Resolving Coordination Frictions in Green Labor Transitions:
Minimizing Unemployment, Costs, and Welfare Distortions

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ABSTRACT

Achieving carbon neutrality by 2050 requires substantial labor reallocation into green sectors, yet this transition is impeded by a classic chicken-and-egg coordination friction: workers hesitate due to high entry costs and uncertainty about green job availability, while firms delay green investments without assured labor supply. Current policies emphasize firm-side production subsidies but largely overlook this two-sided bottleneck, resulting in suboptimal efficiency in the labor market transition.

This paper extends the Diamond–Mortensen–Pissarides (DMP) model to quantify how strategically designed subsidies targeting both workers and firms simultaneously can improve policy efficiency by minimizing unemployment risks, reducing fiscal costs, and mitigating aggregate welfare loss during the green transition. Calibrated to U.S. data, our analysis shows that while either worker-only or firm-only subsidies alone could theoretically raise green-sector employment from 2% to the target of 14% by 2030, only a *combined* subsidy strategy effectively reduces unemployment (by up to 15%) and cuts fiscal expenditures (by over 20%) compared to one-sided approaches. Furthermore, we identify that mild increasing returns to scale in the matching function amplify these efficiency gains, further shrinking unemployment, enhancing welfare, and lowering overall funding requirements. Lastly, considering the broader macroeconomic implications of climate policy, we determine a critical threshold—a 0.6% economy-wide productivity externality from green sector—above which these green policies generate positive net welfare effects. Our results offer a clear policy insight: to accelerate green labor reallocation in a fiscally sustainable and socially efficient way, climate policy must treat both sides of the labor market as co-dependent levers—not isolated targets.

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1 Introduction

The global push toward carbon neutrality by 2050 demands a substantial reallocation of labor from carbon-intensive sectors to green industries. While many macroeconomic-climate models assume that these labor transitions occur seamlessly, real-world experiences suggest otherwise. For example, the rise of Chinese import penetration in the United States left numerous communities persistently jobless (Autor, Dorn, and Hanson, 2013), illustrating that large-scale labor reallocations can be protracted and disruptive. By analogy, the transition to a green economy may face similar challenges when shifting workers out of fossil-fuel sectors and into clean-energy firms.

Recent headlines underscore two critical dimensions of this frictional transition. On one hand, workers in carbon-intensive sectors face significant uncertainty about their future in a rapidly evolving green economy; on the other, employers in green industries are struggling to find a sufficiently skilled workforce. Unemployment among fossil-fuel workers remains a central concern in climate-policy debates (Bluedorn, Hansen, Noureldin, Shibata, and Tavares, 2023), while evidence also points to an emerging labor shortage in green sectors. For instance, LinkedIn's *Global Climate Talent Stocktake 2024* reports a 22.4% increase in green job postings between 2022 and 2023 compared to only a 12.3% growth in the green workforce (LinkedIn, 2024). Moreover, projections by the International Labour Organization and Boston Consulting Group suggest a shortfall of more than 7 million green workers by 2030 (ILO, 2019; BCG, 2023). This situation creates a classic "chicken-and-egg" dilemma: firms hesitate to expand green production without a reliable talent pool, while workers are reluctant to bear the costs of transitioning unless they are assured of abundant green jobs. Although major initiatives such as the Inflation Reduction Act (IRA) (IRA, 2023) offer firm-side production subsidies, these measures often do not address worker-specific barriers—such as training expenses, relocation costs, and uncertainty regarding stable green job prospects—thus perpetuating coordination frictions that could undermine the pace and effectiveness of decarbonization policies.

In this paper, we develop and calibrate an extended Diamond–Mortensen–Pissarides (DMP) model to evaluate three policy interventions designed to overcome these labor-market frictions: subsidies targeting firms, subsidies targeting workers, and a combined strategy. We specifically assess their capacity to boost green employment from 2% to 14% by 2030 (WorkingNation, 2024). While either worker- or firm-only incentives can, in theory, meet this target, they tend to incur significantly higher unemployment and public funding costs. By contrast, our analysis demonstrates that a *combined approach* not only reduces unemployment by up to 15% relative to one-sided incentives but also lowers the total required subsidies by more than 20%. Further quantitative analysis yields two additional policy-relevant insights. First, incorporating *mild increasing returns to scale* (IRS) in the matching process reduces overall unemployment, enhances welfare, and diminishes the tax burden needed to finance these subsidies. Second, when accounting for a *positive externality* of green jobs—an environmental benefit not captured by private returns—our model indicates that if this externality is equivalent to approximately a 0.6% gain in overall productivity, green labor subsidies can yield net welfare gains.

A key policy insight from our framework is that only a dual-approach—addressing barriers faced by both workers and firms—can mitigate the deep coordination friction stalling green labor reallocation. By simultaneously subsidizing worker transition costs and green production subsidies, policymakers reduce unemployment risks and avoid costly one-sided incentives that demand higher funding. In practical terms, this means coupling production tax credits or firm-level green subsidies with targeted support (e.g., training vouchers or relocation aid) so that labor supply and demand move in tandem.

2 Relevant Literature

The macroeconomic literature on decarbonization has advanced our understanding of how inputs reallocate between carbon-intensive and green sectors, yet it still overlooks crucial aspects of labor market dynamics. A common simplification in climate-macro frameworks is to assume frictionless movement of labor across sectors (Bilal and Stock, 2025). While this simplifies analysis, it clashes with empirical evidence of prolonged adjustment periods during structural shifts, such as the delayed workforce transitions observed in Europe's coal phase-outs and the sluggish reskilling rates in U.S. manufacturing regions. Early studies using computable general equilibrium (CGE) models provide insights into sectoral job reallocation but typically assume full employment and overlook critical labor market frictions such as unemployment, search costs, and skill mismatches (Patuelli, Nijkamp, and Pels, 2005; Sancho, 2010; Böhringer, Rivers, and Rutherford, 2013; Freire-González, 2018). Subsequent advances introduced labor market frictions (Hafstead and Williams III, 2018; Hafstead, Williams III, and Chen, 2022), yet focused narrowly on aggregate outcomes like net job creation rather than the strategic interplay between firms' hiring decisions and workers' transition incentives. There are some some empirical work in this area. Walker (2011, 2013) examines how environmental regulations like the Clean Air Act affect worker displacement at the plant level, finding modest costs relative to regulatory benefits. More recently, Shapiro and Metcalf (2023) evaluate carbon taxes in a general equilibrium framework with unemployment and find that long-run impacts hinge on green technology adoption. Conte, Desmet, and Rossi-Hansberg (2022) study spatial heterogeneity in the impacts of carbon pricing in the presence of agglomeration forces. A growing strand of research applies search-and-matching frameworks to examine how skill bottlenecks and hiring lags impede worker relocation (Gibson and Heutel, 2023; Lankhuizen, Rojas-Romagosa, and van Ewijk, 2022). Although existing work shows that even modest frictions can cause persistent unemployment during green transitions, it often overlooks a deeper coordination failure: firms are hesitant to create green jobs without a reliable labor force, and workers are reluctant to retrain without concrete job opportunities. This "chicken-and-egg" dynamic can lock both sides into waiting, delaying labor reallocation.

