermediate input elasticity	0.20%	-0.10	0.11%
Higher labor-intermediate input elasticity	0.56%	-0.27	0.26%

Overall, our steady state analysis using the search-CGE model from Hafstead et al. (2018) predicts that environmental policies are likely to both create and destroy jobs across regulated and unregulated sectors of the economy, and that this reallocation of jobs across sectors is likely to be much larger than the overall change in employment. Our results on labor market spillovers also strongly suggest that general-equilibrium analysis is needed to evaluate the jobs impact of a regulation; difference-in-difference estimators that use unregulated sectors as a control group will tend to be seriously biased and could potentially have the wrong sign, even for small and targeted regulations.

And although we cannot directly compare employment levels across policies, we can gain a few key insights by examining the differences in labor market outcomes across policies. First, it appears that direct regulation should be least preferred by policy makers. Despite likely being the policy with the smallest environmental benefits (due to its narrow scope and limited stringency), the durable manufacturing regulation actually has the largest negative employment impacts. The direct regulation has large employment impacts (at least partially) because it has no mechanism for alleviating direct or indirect negative employment impacts. A performance standard, on the other hand, mitigates the direct employment impacts on the covered industry through the implicit subsidy on output that a performance standard provides. In our analysis of the power sector performance, the supply chain spillovers to the coal mining industry almost exactly offset the increased demand for labor in the power sector; as a result, there are small labor market spillovers and the policy generates the least worker reallocation of any of the policies considered.[37] Finally, the economy-wide carbon tax (with labor tax cuts) generates significant reallocation of workers, and thus policy makers who want to minimize job reallocation may prefer other policy instruments. But it actually increases employment overall by reducing negative spillovers and increasing positive spillovers through the cuts in labor taxes. Using revenues for other uses, however, would still likely imply large reallocation, but would not provide this positive tax spillover and thus would likely cause net job losses.[38]

This analysis, however still leaves open many questions that policymakers care about. First, we have ignored worker heterogeneity – we've been silent on *who* benefits or loses from the changes in job flows across sectors. Answers to those distributional questions are important. And the analysis also cannot answer *when* and *how* reallocation occurs, questions that are fundamental to determining if changes in job flows have aggregate social costs. In the next section, we look at the transitional labor dynamics to attempt to answer some of these questions.

6. Transitional Labor Dynamics

Hafstead and Williams (2018) examine the transitional labor dynamics of environmental regulations in a two-sector model, showing that both industry switching costs and sticky wages (in the short run) could significantly affect the transition of the economy from a pre-regulation steady state to a post-regulation steady state. In this paper and in Hafstead and Williams (2019), we add both of those transitional frictions to the 22-sector search-CGE model in Hafstead et al. (2018).

Examining the transition in this model, as discussed above, can help answer when and how employment changes occur. For example, the model can indicate if changes in employment occur through changes in separations or changes in hiring rates; there may be large social costs of the former but not of the latter. The timing is also particularly important to policymakers; if short-run frictions cause a short-run spike in unemployment, policymakers facing reelection may

[37] Whether or not this holds true for performance standard policies generally or if the power sector is a special case, however, remains an open question and more research is necessary to generalize this result.

[38] Our model indicates that the unemployment rate increases 0.3 percentage points under the carbon tax with lump-sum rebates.

be unwilling to pursue these regulations even if the long-run impacts on employment are minimal. Looking at the transition will also illustrate whether spillovers become more or less important as we move from the short to the long run.

The transition model can also identify short-run impacts across workers by industry through the introduction of industry switching frictions, but our model is not detailed enough to identify which types of workers (age, education, skill set, etc) are more or less affected by regulation. Our model also ignores capital, which could take decades to adjust to new environmental policy due to the high capital intensity of industries likely to face environmental regulation and the long-lived capital stock in those industries. The impact of adding capital on our results would depend primarily on whether capital and labor are substitutes or complements in production.

Figure 1 displays the change in employment for the regulated sector and all sectors for the durable manufacturing regulation, the power sector performance standard, and the economy-wide carbon tax (with labor tax recycling) over the first 3.5 years after policy implementation. In the first period of the policy (period 0), employment changes can only occur through increased separations. Under the durable manufacturing regulation, there are no projected additional separations in any sector. Under both the power-sector performance standard and the economy-wide carbon tax, increased separations in the first period cause employment to fall immediately. Under the power sector performance standard, increased separations occur in the unregulated coal sector, while under the economy-wide carbon tax, increased separations occur in both regulated (oil&gas, coal, petroleum refining) and unregulated sectors (mining services).

After the policy has been implemented, changes in employment occur through changes in hiring rates. Under the power sector performance standard, the implicit output subsidy leads to increased hiring and more employment in the regulated sector; in the other two policies, the regulated sectors respond to the policy by reducing hiring and reducing employment. In each of the three policies, employment in the regulated sectors quickly converges to its new long-run equilibrium level.

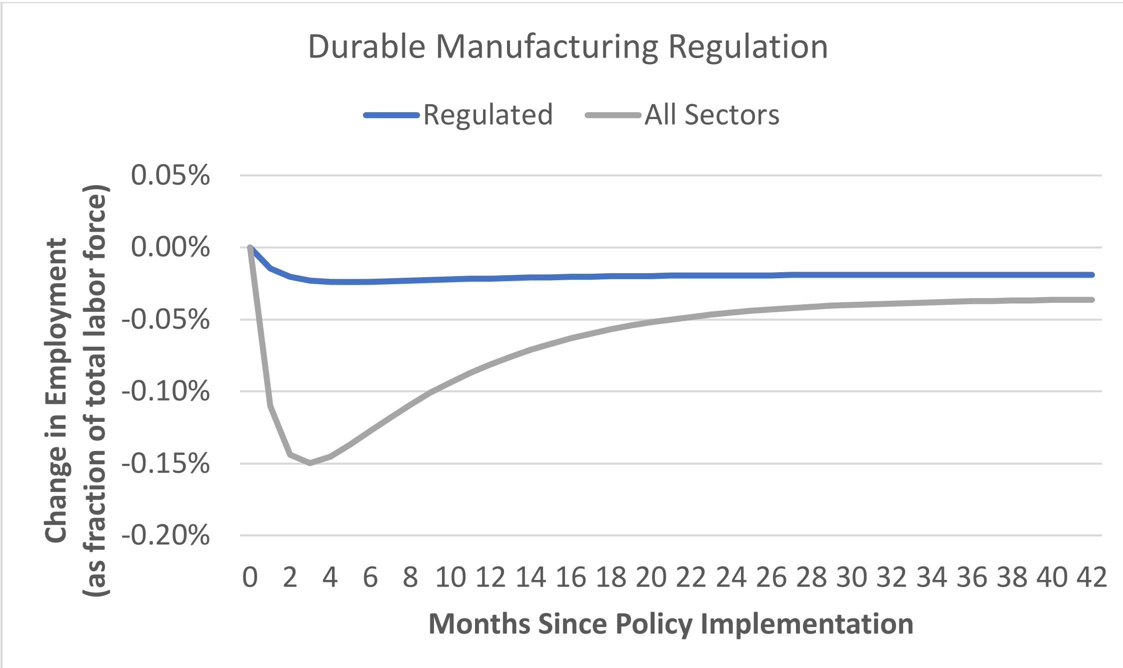
Under the durable manufacturing and carbon tax policies, employment spillovers to unregulated industries are much larger in the short run than the long run, primarily because industry switching frictions and sticky wages limit adjustment in the short run. As a result, difference-in-difference estimates of short-run employment impacts are likely to be even more biased than estimates of long-run employment impacts. Further, the negative spillovers peak before falling back to steady state levels, with the timing of the peak corresponding with the wage adjustments; when wages start adjusting down, employment is likely to rise in both negative and positive spillover industries.