Our paper addresses this gap by explicitly modeling the strategic interdependence between firms and workers during the transition. We extend a search-and-matching framework to capture how their decisions are mutually contingent, and we focus on designing and evaluating policies—such as targeted subsidies to firms, workers, or both—that can break this coordination failure. Our contribution lies in showing how well-designed interventions can minimize economic disruptions, including fiscal costs, unemployment, and aggregate welfare losses. By emphasizing the role of coordination, we offer a framework for promoting smoother, more efficient labor transitions in the shift to a low-carbon economy.

3 Model

We begin with a static version of the modified Diamond–Mortensen–Pissarides (DMP) model to characterize equilibrium outcomes amidst the coordination frictions present in the labor reallocation challenges of the green transition. This static framework focuses on understanding how subsidies and costs influence equilibrium in segmented labor markets. Building on these insights, the dynamic version of the model examines equilibrium dynamics over time, enabling analysis of total unemployment, policy funding requirements, and aggregate welfare—central issues in current green transition policy discussions.

3.1 Static Model: DMP Framework

The static model provides a simplified environment to analyze how workers and firms interact within segmented labor markets in response to various climate policies. The focus is on the multiplicity of the equilibria that arises because of the underlying coordination friction, the effects of subsidies and costs on equilibrium outcomes, and the efficiency condition in this set-up.

3.1.1 Physical Environment

We develop a one-shot version of the Diamond–Mortensen–Pissarides (DMP) model (Pissarides, 2000), extended to include two sectors: green and non-green. The labor force is normalized to 1. The labor market is segmented into green and non-green sectors, denoted by subscripts g and n, respectively. A continuum of unemployed workers receive an unemployment benefit z, and both workers and firms decide optimally which market to enter.

Firms that enter either sector incur a recruiting cost c. Green firms receive a production subsidy τ_g, while non-green firms face a tax τ_n, which funds the subsidies.[1] On the worker side, entry into the green sector requires paying a flow cost κ_g, which is partially offset by a subsidy policy parameter s_g. The effective cost of entry for workers in the green sector becomes $(1 - s_g)\kappa_g$, where $s_g \in [0, 1]$ represents the fraction of κ_g subsidized. In contrast, entry into the non-green sector involves no cost.

The matching function in each sector $j \in \{g, n\}$ is:

$$f(u_j, v_j) = \delta_j \left(\frac{u_j v_j}{u_j + v_j} \right)^{1-\psi} (u_j v_j)^{\psi}, \quad \psi \in [0, 1], \tag{1}$$

where u_j and v_j are the number of unemployed workers and vacancies, respectively, and δ_j is a sector-specific matching efficiency parameter. For simplicity, we assume constant returns to scale ($\psi = 0$)[2]. The matching probabilities are given by:

$$\alpha_{wj} = \frac{v_j}{u_j + v_j}, \quad \alpha_{fj} = \frac{u_j}{u_j + v_j}, \quad j \in \{g, n\}. \tag{2}$$

After matches are formed, wages are determined through Nash bargaining, where workers have bargaining power η. Other parameters, including the unemployment benefit z and matching efficiency δ_j, are identical across sectors.

This framework captures a critical coordination problem inherent to the green labor

[1] We have also solved a version of the model where all sectors are taxed to fund green subsidies. However, including both taxation and subsidies for green firms adds complexity without altering the main results. For clarity, we focus on the version where only non-green sectors are taxed.

[2] We also analyzed the model with increasing returns to scale (IRS) later in the dynamic version of the model that yields interesting policy-relevant responses.

market. Firms benefit from subsidies (τ_g), which encourage their entry into the green sector, while workers bear the effective entry cost $(1-s_g)\kappa_g$. This misalignment of costs and incentives creates interdependence in decision-making: firms are reluctant to enter the green sector unless they anticipate a sufficient pool of workers, while workers hesitate to transition without confidence in job availability. These dynamics reflect a coordination game, where the entry decisions of firms and workers depend on their beliefs about the actions of the other. For instance, firms expecting insufficient worker entry may reduce vacancies, further discouraging workers from entering the green sector. Conversely, strong expectations of mutual participation can lead to successful sector growth. On solving the model, we will soon see how the multiple equilibria arise depending on these beliefs.

By incorporating this coordination friction, the model enables analysis of how different targeted subsidies (τ_g, s_g) can align firm and worker incentives to resolve these frictions and achieve green employment targets effectively.

3.1.2 Workers

Workers receive an unemployment benefit z when they are unemployed. If they choose to enter the green sector, they incur the effective training cost $(1-s_g)\kappa_g$, while entry into the non-green sector is free. The expected utility for workers in each sector is:

$$\begin{aligned}&\text{Green: } -(1-s_g)\kappa_g+\alpha_{wg}w_g+(1-\alpha_{wg})z,\\&\text{Non-Green: } \alpha_{wn}w_n+(1-\alpha_{wn})z.\end{aligned}$$

In equilibrium, workers must be indifferent between entering the two sectors:

$$-(1-s_g)\kappa_g+\frac{v_g}{\pi+v_g}w_g+\left(1-\frac{v_g}{\pi+v_g}\right)z=\frac{v_n}{1-\pi+v_n}w_n+\left(1-\frac{v_n}{1-\pi+v_n}\right)z. \quad (3)$$

3.1.3 Firms

Firms in each sector post vacancies and hire workers until the expected profit equals the recruiting cost c. The free entry conditions for the two sectors are:

$$\begin{aligned}&\text{Green: } c=\alpha_{fg}(y+\tau_g-w_g),\\&\text{Non-Green: } c=\alpha_{fn}(y-\tau_n-w_n).\end{aligned}$$

Here, y represents the productivity of workers, which is assumed to be the same in both sectors, while subsidies (τ_g) and taxes (τ_n) create differences in net returns.

3.2 Wage Determination (Nash Bargaining)

Wages in the green sector are determined by the Nash solution to

$$\max_{w_g} (w_g - z)^{\theta} \left[(y + \tau_g) - w_g\right]^{1-\theta},$$

leading to

$$w_g = \theta\,(y + \tau_g) \;+\; (1-\theta)\,z.$$

For the non-green sector, the presence of a tax τ reduces the firm's surplus from $(y + \tau_g)$ to $(y - \tau_n)$:

$$w_n = \theta\,\big(y - \tau_n\big) \;+\; (1-\theta)\,z.$$

Full derivations appear in Appendix A.