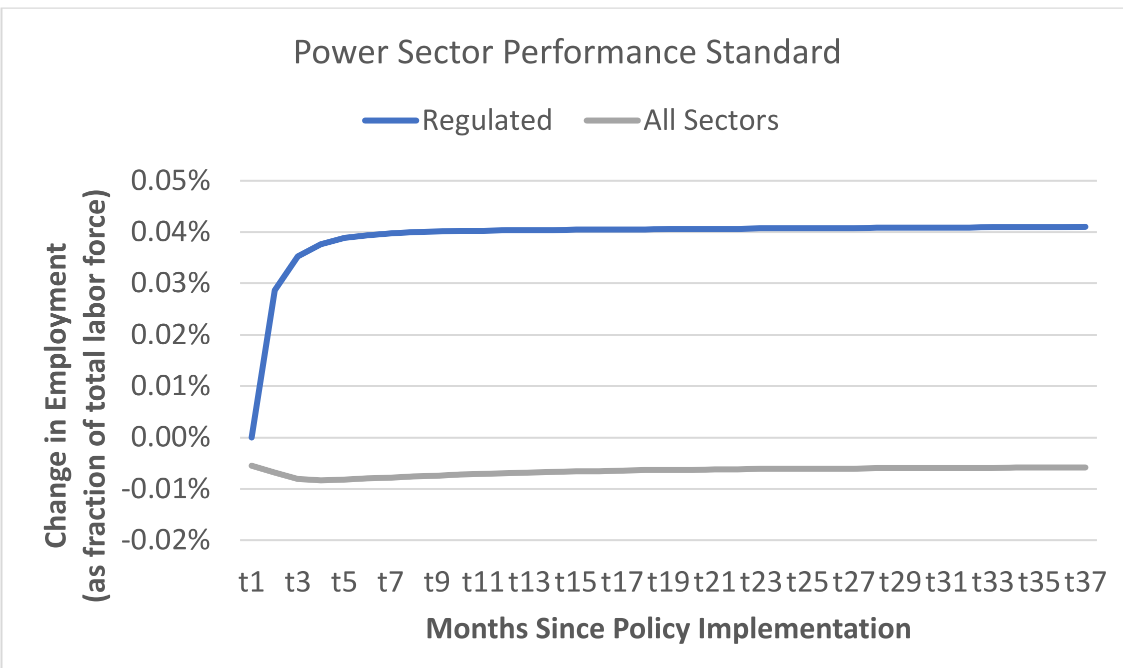
The carbon tax (with labor tax cuts) also demonstrates the importance of analyzing both the transition and steady state of the policy. Despite having a small net increase in long-run employment (due to the reduction in labor taxes), the policy generates significant negative short-run spillovers: the change in employment at its peak (in absolute terms) equates to a one percentage point increase in the overall unemployment rate (from 5 to 6 percent).[39]

The power sector performance standard stands in contrast to the other two policies. In addition to employment increasing in the regulated sector (likely as a result of the implicit output subsidy), the overall change in employment does not exhibit the same short-run pattern as the other two policies, with only a very small differences between overall employment impacts in the short and long-run. Increased labor demand in the power sector largely offsets the decreased labor demand in the coal mining sector and therefore the channels through which large short-run spillovers to other industries occur (wages and recruitment costs) appear to be mitigated.

[39] Remember that none of the policies we consider includes a phase-in or preannouncement. Either of those might reduce the magnitude of this peak.