3.2.1 Equilibrium

An equilibrium comprises of wages (w_g, w_n), measure of green and traditional vacant firms (v_g, v_n), measure of green and traditional unemployed and employed workers (u_g, u_n, e_g, e_n), fraction of unemployed workers and vacant firms respectively who choose to be green π, and a green production subsidy τ_g given a flat tax τ that satisfy the above listed equilibrium conditions.

Proposition 1. *There are multiple equilibria with following properties*[3]*:*

- $\exists$ *a corner equilibrium where* $\pi = 0$ *and there are no jobs/production in the economy is green.*
- $\exists$ *a corner equilibrium where* $\pi = 1$ *and all jobs/production in the economy is green.*
- *For CRS case with* $\psi = 0$, $\lim_{\pi\to 0^+} G(\pi) > 0 > G(0)$ *and* $\lim_{\pi\to 1^-} G(\pi) < 0 < G(1)$, *i.e. the corner equilibria are not robust to small trembles, but* $\exists$ *at least one robust interior equilibrium.*

[3] In a different context centered on asset liquidity, (Geromichalos, Herrenbrueck, and Lee, 2023) investigates how agents select among various asset markets when faced with random liquidity demands, deriving a solution that mirrors the characterization presented here.

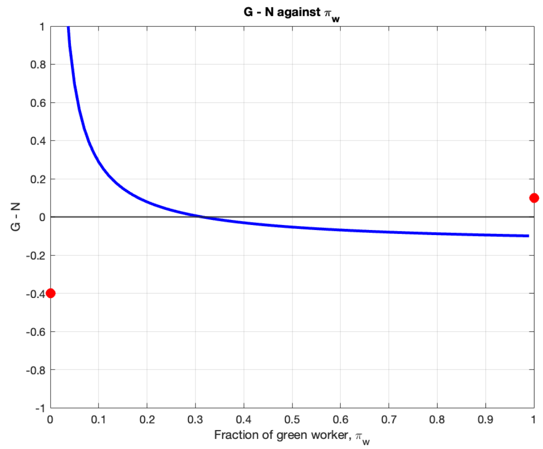

Figure 1. Multiplicity of equilibria (CRS) in the one-shot version

3.3 Comparative Statics

We can conduct comparative statics in the one-shot model to illustrate the main policy channels. As shown in Figure 5, decreasing workers' entry cost increases the equilibrium entry into the green sector, while Figure 6 shows that increasing firm subsidies similarly raises green sector entry.

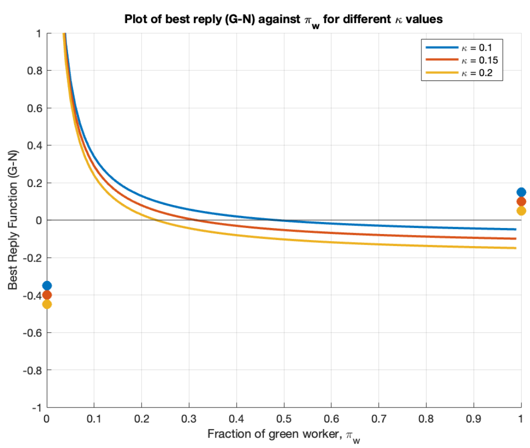

Figure 2. Increasing training cost decreases equilibrium entry into green sector

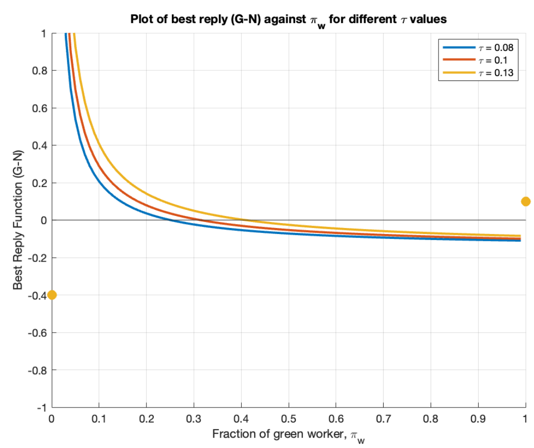

Figure 3. Increasing green subsidy increases equilibrium entry into green sector

Overall, the one-shot framework clearly illustrates the essential role of incentivizing *both* workers and firms. Before we extend our analysis to a dynamic setting, the static version provides a transparent context to first examine efficiency conditions, particularly highlighting how environmental externalities interact with the traditional search externality.

3.4 Social Efficiency and Policy Implications [4]

The decentralized equilibrium may be inefficient due to two key factors: (1) standard search-match frictions and (2) uninternalized positive externalities from green job creation. We characterize efficiency through the lens of a social planner who internalizes these effects.

3.4.1 Planner's Problem Without Environmental Externalities

When green jobs generate no external benefits ($\phi = 0$), the planner maximizes total surplus:

$$\max_{\{\pi, v_g, v_n\}} \quad L(\pi, v_g, v_n) = \underbrace{\pi \frac{v_g}{\pi + v_g}(y-z)}_{\text{Green matches}} + \underbrace{(1-\pi)\frac{v_n}{(1-\pi)+v_n}(y-z)}_{\text{non-green matches}} - c\,(v_g + v_n) - \pi\,\kappa_g. \tag{4}$$

Proposition 2. *Without externalities ($\phi = 0$), the social planner's solution is a corner with $\pi^* = 0$: all workers go non-green if $\kappa_g > 0$. No interior solution arises.*

Proof in Appendix B.1.

This stark result arises because green entry costs κ_g dominate any private productivity gains, making non-green sector dominance efficient.

3.4.2 Positive Externalities and Policy Design

When green jobs generate external benefits $\phi > 0$ per match, the social planner chooses $(\pi,\ v_g,\ v_n)$ to maximize the flow surplus:

$$\max_{\{\pi, v_g, v_n\}} \quad L(\pi, v_g, v_n) = \underbrace{\pi \frac{v_g}{\pi + v_g}\big[(y-z)+\phi\big]}_{\text{Green matches with externality } \phi > 0} + \underbrace{(1-\pi)\frac{v_n}{(1-\pi)+v_n}(y-z)}_{\text{non-green matches}} - c\,(v_g + v_n) - \pi\,\kappa_g, \tag{5}$$

When we consider competitive equilibrium where each green match generates an external benefit that accrues to *all* workers, this externality is not internalized by individual workers or firms, leading to an underinvestment in green jobs.

Proposition 3. *In presence of the positive environmental externalities ($\phi > 0$), the efficiency requires:*

[4] All the proofs and derivations are in Appendix B.

1. *Hosois condition in both sector:* $\eta^{g*} = \frac{v_g^*}{\pi^* + v_g^*} = \eta^{n*} = \frac{v_n^*}{1-\pi^* + v_n^*} = \theta$.

2. *Firm-side alignment:* $\phi = \frac{\tau_g + \tau_n}{1-\theta}$.

3. *Workers-side alignment:* $\phi = \frac{\tau + \tau^g}{\theta(1-s^g)}$.

Proof in Appendix B.2.

In addition to the standard hosois condition, we now also have alignment conditions for both firms and workers. These conditions must be satisfied for a feasible set of policy instruments (τ, τ_g, s_g) to decentralize the efficient allocation. Importantly, note that the policy parameters are interdependent and not all combinations are feasible. Comparative statics in the one-shot model highlight these policy channels. To my knowledge, this paper is the first to explicitly explore the efficiency condition within a search-match model featuring environmental externalities.

We now turn to the dynamic version of the model with unemployment dynamics.

3.5 Dynamic Model: Extended DMP Framework

Building on the static framework, the dynamic model incorporates time and introduces sectoral dynamics for a more comprehensive analysis of green labor market transitions. This dynamic extension enables the study of unemployment dynamics, funding requirements, and overall welfare analysis—key concerns for achieving a smooth green transition.

3.5.1 Physical Environment

Time is discrete and divided into periods $t = 0, 1, 2, \ldots$. Agents discount future payoffs at rate β. The labor force remains normalized to 1, and the segmentation of green and non-green sectors persists. Existing jobs are destroyed at rate λ, creating ongoing vacancies that firms aim to fill. The government continues to provide a production subsidy τ_g for green firms, funded by a tax τ_n on non-green firms. Workers entering the green sector face a recurring cost κ_g, partially offset by a subsidy s_g, while entry into the non-green sector remains costless.

3.5.2 Matching Function

The matching function and probabilities are same as in the static model:

$$f(u_j, v_j) = \delta_j \left(\frac{u_j v_j}{u_j + v_j} \right)^{1-\psi} (u_j v_j)^{\psi}, \quad \psi \in [0, 1].$$

With the CRS case of $\psi = 0$, $\alpha_{wj} = \frac{v_j}{u_j + v_j}, \quad \alpha_{fj} = \frac{u_j}{u_j + v_j}, \quad j \in \{g, n\}$.

3.5.3 Discussion of Modeling Choices and Empirical Relevance

Before we move on to the full quantitiative analysis, we want to discuss some modeling choices.

Definition of Green Jobs

Defining green jobs is essential for capturing their dynamics in the labor market. Broad definitions, such as those provided by the International Labour Organization (ILO), describe green jobs as "decent jobs that contribute to preserving or restoring the environment" (International Labor Organization, 2024). Task-specific classifications based on databases like O*NET refine this further by focusing on job-specific contributions to the green transition (Vona, Marin, Consoli, and Popp, 2018; Vona, Marin, and Consoli, 2019; Consoli, Marin, Marzucchi, and Vona, 2018). However, these approaches often fail to include emerging occupations like "solar panel installer" relevant to the green economy. This paper adopts the definition from Curtis and Marinescu (2022), which encompasses all employment in renewable energy sectors, including solar, wind, and electric vehicles. This definition aligns well with both empirical and policy contexts, as energy-related activities account for 70% of U.S. anthropogenic emissions (World Nuclear Association, 2024), and recent policies such as the Inflation Reduction Act (IRA) focus heavily on renewable energy and EV sectors (Bushnell and Smith, 2024).

Entry Costs for Workers: κ_g

Worker entry costs in the green sector (κ_g) represent the structural barriers faced by workers transitioning to green jobs. These costs are modeled broadly to reflect various frictions:

- *Training Costs.* Green jobs often demand new technical and managerial skills, requiring reskilling even in related occupations (Vona et al., 2018; Consoli et al., 2018).

- *Relocation Costs.* Green jobs are geographically dispersed, necessitating relocation from fossil fuel hubs to regions rich in renewable resources (Brookings Institute, 2022; Johnson and Schulhofer-Wohl, 2019; Lim et al., 2023).
- *Unionization and Benefits.* Fossil fuel jobs typically offer stronger union representation and better benefits compared to green jobs, deterring workers from transitioning (Emden and Murphy, 2019; Pollin, Garrett-Peltier, et al., 2020).
- *Uncertainty and Behavioral Barriers.* Perceived instability in green jobs and behavioral factors such as risk aversion or sunk costs further impede transitions (Villas-Boas, 2021; Dixit and Rob, 1994).

Although the model remains agnostic about the exact composition of κ_g, its inclusion reflects the real-world barriers to green labor market flexibility and the economics of the model goes through any of those assumptions.

Subsidy to Firms: τ_g

The Inflation Reduction Act (IRA) provides substantial production and investment tax credits (τ_g) to incentivize renewable energy deployment, with credits ranging from \$5/MWh to \$32/MWh based on criteria such as labor conditions and domestic content (Bistline et al., 2023). These subsidies have accelerated green technology adoption but have largely overlooked workforce development (Walsh, 2023). By modeling τ_g, the framework captures the financial incentives driving renewable energy expansion while highlighting the gap in policies targeting the labor market.

Why Policy-Driven Solutions?

The green transition relies heavily on government policy, unlike past structural changes such as globalization or automation, which were primarily market-driven. While gradual technological change allows labor markets to adapt naturally (Pissarides, 2000), the clean energy transition demands the rapid reallocation of millions of workers by 2050 to meet decarbonization targets. This accelerated timeline creates bottlenecks and coordination challenges, as polluting job losses may outpace the creation of green jobs. Historical transitions, such as the Soviet Union's economic restructuring, illustrate the risks of unmanaged labor shifts (Oei et al., 2020). Policy interventions, including subsidies and training programs, are therefore critical to aligning labor supply and demand, resolving coordination frictions, and ensuring a smooth and equitable transition.

3.5.4 Analysis of the Model

We now analyze the model by deriving the equilibrium conditions in the labor market. We examine how green production subsidies and worker entry costs affect equilibrium outcomes, focusing on the Beveridge curves, value functions, and wage determination. This allows us to derive policy implications for achieving optimal green sector employment.

3.5.5 Beveridge Curves

We start with the derivation of the Beveridge curves, which describe the relationship between unemployment and job vacancies in both the green and non-green sectors. Figure 4 helps illustrate the worker flows between the various states in the economy.

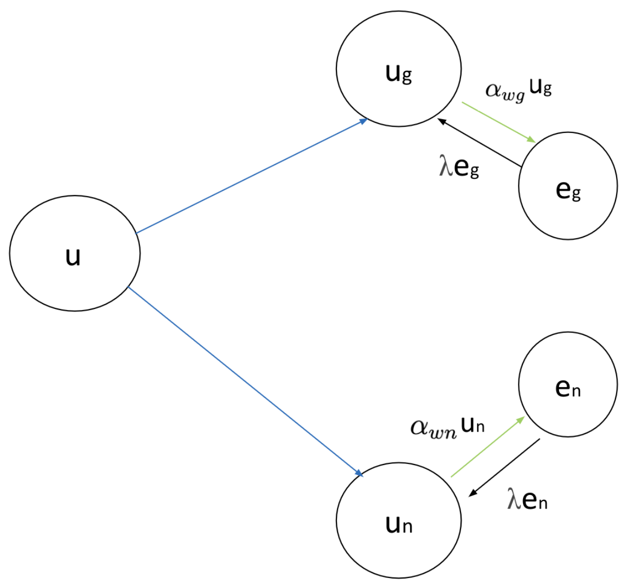

Figure 4. Worker flows between unemployment and employment in both sectors.