Figure 1: Changes in Employment by Sector





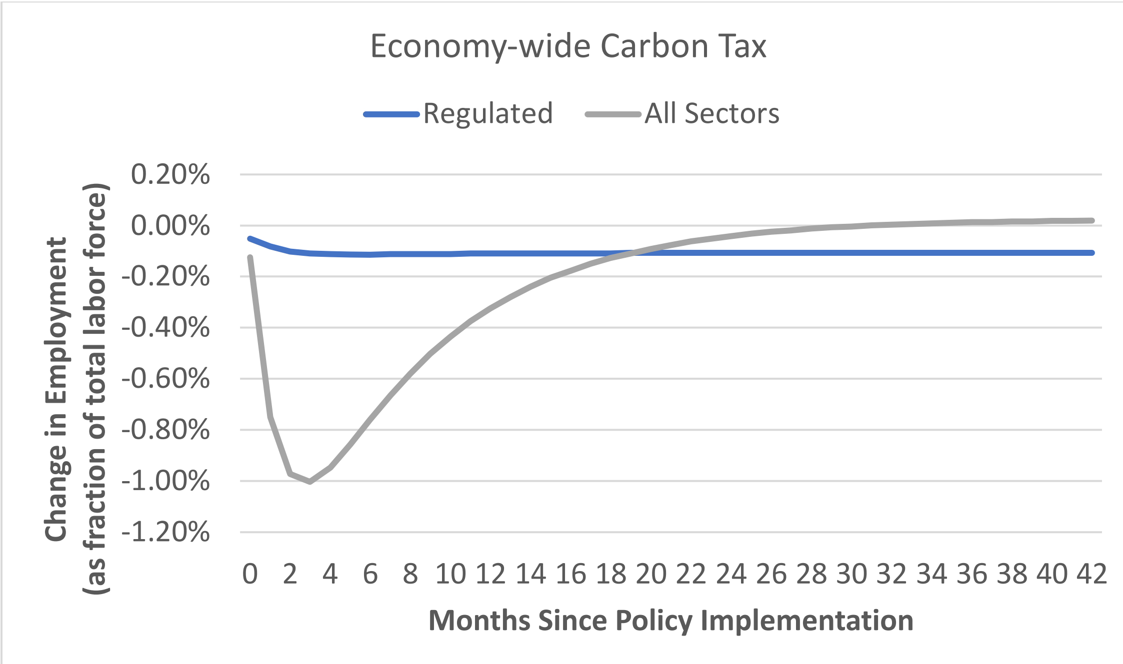
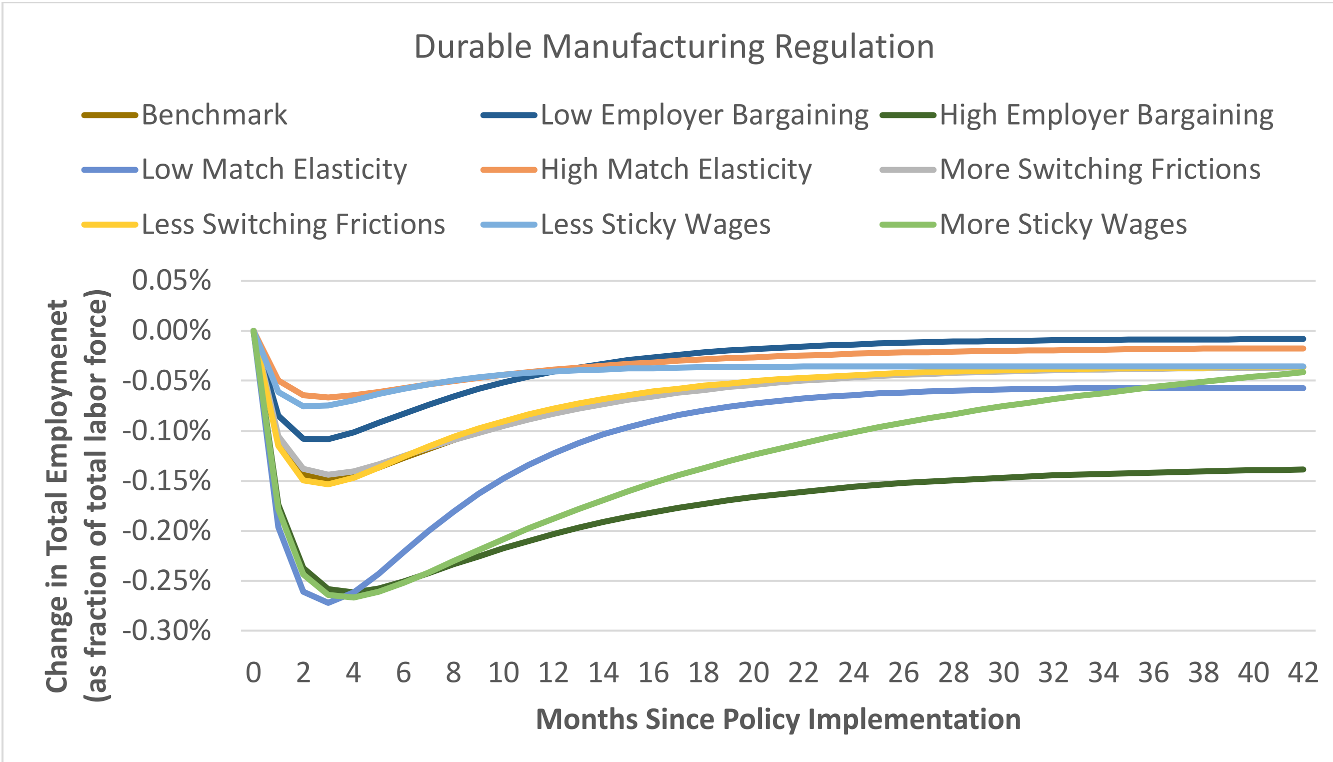
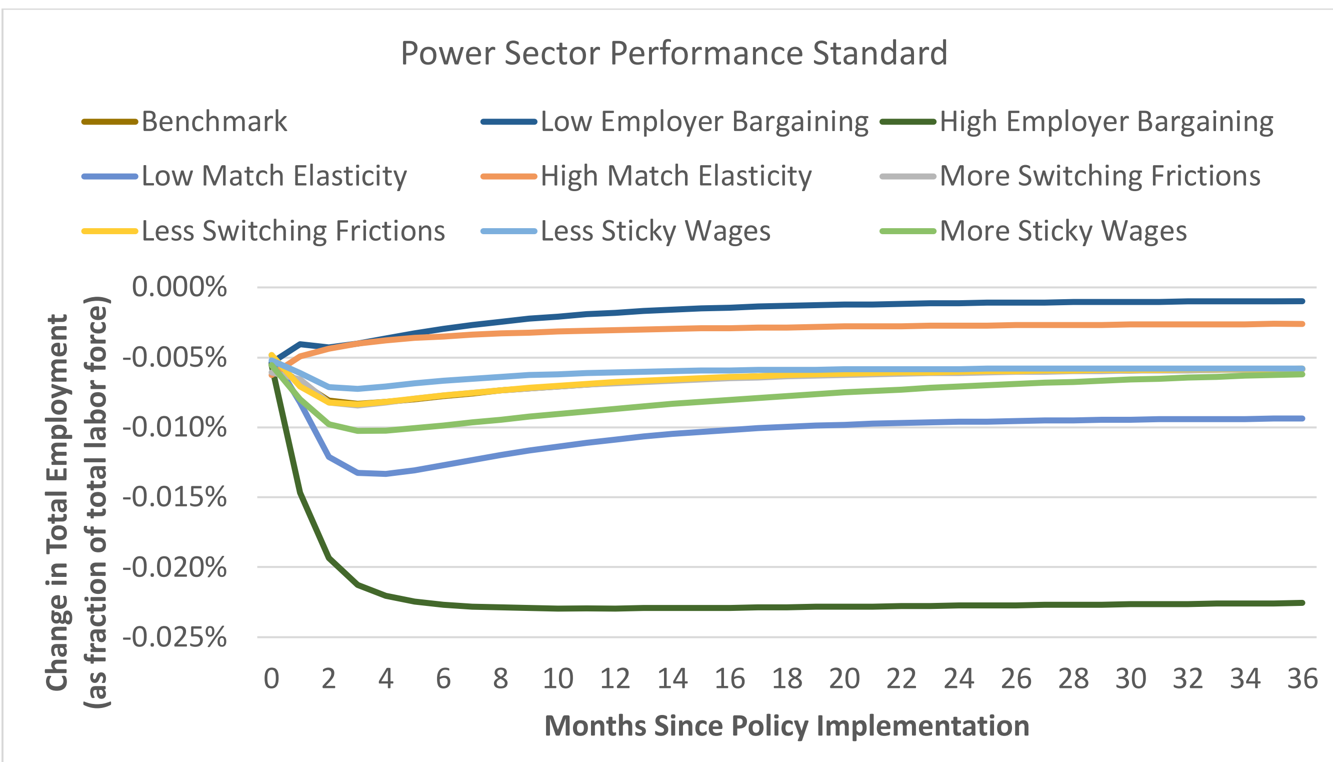


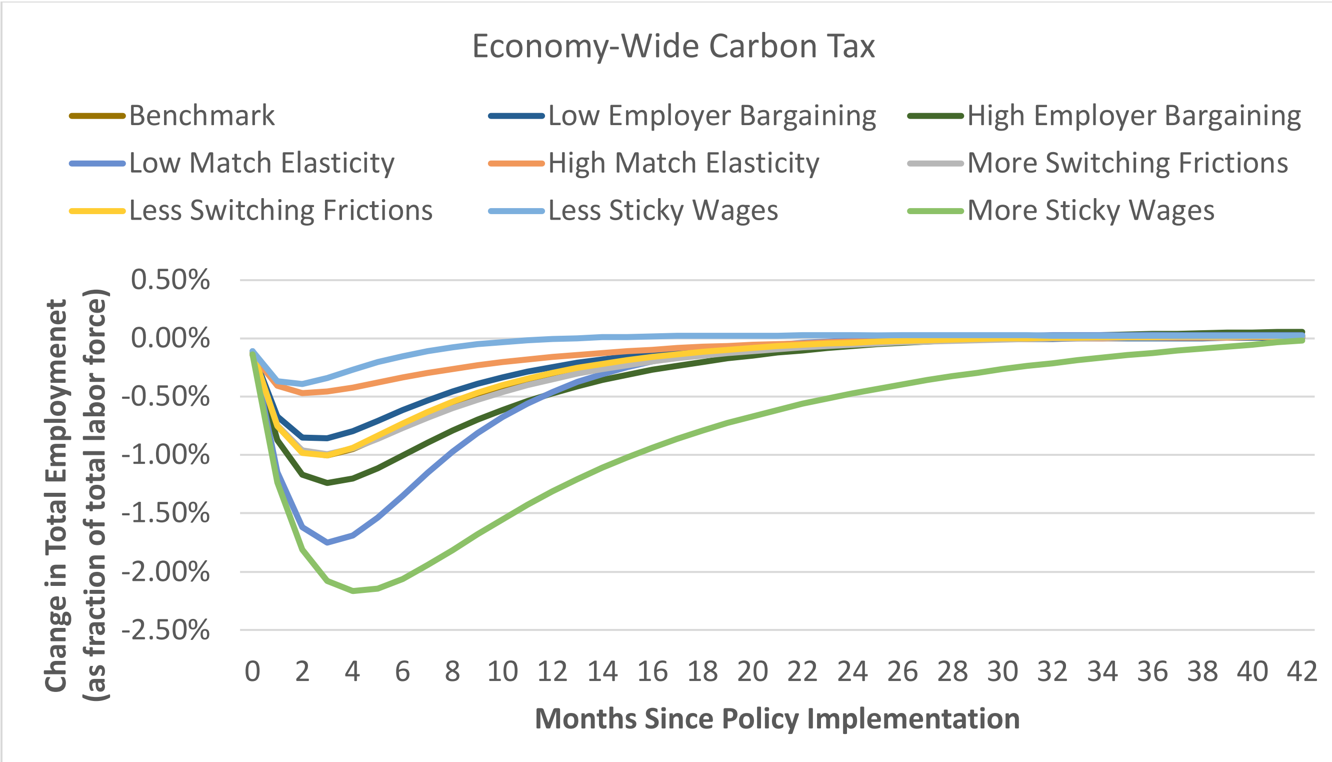
Figure 2 displays the change in total employment across all three policies and a range of alternative parameter values. Here we consider the parameter values that had important effects on steady-state employment (bargaining power and match elasticity) as well as the parameters governing industry switching frictions and wage stickiness (which matter only for the transition, and don't affect the steady state). Wage stickiness appears to play a significant role in the pattern of overall employment effects across time. In our benchmark calibration, the average firm in an industry can adjust its wages after 9 months; in our less and more sticky wage scenarios we consider expected adjustments of 4.5 and 18 months. In the initial months after the policy is implemented, the change in employment under the "more sticky" scenario is approximately as large as the change in employment under the high employer bargaining power scenario (though the change in employment in the "more sticky" scenario falls at a much steeper rate than the change in the high bargaining power scenario). A low match elasticity also implies a steep initial decline in overall employment, due to relatively smaller positive spillovers created through the match process. Finally, as discussed in Hafstead and Williams (2018), industry switching frictions largely determine the rate of reallocation of workers across sectors, but do not significantly affect the rate of change in overall employment; our results here are consistent with those findings. In our benchmark scenario, industry switching frictions are calibrated to match the probability workers switch industries (67 percent) when finding a new job. Smaller switching frictions (86 percent probability of switching industries) or larger industry switching frictions (48 percent probability of switching industries) do not significantly alter the rate of change in overall employment over time.

Comparing the durable manufacturing and economy-wide carbon tax policies, the pattern of short-run changes in overall employment are similar across all parameters: employment falls in the first few months of the policy, reaches a trough, and then increases slowly over time. The alternative parameters considered here only affect when the trough occurs, how deep the trough is, and how slowly overall employment increases as workers begin to find jobs in unregulated sectors. The performance standard, however, is different in that the pattern is not robust across parameter values. Under low bargaining power or high match elasticity (two cases with high spillover potential) overall employment immediately increases after the initial shock (job loss in coal mining) whereas under high bargaining power employment does not increase after reaching a trough in overall employment levels.