As shown in the diagram, unemployed workers (u) can choose to enter either the green (u_g) or non-green (u_n) sector, where they may find a job and transition to employment (e_g and e_n, respectively). Similarly, employed workers in both sectors face the possibility of job destruction at rate λ, which returns them to unemployment. Equating the flows in and out of each state gives us the following relationships in steady state:

- For the green sector:

$$\alpha_{wg} u_g = \lambda e_g \tag{6}$$

- For the non-green sector:
$$\alpha_{wn} u_n = \lambda e_n \tag{7}$$

- The total labor force is normalized to 1:
$$u_g + u_n + e_g + e_n = 1 \tag{8}$$

These Beveridge curves will play a critical role in understanding the dynamics of the labor market under different climate policies, as the green and non-green sectors respond differently to government interventions such as subsidies and taxes.

3.5.6 Firms' Value Functions and Free Entry

Firms choose between entering the green or non-green sectors based on expected profits, which is analogous to free entry in both sectors. Let V represent the value of a vacant firm, and $V_g(J_g)$ and $V_n(J_n)$ be the values of vacant (filled) jobs in the green and non-green sectors, respectively.

- **Vacant Firms**: A firm posts a vacancy in either sector, choosing the one with higher expected returns:
$$V = \max\{V_g, V_n\}$$
The value of a vacancy in the green sector is:
$$V_g = -c + \beta \left[\alpha_{fg} J_g + (1 - \alpha_{fg}) V\right],$$
and in the non-green sector:
$$V_n = -c + \beta \left[\alpha_{fn} J_n + (1 - \alpha_{fn}) V\right],$$
where c is the recruiting cost, and α_{fg} and α_{fn} are the probabilities of filling vacancies in the green and non-green sectors, respectively.

- **Filled Firms**: Once matched, a firm produces output p. Green firms also receive a subsidy τ_g, while non-green firms pay a tax τ_n:
$$J_g = (1 + \tau_g)p - w_g + \beta \left[\lambda V + (1 - \lambda) J_g\right],$$
$$J_n = p - w_n - \tau_n + \beta \left[(1 - \lambda) J_n + \lambda V\right],$$

where w_g and w_n are wages, and λ is the job destruction rate.

In equilibrium, firms enter the sector where expected profits are highest, balancing wages, subsidies, and taxes. In this framework, allowing firms to choose between green and non-green sector is analogous to allowing for free entry in both sector which is what I do hereon. Free entry in both sectors implies that in equilibrium $V_g = V_n = V = 0$, therefore, we can state the free entry conditions as:

$$c = \beta \alpha_{fg} J_g \tag{9}$$

$$c = \beta \alpha_{fn} J_n \tag{10}$$

Imposing free entry to the value functions for filled firms also gives:

$$J_g = (1 + \tau_g)p - w_g + \beta(1 - \lambda)J_g \tag{11}$$

$$J_n = p - w_n - \tau_n + \beta(1 - \lambda)J_n \tag{12}$$

3.5.7 Workers' Value Functions and Optimal Sector Choice

Now, let's examine the value functions of workers in different states. In our model, workers make an endogenous decision to enter either the green or non-green sector, optimizing their choice based on expected utility. This decision forms part of the equilibrium, where the expected utilities for both sectors must equalize. Let U represent the value of an unemployed worker, with $U_g(W_g)$ and $U_n(W_n)$ denoting the values of unemployed (employed) workers in the green and non-green sectors, respectively.

- **Unemployed Workers**: An unemployed worker chooses the sector that maximizes their expected utility. The overall value of being unemployed is given by:

  $$U = \max\{U_g, U_n\}$$

  The value of being unemployed in the green sector is:

  $$U_g = z - (1 - s_g)\kappa_g + \beta \left[\alpha_{wg} W_g + (1 - \alpha_{wg})U_g\right], \tag{13}$$

  and in the non-green sector:

  $$U_n = z + \beta \left[\alpha_{wn} W_n + (1 - \alpha_{wn})U_n\right], \tag{14}$$

where z is the unemployment benefit, $(1 - s_g)\kappa_g$is the effective entry cost, and α_{wg} and α_{wn} are the probabilities of finding a job in the green and non-green sectors, respectively.

- **Employed Workers**: Once employed, a worker earns wage w_j in their respective sector. If a job is destroyed at rate λ, the worker returns to unemployment. The value of being employed in the green sector is:

$$W_g = w_g + \beta\left[(1-\lambda)W_g + \lambda U\right], \tag{15}$$

and in the non-green sector:

$$W_n = w_n + \beta\left[(1-\lambda)W_n + \lambda U\right], \tag{16}$$

where w_g and w_n are the wages in the green and non-green sectors, respectively, and λ is the job destruction rate.

- **Workers' Optimal Entry**: Workers choose which sector to enter based on the expected utility in each sector. Combining the value functions for unemployed and employed workers in each sector, we get:

$$U_g = \frac{[1-\beta(1-\lambda)](z-(1-s_g)\kappa_g) + \beta\alpha_{wg}w_g}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))} \text{ and } U_n = \frac{[1-\beta(1-\lambda)]z + \beta\alpha_{wn}w_n}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}.$$

In equilibrium, workers are indifferent between entering the green and non-green sectors, so the following condition must hold:

$$U_g = U_n,$$

$$\Longrightarrow \frac{[1-\beta(1-\lambda)](z-(1-s_g)\kappa_g) + \beta\alpha_{wg}w_g}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))} = \frac{[1-\beta(1-\lambda)]z + \beta\alpha_{wn}w_n}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}. \tag{17}$$

This condition ensures that workers optimally choose their sector based on expected payoffs.

With the value functions of all economic agents fully detailed, we now turn our attention to analyzing the bargaining challenges across various meeting scenarios.

3.5.8 Bargaining Problems

Non-green sector: Let us start by describing the terms of trade in a meeting between a firm and an unemployed in the non-green sector. Solving the standard Nash bargaining problem leads to the following condition that must be satisfied:

$$(1-\eta)(W_n - U_n) = \eta J_n, \tag{18}$$

This condition indicates that each party receives a share of the total surplus from the match, proportional to their bargaining power. (Recall that η represents the worker's bargaining power.) Substituting the value functions J_n, U_n, and W_n from above equations (7), (9), and (11) respectively, we can express the wage in the non-green sector as follows:

$$w_n = \frac{(1-\eta)z[1-\beta(1-\lambda)] + \eta(p-\tau_n)[1-\beta(1-\lambda-\alpha_{wn})]}{1-\beta(1-\lambda-\eta\alpha_{wn})}. \tag{19}$$

See Appendix C.1 for the derivation. This establishes a relationship between the wage of workers in non-green sector and their job arrival rate α_{wn}, which depends on firm entry and market tightness. A key insight here is that w_n decreases as the tax imposed on non-green firms τ_n increases, introducing a new dynamic into the wage determination for non-green workers.

Green sector: Next, consider the bargaining problem between a firm and a worker in the green sector, where workers incur real costs to enter the sector, while firms receive government subsidies when they match with workers and produce. Again, we have:

$$(1-\eta)(W_g - U_g) = \eta J_g. \tag{20}$$

Similar to before, we can substitute the value functions J_g, U_g, and W_g from above equations (6), (8), and (10) respectively to derive the wage in the green sector to be:

$$w_g = \frac{(1-\eta)(z-(1-s_g)\kappa_g)[1-\beta(1-\lambda)] + \eta p(1+\tau_g)[1-\beta(1-\lambda-\alpha_{wg})]}{1-\beta(1-\lambda-\eta\alpha_{wg})}. \tag{21}$$

See Appendix C.2 for the derivation. Again, we derive a relationship between the wage for green sector workers and their job arrival rate α_{wg}, which is influenced by firm entry and market conditions. Here, τ_g represents the green production subsidy to firms, κ_g is the entry cost for workers in the green sector, and s_g is the entry cost subsidy to workers in the green sector. Notice that an increase in τ_g and s_g leads to an increase in w_g, while a rise in κ_g causes w_g to decrease.

3.5.9 Government's Budget Constraint

The government's budget constraint requires that tax revenues from the non-green sector fully finance the subsidies provided to green workers and firms. In other words, the tax imposed on all non-green firms must balance the total subsidies granted to green firms (via production subsidies) and to workers (through green worker subsidies). This relationship is captured by the following equation:

$$\tau_n = \frac{\tau_g \cdot \alpha_{fg} v_g + s_g \cdot u_g}{\alpha_{fn} \cdot v_n}, \tag{22}$$

where τ_n represents the tax on non-green firms, τ_g is the subsidy for green firms, s_g is the subsidy for green workers, u_g is unemployed pool of workers in the green sector, α_{fg} and α_{fn} are the firm matching rates in the green and non-green sectors, respectively, and v_g and v_n are the vacancies in the green and non-green sectors.

3.5.10 Definition of Steady State Equilibrium

A steady state equilibrium in our model consists of wages (w_g, w_n) for workers in the green and non-green sectors, a green production subsidy τ_g, a flat tax τ_n paid by non-green firms, measures of vacancies in both sectors (v_g, v_n), and measures of employed and unemployed workers in the various states (u_g, u_n, e_g, e_n). The subsidy and tax satisfy the government budget constraint (22). The remaining equilibrium variables satisfy the free entry condition (9, 10), the wage curve (21, 19), three Beveridge curves (6, 7, 8), and optimal entry condition (17), after one replaces the various α's with the respective matching probabilities given in (2).

4 Calibration

We calibrate the benchmark model to the U.S. economy in 2022, with a focus on the green transition in the labor market. A period in the model corresponds to one month in calendar time. Several parameters that have direct empirical counterparts are set exogenously. The discount factor β is set to 0.9959, consistent with an annual interest rate of 5%. Worker productivity p is normalized to 1, and the matching function exhibits constant returns to scale (CRS) with $\psi = 0$. In line with Shimer (2005), the worker's bargaining power η is set to 0.72, and the non-employment benefit z is set to 40% of average productivity.

We use several key data targets to guide our calibration. First, the wage premium for green sector workers relative to non-green sector workers is targeted at 2%, based on estimates from the Fund (2022)[5]. Additionally, the green employment share is set at 2% of the total U.S. workforce, consistent with 2022 estimates from the Energy Information Administration (EIA) ((EIA), 2024) and calculation of employment share in the renewable sector[6]. The hiring likelihood ratio, which compares the probability of workers with green skills being hired relative to those without such skills, is calibrated to 29%, as reported by LinkedIn (2023). Labor market tightness, measured as the ratio of job vacancies to unemployed workers, is set at 1.868 based on data from FRED Blog (2024). Finally, the unemployment rate is targeted at 3.5%, consistent with Bureau of Labor Statistics (BLS) data from 2023 (of Labor Statistics (BLS), 2023). In addition, we account for the green tax subsidy, which ranges from 0.1% of U.S. GDP, based on estimates from the Inflation Reduction Act (IRA) of 2022.[7]

The model's performance in matching these calibration targets is summarized in the table below:

Data Moments	Model Values	Target Values
Wage Premium (Green/Non-green)	1.018	1.02
Employment Share (Green)	0.0195	0.0195
Hiring Likelihood Ratio (Green/Non-green)	1.29	1.29
Labor Market Tightness	1.868	1.868
Unemployment Rate	3.5%	3.5%

Table 1: Model performance in matching the calibration targets.

The internally calibrated parameters that allow the model to replicate green and non-green labor market dynamics are given in the table 2.

The calibrated baseline model captures the essential dynamics of the U.S. labor market in the context of the green transition in 2022. With these parameters, we are now equipped to tackle the key question of this paper: *How can the U.S. increase green employment from 2% to 14% of total U.S. jobs by 2030?* As projected by WorkingNation (2024), green jobs are expected to grow to nearly 24 million by 2030, comprising 14% of the U.S. workforce. This calibration enables us to analyze the necessary policy interventions to reach this ambitious target and assess the best policy in terms of welfare, unemployment

[5]This estimate is on the lower end compared to other studies, which find the green wage premium to be around 4% in VoxEU (2023) and approximately 20% in Curtis and Marinescu (2022).

[6]In 2022, there were 3.3 million renewable energy jobs ((E2), 2023) and 212.4 million total jobs ((REA), 2024), resulting in $e_g/e \approx 2\%$.

[7]This estimate is based on the range of production tax credits for renewable energy generation, which vary from \$5/MWh to \$32/MWh depending on eligibility factors (Bushnell and Smith, 2024). With 0.91 billion MWh of renewable electricity generated in 2022 (of Energy, 2023) and a U.S. GDP of 25.44 trillion USD (Bank, 2022), the green production credits range from approximately 0.01788% to 0.11445% of total GDP.

Parameter	Description	Calibrated Value
c	Vacancy creation cost	0.1640
λ	Separation rate	0.0188
δ_g	Matching efficiency in green sector	0.8826
δ_n	Matching efficiency in non-green sector	0.7961
κ_g	Green entry barrier cost	0.7246

Table 2: Internally calibrated parameters.

outcomes, and funding requirement.