Figure 2: Changes in Overall Employment, Sensitivity Analysis





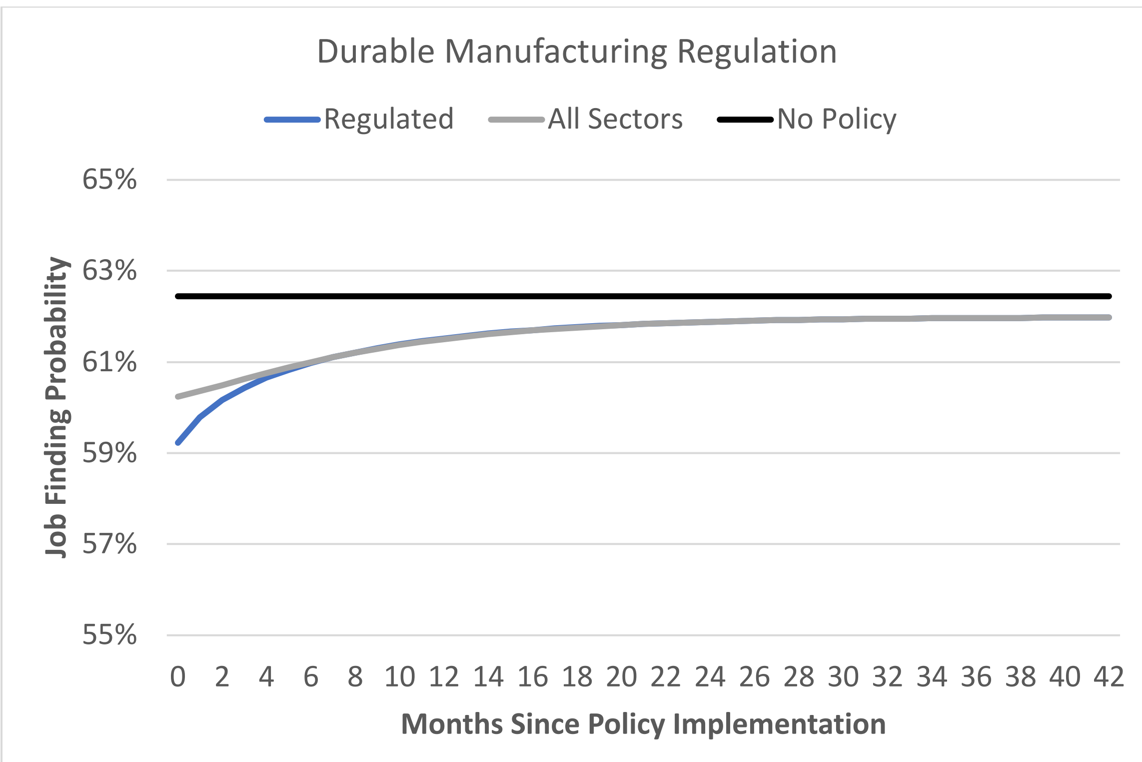


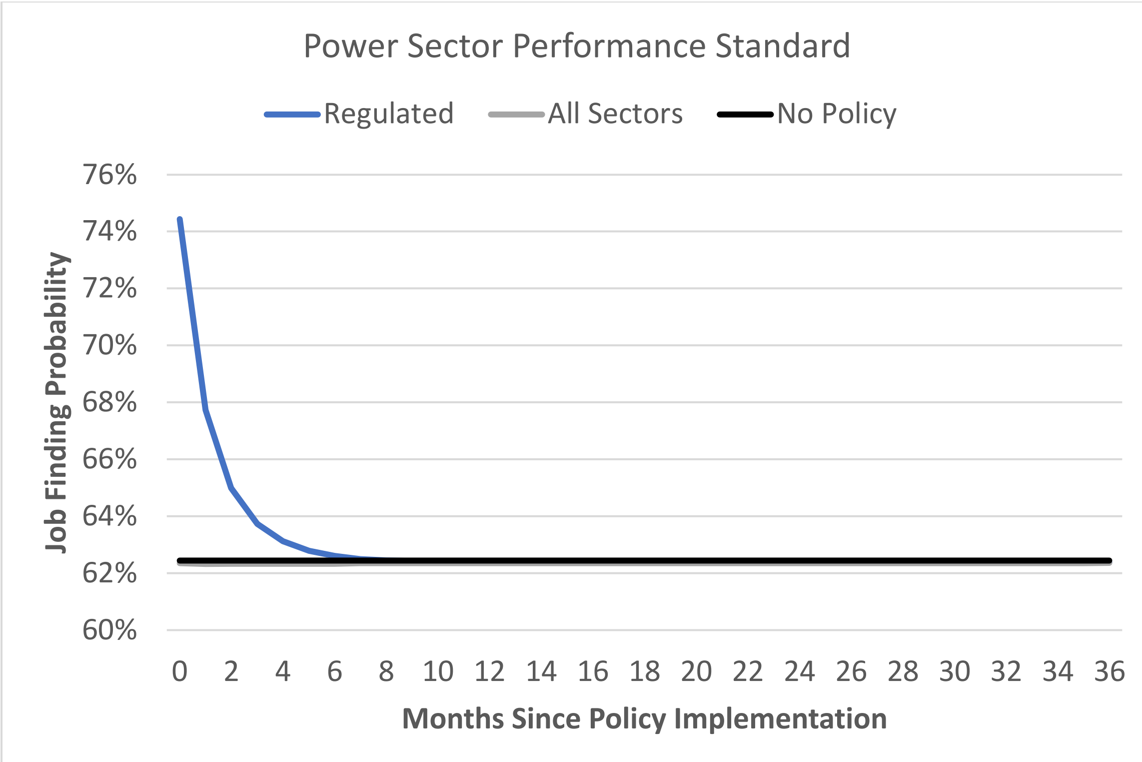
In an attempt to answer the question of *who* is affected most (or least) by environmental regulations, we evaluate the job-finding probabilities of unemployed workers who have most recently worked in a regulated sector, the average job-finding probability of all workers, and the job-finding probability in the absence of the environmental policy in Figure 3.

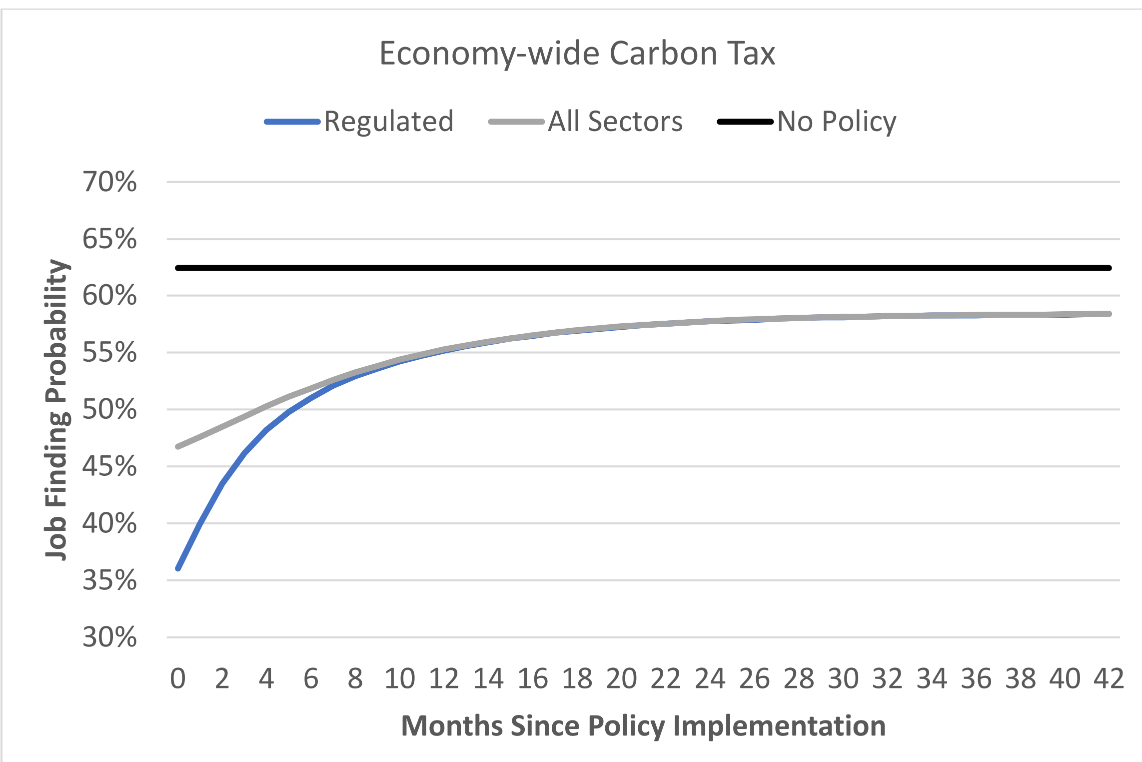
Under the power sector performance standard, the power sector immediately increases its employment in response to the implicit output subsidy included in the performance standard; unemployed workers previously employed in the power sector are much more likely to find a job in the first six months of the policy than the average unemployed worker. Overall, however, the average job-finding rate changes very little in response to the performance standard (the black "No Policy" line sits almost on top of the grey "All Sectors" line), either in the short run or the long run.