5 Quantitative Analysis

The U.S. aims to increase green employment from 2% to 14% of total U.S. jobs by 2030, as per (WorkingNation, 2024), where green jobs are projected to expand to nearly 24 million. This quantitative analysis uses the calibrated model to explore the channels through which we can achieve this ambitious goal. We focus on two key policy levers: reducing the green sector entry cost for workers and increasing green production subsidies for firms.

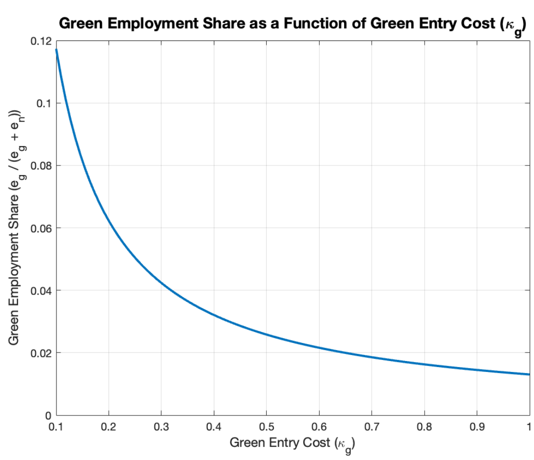

Figure 5. Decreasing green sector entry cost increases green employment share.

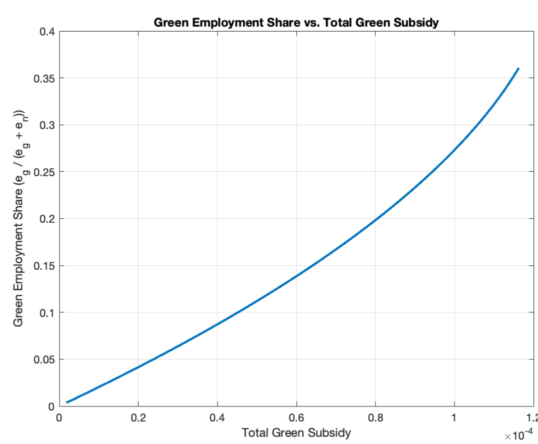

Figure 6. Increasing green subsidy increases green employment share.

The figure above shows how reducing worker entry costs, κ_g (using the worker subsidy s_g) increases the green employment share, while raising production subsidies to firms, τ_g, similarly boosts the equilibrium green employment share. Both policies are effective independently (see Appendix 3.3), but their combined impact, as demonstrated in the comparative statics of the one-shot model, is even more substantial.

5.1 Achieving the Green Employment Target

Table 3 compares the effectiveness of various policy strategies in achieving the green employment target. The policies analyzed include: (i) maintaining a fixed per-firm green subsidy while subsidizing worker entry costs through taxes collected from non-green firms, (ii) fixing the total green subsidy across all green firms and reducing worker entry costs, recognizing the distinction between per-firm subsidies and aggregate subsidies, (iii) holding worker entry costs constant while increasing the green firm subsidy, and (iv) simultaneously reducing worker entry costs and increasing firm subsidies.

Table 3: Comparison of Different Approaches to Achieve Green Employment Target

Equilibrium	**Per worker cost subsidy**	**Per firm green subsidy**	**Total green firm subsidy**	**Green emp. share**
Reduce workers' cost, increase firm subsidy	**0.889514**	**0.256501**	**6.4500e-04**	**14%**
Fix per firm subsidy, reduce workers' cost	0.905630	0.0272	6.8000e-05	14%
Fix total firm subsidy, reduce workers' cost	0.900243	0.0036	8.9074e-06	14%
Fix workers' cost, increase per firm subsidy	0	2.52733	0.0063	14%
Baseline	0	0.0272	8.9074e-06	2%

The baseline scenario reveals that only 2% of U.S. jobs are currently in the green sector. All other rows demonstrate how various combinations of subsidies targeting worker entry costs and green firm production can achieve the target of 14% green employment. This exercise highlights the effectiveness of individual subsidies as well as a combined approach in reaching the desired green employment target. The next section evaluates these policy mixes to identify the optimal strategy in terms of welfare, funding requirements, and unemployment outcomes.

5.2 Key Results: Welfare, Funding, and Unemployment

Table 4 presents the outcomes of each policy combination, comparing their effects on welfare, funding requirements, and aggregate unemployment. The combined strategy of reducing worker entry costs while increasing green subsidies emerges as the most effective approach, delivering the highest welfare, the lowest funding requirement, and the largest reduction in unemployment.

The combined strategy offers a welfare gain of 0.20% compared to fixing per firm subsidies while reducing worker entry costs, and 0.21% compared to fixing total green subsidies with reduced worker entry costs. It achieves a 7.48% reduction in funding requirements relative to fixed per firm subsidies with reduced entry costs, and a 24.03% reduction compared to fixed worker entry costs with increased firm subsidies. Aggregate

Table 4: Welfare, Funding Requirement, and Aggregate Unemployment

Equilibrium	Welfare	Funding Req.	Agg. Unemployment
Reduce workers' cost, increase firm subsidy	**0.9617**	**0.004801**	**0.044954**
Fix per firm subsidy, decrease workers' cost	0.9598	0.005173	0.047638
Fix total green subsidy, decrease workers' cost	0.9597	0.005190	0.047842
Fix workers' cost, increase firm subsidy	0.9554	0.006300	0.053251
Baseline	0.9675	8.9074e-06	0.035000

unemployment decreases by 5.84% compared to fixed per firm subsidies with reduced entry costs, and by 15.76% compared to fixed worker entry costs with higher subsidies.

In summary, reducing worker entry costs and increasing green subsidies is the most efficient policy combination, maximizing welfare, minimizing funding burdens, and significantly lowering unemployment. It is important to note that *all* of these welfare levels remain below the baseline scenario (0.9675). This is because our standard DMP framework does not, in these experiments, internalize the potential positive externalities of green employment. Consequently, the green reallocation somewhat reduces overall productivity as long as it is purely policy-driven and does not yield environmental or social benefits in the model's welfare function. In the next section, we explicitly include such externalities to see under which conditions these interventions can deliver a net welfare improvement.

5.3 Increasing Returns to Scale (IRS) in the Matching Function

We also investigate what happens if the matching function exhibits *mild increasing returns to scale* (IRS), i.e. $\psi > 0$ (inspired by non-constant returns to scale in labor market in (Martellini and Menzio, 2020)). Table 5 illustrates that even a small positive ψ amplifies our channels: reduces unemployment further, slightly raises welfare, and lowers the total subsidies needed to meet the same green employment target. In essence, the feedback loop between firm vacancies and worker entry is amplified: once a critical mass of green workers and firms emerges, matches become easier to form, reinforcing the momentum of the transition.