Under the durable manufacturing regulation and carbon tax, both the average worker and workers previously employed in regulated industries experience a sharp decline in job-finding rates in the first month of the policy. The job-finding rates then slowly converge over time to the new (slightly lower) long-run job-finding rates. And because the average unemployment spell is directly related to the job-finding rate, average unemployment spells are likely to be much higher for workers that separate at the time of the policy than workers that separate years after implementation. The initial change in job-finding rates is also much greater for workers previously employed in regulated sectors: unemployed workers from those industries are likely to have a much harder time finding employment than the average worker. Correspondingly, workers separating from regulated industries immediately after regulation are likely to have longer average unemployment spells than the average worker.

Figure 3: Job-Finding Rates by Types of Unemployed Workers




Power Sector Performance Standard
Regulated
All Sectors
No Policy
Job Finding Probability
76%
74%
72%
70%
68%
66%
64%
62%
60%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Months Since Policy Implementation


Economy-wide Carbon Tax
Regulated
All Sectors
No Policy
Job Finding Probability
70%
65%
60%
55%
50%
45%
40%
35%
30%
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42
Months Since Policy Implementation

Overall, our analysis of transitional labor dynamics shows that the short-run dynamics as the labor market adjusts to a new environmental regulation are crucially important. In particular, the transitional analysis shows that labor market spillovers are even more significant in the short run than the long run and the size of the short-run spillovers significantly depend on key parameters such as employer bargaining power, the match elasticity, and wage rigidity. Further, and perhaps unsurprisingly, we find that unemployed workers associated with regulated industries are much less likely than the average unemployed worker to find jobs in the period immediately after implementation of a new regulation (conditional on a negative employment effect in the regulated industry). However, because our model makes no distinction between workers besides industry, we are unable to address questions related to the transitional labor dynamics of types of workers (age, occupation, education, etc).

Finally, the analysis of transitional labor dynamics suggests that reductions in jobs in regulated (and unregulated) industries could occur through reductions in new hires exclusively or a combination of additional separations in the first period and reductions in new hires in subsequent periods, depending on the policy. For example, increased separations would likely occur in the coal mining industry if regulations were intended to reduce energy-related carbon dioxide emission, due strictly to the carbon intensity of coal. However, this analysis did not also consider pre-announced policies. In the real world, there is often some delay between substantive policy discussions, legislative votes and/or agency rule making, and the implementation of policy. In Hafstead and Williams (2019), we show that relatively short policy pre-announcement or phase-in periods can meaningfully reduce the short-run negative employment impacts, especially for workers in the most affected industries. Forward-looking firms immediately reduce hiring and thus generally avoid laying off workers. This reduces the direct short-run negative impacts on workers in regulated industries and also limits negative short-run spillovers to other industries.

7. Conclusions

In this paper, we've attempted to address a range of questions about jobs and environmental policy. To do so, we've drawn on our own recent work and on the broader economic literature, and brought some new modeling to bear on some of these questions.

7.1 Summary and Review

Sections 2 and 3 review the recent literature and provide an intuitive discussion of some of those key questions, considering both how policy affects jobs and how those effects influence the efficiency and distributional implications of the policy in question. For some of these questions, we think research provides clear answers. Policy-driven changes in jobs are mostly reallocation, rather than net job gains or losses. And given the underlying rate of job churn in the US economy, substantial job reallocation can be accomplished primarily via changes in rates of new hiring, rather than requiring increased job separations. For other questions, the answer is less clear. Does job reallocation entail a significant social cost? How important are the distributional effects caused by job reallocation? And what can we say about the effects of policy not just on the number of jobs, but on job quality? On those questions, we can outline key effects, but further research is clearly needed.

The modeling analysis in sections 4 and 5 demonstrates the strengths and weaknesses of current economic modeling in addressing questions related to jobs and environmental policy. Across a broad range of policy instruments, we've demonstrated that environmental regulation is likely to generate both negative and positive spillovers in both the short and long run. As a result, partial-equilibrium studies that rely on difference-in-difference estimators (using unregulated firms as controls) are highly unlikely to accurately estimate the effect on jobs in regulated sectors, much less the effect in unregulated sectors, even for small and targeted policies. Across the various policies considered, the modeling also demonstrates that regulation leads to a reallocation of workers across industries rather than substantial changes in overall employment levels, even for very large policies such as an economy-wide carbon tax.

7.2 Policy Takeaways

We see six key takeaway lessons for policy from the research described in this paper and our other recent work on employment effects of environmental policy (Hafstead & Williams 2018 and 2019, and Hafstead, Williams, & Chen, 2018).

First, one should be very cautious about relying on empirical job estimates or simulation modeling of job effects when making policy decisions. As discussed above, partial-equilibrium empirical studies are likely to be seriously biased. And most general-equilibrium studies use full-employment models, which cannot credibly model effects on jobs. We would even argue for caution with the results from our own modeling: while we believe it represents a substantial advance, and that the qualitative results from our modeling are reliable, much more research (especially empirical work) will be needed before one can say that specific numerical results will be accurate predictions of the effect of policy given the model sensitivities discussed previously.

Second, the effects of environmental policy on overall employment are likely to be small, especially in the long run. Even the large short-run effects of large-scale economy-wide environmental policy are much smaller in magnitude and/or duration than typical business-cycle variation in employment and unemployment.

Third, environmental policy can cause substantial job reallocation: fewer jobs in some industries and more jobs in others. In many cases, even for substantial reallocation, this reallocation will simply represent reduced hiring in the industries that are negatively affected. But depending on the scale, scope, and speed of implementation of the policy, it could also imply layoffs. This can have important distributional effects for workers in industries that lose jobs, even if the overall employment effect is insignificant.

Fourth, for a given reduction in emissions, emissions pricing has a lower overall cost and leads to higher long-run employment than intensity standards. But intensity standards imply less job reallocation. Policymakers may view less reallocation as a goal in and of itself. And, all else equal, less reallocation will generally imply lower short-term unemployment.

Fifth, the scope and scale of environmental policy is an important determinant of short-term labor market effects (on unemployment, etc.) but is less important for long-term effects. Accommodating small amounts of job reallocation with minimal disruption is relatively easy due to normal job turnover, but that becomes more and more difficult as the amount of reallocation grows. As a result, short-run labor market effects increase more than proportionately with increases in the scale and scope of policy. In the long-run, however, the type of policy can be more important for the overall effect on employment than scope or scale.

Sixth, preannouncements and phase-ins can substantially reduce short-term labor market effects, by allowing more time for the necessary reallocation to occur. While such preannouncements and phase-ins will often reduce overall economic efficiency, the reduced short-term labor-market disruption may have substantial distributional benefits as shown in Hafstead and Williams (2019).[40]

---

[40] See Williams (2012) for an analysis of environmental policy phase-ins and preannouncements.

7.3 Open Questions and Directions for Future Research

The obvious question that follows the result on the reallocation of workers is about the distributional impacts of reallocation. How do the changes in job creation and job destruction across regulated and unregulated industries affect different types of workers? Do workers simply transition from one industry into another, without much (if any) individual or aggregate welfare loss? Or is some class of worker temporarily or permanently harmed (they lose jobs and remain unemployed) while another class of worker is temporarily permanently advantaged (increasing demand for a worker class raises wages)? These questions are beyond this modeling analysis. And more recent literature such as Aubert and Chiroleu-Assouline (2019) and Fernandez Intriago (2019) have yet to fully investigate these questions, particularly in regards to the distributional impacts of reallocation of transitional labor dynamics and the question of increased separations vs. reduced hiring in response to regulation.

Our analysis is also unable to address the broader range of questions posed in Section 3, such as the social costs of job losses or reallocation (our model does not have industry-specific human capital), the relationship between efficiency and equity, job quality, or geographic heterogeneity. Clearly, more research is needed to fully address the types of questions policymakers face when considering or implementing new environmental regulations. Further, our analysis also points to the need for further research on key labor market parameters. In particular, wage formation and the flexibility of wages to adjust to policy, in both the short and long run, appears to be particularly important. And while there is some existing research on key model parameters such as match elasticity and wage bargaining, these estimates are typically based on aggregate economy-wide data and there is little solid empirical evidence on how these parameters would vary by sector. Nor is there evidence on how quickly wages adjust to new regulations.

Economists have started to bridge the gap between policymakers and academic research on the question of jobs and regulation, but there is clearly more to work that needs to be done.

References

Aubert, Diane and Mireille Chiroleu-Assouline. 2019. "Environmental Tax Reform and Income Distribution with Imperfect Heterogeneous Labour Markets." *European Economic Review* 116:60-82.

Autor, David, David Dorn, and Gordon Hanson. 2013. "The China syndrome: Local labor market effects of import competition in the United States." *American Economic Review*, *103*(6), 2121-68.

Berman, Eli, and Linda T.M. Bui. 2001. "Environmental Regulation and Labor Demand: Evidence from the South Coast Air Basin." *Journal of Public Economics* 79 (2): 265–95.

Bernstein, Paul, W. David Montgomery, Bharat Ramkrishnan, and Sugandha D. Tuladhar. "Impacts of Greenhouse Gas Regulations on the Industrial Sector." Washington, DC: NERA Economic Consulting.

Blackburn, McKinley, and David Neumark. 1992. "Unobserved Ability, Efficiency Wages, and Interindustry Wage Differentials." *The Quarterly Journal of Economics, 107*(4), 1421-1436.

Curtis, E. Mark. 2018. "Who Loses Under Power Plant Cap-and-Trade Programs? The Labor Market Effects if the NO_x Budget Trading Program" *Review of Economics and Statistics* 100(1): 151-161.

Davis, Donald and James Harrigan. 2011. "Good Jobs, Bad Jobs, and Trade Liberalization." *Journal of International Economics* 84(1): 26-36.

Davis, Steven and Till von Wachter. 2011. "Recessions and the Costs of Job Loss," *Brookings Papers on Economic Activity,* 43(2): 1-72.

Fernández Intriago, Luis A. 2019. "Carbon Taxation, Green Jobs, and Sectoral Human Capital." Working Paper, Arizona State University.

Gertler, Mark and Antonella Trigari. 2009. "Unemployment Fluctuations with Staggered Nash Wage Bargaining." *Journal of Political Economy* 117 (1): 38–86.

Gibbons, Robert and Lawrence Katz, 1992. "Does unmeasured ability explain inter-industry wage differentials?" *The Review of Economic Studies*, *59*(3), pp.515-535.

Goulder, Lawrence H., Marc A.C. Hafstead, and Roberton C. Williams III. 2016. "General Equilibrium Impacts of a Federal Clean Energy Standard." *American Economic Journal: Economic Policy* 8(2): 186-218.

Greenstone, Michael. 2002. "The Impacts of Environmental Regulations on Industrial Activity: Evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufactures." *Journal of Political Economy* 110 (6): 1175–1219.

Hafstead, Marc A.C., Roberton C. Williams III, and Yunguang Chen. 2018. "Environmental Policy, Full-Employment Models, and Employment: A Critical Analysis." Discussion Paper 18-03. Washington, DC: Resources for the Future.

Hafstead, Marc A.C. and Roberton C. Williams III. “Unemployment and Environmental Regulation in General Equilibrium.” *Journal of Public Economics* 160: 50-65.

Hafstead, Marc A.C. and Roberton C. Williams III, 2019. “Distributional Effects of Environmental Policy across Workers: A General-Equilibrium Analysis” Discussion Paper 19-21. Washington, DC: Resources for the Future.

Hall, Robert E. and Paul R. Milgrom. 2008. “The Limited Influence of Unemployment on the Wage Bargain.” *American Economic Review* 98 (4): 1653–74.

Hosios, Arthur J. 1990. “On the Efficiency of Matching and Related Models of Search and Unemployment.” *The Review of Economic Studies* 57(2): 279-298.

Jorgenson, Dale W. and Peter J. Wilcoxen. 1996. “Reducing U.S. Carbon Emissions: An Econometric General Equilibrium Assessment.” In *Reducing Global Carbon Dioxide Emissions: Costs and Policy Options*, eds. Darius Gaskins and John Weyant. Energy Modeling Forum, Stanford University, Stanford, Calif.

Krueger, Alan, and Lawrence Summers. 1988. “Efficiency Wages and the Inter-Industry Wage Structure.” *Econometrica* 56(2): 259-293.

Mangin, Sephorah and Benoit Julien. 2018. “Efficiency in Search and Matching Models: A Generalized Hosios Condition.” Becker Friedman Institute for Research in Economics Worker Paper No. 2018-10. Chicago, IL: University of Chicago.

Melitz, Marc. 2003. “The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity.” *Econometrica* 71(6): 1695-1725.

Merz, Monika. 1995. “Search in the Labor Market and the Real Business Cycle.” *Journal of Monetary Economics* 36 (2): 269–300.

Molloy, Raven, Christopher L. Smith, and Abigail Wozniak. 2014. “Declining Migration within the US: The Role of the Labor Market.” NBER Working Paper No. 20065. Cambridge, MA: National Bureau of Economic Research.

Morgenstern, Richard D., William A. Pizer, and Jhih-Shyang Shih. 2002. “Jobs versus the Environment: An Industry-Level Perspective.” *Journal of Environmental Economics and Management* 43: 412–36.

Mortensen, Dale T. and Christopher A. Pissarides. 1994. “Job Creation and Job Destruction in the Theory of Unemployment.” *Review of Economic Studies* 61 (3): 397–415.

Pissarides, Christopher A. 1985. “Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages.” *American Economic Review* 101 (6): 2823–43.

Shapiro, Carl and Joseph E. Stiglitz. 1984. “Equilibrium Unemployment as a Worker Discipline Device.” *The American Economic Review* 74(3): 433-444.

Shimer, Robert. 2010. *Labor Markets and Business Cycles*. Princeton, NJ: Princeton University Press.

———. 2013. “A Framework for Valuing the Employment Consequences of Environmental Regulation.” Working paper. University of Chicago.

Silva, Jose I. and Manuel Toledo. 2009. "Labor Turnover Costs and the Cyclical Behavior of Vacancies and Unemployment." *Macroeconomic Dynamics* 13(Supplement 1): 79–96.

Walker, W. Reed. 2013. "The Transitional Costs of Sectoral Reallocation: Evidence from the Clean Air Act and the Workforce." *Quarterly Journal of Economics* 128 (4): 1787–1835.

Williams III, Roberton C. 2012. "Setting the Initial Time-Profile of Climate Policy: The Economics of Environmental Policy Phase-Ins." D. Fullerton and C. Wolfram (eds.) *The Design and Implementation of U.S. Climate Policy*, University of Chicago Press.

Appendix: Data and Model Calibration

For a full model description, see Hafstead et al. (2018). Here, we briefly summarize data and calibration assumptions.

Data

Data on input use by sector, consumption by households, and labor input by sector are aggregated from the 2015 Bureau of Economic Analysis (BEA) Make and Use Tables from the Annual Industry Accounts.[1] Industry-specific separation rates are derived by averaging monthly total separation rates for each industry grouping in the Job Opening and Labor Turnover Survey from the Bureau of Labor Statistics. Table 1 displays these industry-specific separation rates. We calibrate energy-related carbon dioxide emissions coefficients to match emissions data from the Energy Information Administration (EIA).

Standard CGE Labor Market Parameters

The time period in the model is one month. The discount factor is calibrated to be consistent with an annual interest rate of 4 percent. The Frisch elasticity of labor supply is set equal to 1. As discussed in Hall and Milgrom (2008), this represents a middle ground between estimates found for middle-aged men and other single-earner families (0.7) and higher elasticities found for young men and married women. The tax on labor is set to 0.31, a rate that approximates the average marginal combined federal and state income tax rate plus the employee payroll tax contribution. The payroll tax is set to 0.06, representing the employer share of payroll taxes. We apply an elasticity of substitution across consumption goods to be a conservative 0.75. Elasticities of substitution in production are taken from Jorgenson and Wilcoxen (1996).

Search and Matching Parameters

---

[1] https://www.bea.gov/industry/io_annual.htm
In some cases, the level of aggregation in the two models in this paper do not correspond one to one with the summary-level industry aggregation in the BEA annual data. In these cases, the detailed-level industry aggregation in the 2007 Benchmark Accounts is used to disaggregate the summary-level data. Inputs of Oil&Gas extraction and Coal mining are revised to be consistent with EIA data on energy inputs and prices by industry.

For the search and matching labor market parameters, we follow Hafstead and Williams (2018) by assuming relatively standard search-friction parameters. We start by using a steady state unemployment rate of 5 percent and a recruiter productivity of 25 that is equal across all sectors, and we fix hours in the public sector such that employees spend one-third of their time working.[2] Following Hall and Milgrom (2008), we set the match elasticity equal to 0.5, and following Shimer (2010), we set the Nash bargaining parameter equal to 0.5.[3]

Conditional on these assumptions, we then implement a calibration procedure to solve for the disutility of work parameter, the level of unemployment benefits, the match efficiency parameter by sector, and hours per worker in the private sector that are consistent with the model equations and asymmetric separation rates across sectors.[4]

There is no systematic evidence on how often wages are adjusted and therefore we follow Gertler and Trigari (2009) and set the wage renegotiation parameter such that wages are renegotiated once every 9 months, on average. In the generalized matching function, a friction parameter (see Hafstead and Williams (2018) for details) determines the probability an unemployed worker gets rehired by the same industry that worker previously worked in. Two EPA economists, Alex Marten and Andrew Schreiber, have used data from the Current Population Survey to estimate industry-to-industry transition probabilities. This data implies that industry retention rates are low: the share of workers who change jobs but remain in the same industry varies from 6 percent (Management of Companies and Enterprises) to 58 percent (Agriculture, Forestry, Fishing, and Hunting). We choose the friction parameter such that 33 percent of unemployed workers are reemployed in the same industry they previously worked in.

Alternative Parameter Values

In the text, Tables 3 and 5 report the sensitivities of the model's steady state results to alternative parameter values. For employer bargaining power, match elasticity, and labor supply elasticity, we follow Hafstead and Williams (2018). Low and high employer bargaining sets the

---

[2] Silva and Toledo (2009) estimate that the cost of recruiting a single worker is equal to approximately 12 percent of a worker's monthly wage. Adjusting for hours (one-third), this implies that one recruiter can hire 25/3 workers per month.

[3] In models without taxes, setting the bargaining parameter equal to the match elasticity ensures the Hosios condition such that the equilibrium level of unemployment is efficient from the social planner's perspective. However, in the presence of preexisting taxes on labor, the Hosios condition does not hold even when these parameters are equal.

[4] This calibration strategy implies that hours per worker vary across sectors because of differences in marginal products of labor and that the marginal value of employment in each sector varies across sectors.

bargaining parameter at 0.25 and 0.75, respectively; low and high match elasticity sets the elasticity parameter at 0.25 and 0.75, respectively; low and high labor supply elasticity sets the Frisch elasticity of labor supply to be 0.5 and 2, respectively. The elasticity of substitution across consumption goods is decreased to 0.375 and increased to 1.5 in the lower and higher elasticity cases, respectively. For the labor-intermediate input elasticity, our central value from Jorgenson and Wilcoxen (1996) is 0.5; the elasticity is decreased to 0.3 or increased to 0.7 in our sensitivity analysis.

Figure 2 reports the transition path sensitivities. Here, we consider the same alternative values for employer bargaining and match elasticity. In the switching frictions case, we change the switching friction parameter such that 52 percent (more frictions) or 14 percent (less frictions) of unemployed workers do not change industries with their next job, numbers that are approximately equal to the rates in the industries with the least and most switching. For more and less sticky wages, we change reset the wage renegotiation parameter such that the average worker's wage changes every 18 months or 4.5 months, respectively.