Table 5: Impacts of Increasing Returns to Scale (IRS) on Unemployment, Welfare, and Subsidy

$\psi_n = \psi_g$	Total Unemployment ↓	Welfare ↑	Total Subsidy ↑
0.000	0.044954	0.9617	0.004801
0.001	0.042896	0.9628	0.004337
0.010	0.040815	0.9641	0.003678
0.020	0.040924	0.9644	0.003628

Interpretation: Because IRS magnifies the payoff of a larger (worker, firm) pool in one sector, both unemployment and funding needs decline faster once a "critical mass" of green participants is established. This dynamic further supports the notion that coordinated policies targeting both sides of the market can quickly shift the system away from low-green equilibria.

5.4 Welfare Analysis with Green Production Externality

In the standard DMP framework, aggregate welfare is calculated without considering the positive externalities of green sector expansion. This omission explains why all policy interventions yield lower welfare compared to the baseline scenario, despite achieving the green employment target. To address this limitation, we extend the standard DMP welfare function to include a positive production externality from green employment. This addition allows us to quantify how large the externality needs to be for the green sector expansion to result in welfare improvements.

5.4.1 Welfare Function with Externality

The standard DMP welfare function is given by:

$$W_0 = p(e_g + e_n) + (z - \kappa_g)u_g + zu_n - c(v_n + v_g),$$

where e_g and e_n are employment levels in the green and non-green sectors, u_g and u_n are unemployed workers in the green and non-green sectors, κ_g is the worker entry cost in the green sector, and c is the recruiting cost for vacancies.

To incorporate the positive externality, we modify the welfare function as follows:

$$W_\phi = p(e_g + e_n) + (z - \kappa_g)u_g + zu_n - c(v_n + v_g) + \phi e_g,$$

where $\phi > 0$ represents the externality parameter, capturing the environmental benefit generated by each unit of employment in the green sector.

5.4.2 Results and Threshold Analysis

The welfare gain or loss from policy interventions depends critically on the value of ϕ. Figure 7 illustrates the relationship between welfare and the externality parameter ϕ. The analysis shows that welfare under the combined policy intervention (W_ϕ) equals baseline welfare (W_0) when $\phi = 0.0432$. This implies that the positive externality parameter needs to be bigger than $\phi = 0.0432$ for green sector expansion to improve welfare relative to the baseline.

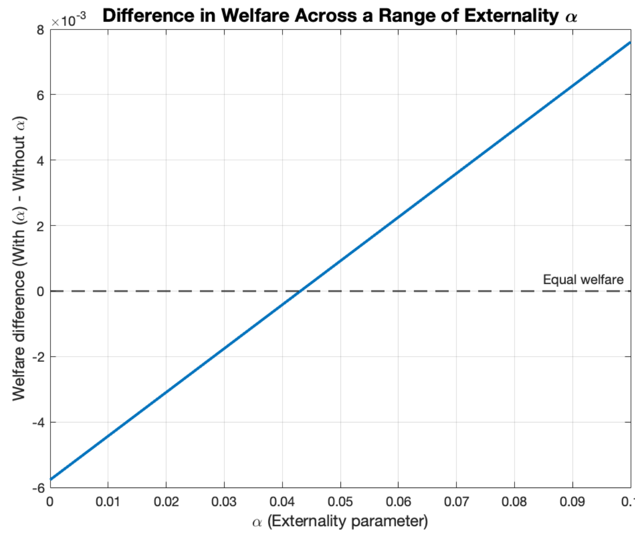

Figure 7. Welfare Gain/Loss as a Function of Externality Parameter ϕ

5.4.3 Productivity Equivalence of the Externality Threshold

To contextualize the threshold $\phi = 0.0432$, we compute its productivity equivalence. This involves finding the percentage increase in productivity (p) required to achieve the same welfare gain as the externality. The results indicate that $\phi = 0.0432$ corresponds to a 0.5957% increase in productivity. Thus, subsidizing the green sector becomes welfare-improving if the environmental externality is equivalent to a 0.6% boost in productivity. This provides a novel approach for quantifying environmental externalities and integrating them into labor market models like DMP.

In summary, the results highlight the importance of explicitly accounting for environmental externalities in welfare analysis. This adjustment not only enriches the standard

DMP framework but also help quantify the aggregate welfare benefits of green sector expansion.

6 Economic Insights

Our findings highlight that a *combined approach*—subsidizing both worker entry costs and firm hiring—most effectively addresses the fundamental coordination friction stalling green transition. By reducing worker entry costs, the policy alleviates supply-side barriers, while firm subsidies reduce hiring costs and boost labor demand. Together, these interventions create a self-reinforcing dynamic that improves matching efficiency, minimizes funding requirements, and maximizes welfare. Isolated policies fail to address this coordination, requiring far larger interventions to achieve comparable outcomes, making them less efficient and fiscally burdensome.

Even a *mild* form of increasing returns to scale (IRS) in matching further accelerates the transition: as soon as workers and firms begin to coordinate, the matching rate improves endogenously, trimming fiscal costs and strengthening the incentive for both sides to go green. However, without incorporating any positive externality from green employment, the overall welfare in these policy scenarios still falls short of the no-policy baseline, reflecting the distortionary costs of pushing workers and firms into a new sector. Once an environmental externality is introduced above a modest threshold, the net benefits surpass baseline welfare. Consequently, properly accounting for environmental and social gains is critical for evaluating such green labor policies on net economic grounds.

7 Conclusion

This paper highlights the central role of policy design in improving the efficiency of the green labor transition. Achieving carbon neutrality requires not only reallocating labor toward greener sectors but doing so in a way that minimizes unemployment, reduces fiscal costs, and improves overall welfare. In this paper, we emphasize a key message: *incentivizing both firms and workers simultaneously is essential to overcoming coordination frictions and maximizing policy efficiency*.

Using an extended Diamond–Mortensen–Pissarides framework calibrated to U.S. labor market data, we show that one-sided policies—targeting either firms or workers alone—leave critical frictions unresolved. Firms delay opening vacancies without a reliable labor supply, and workers hesitate to enter the green sector without clear job opportunities. This misalignment results in higher unemployment, larger fiscal burdens, and greater welfare loss. In contrast, a combined policy approach that reduces worker entry costs and increases firm-side subsidies breaks this chicken-and-egg stalemate. It generates self-reinforcing matching efficiency, substantially raising green employment (from 2% to 14% by 2030), while simultaneously reducing unemployment and funding needs compared to one-sided interventions. Mild increasing returns to scale further enhance these gains. Moreover, when accounting for the broader macroeconomic benefits of green employment—captured as a modest productivity externality—this coordinated strategy delivers net welfare improvements. The results offer a clear policy insight: to accelerate green labor reallocation in a fiscally sustainable and socially efficient way, climate policy must treat both sides of the labor market as co-dependent levers—not isolated targets.

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A One-shot DMP Model

In this section, we present key derivations for the one-shot (static) version of model.

A.1 Bargaining

Green Sector: In the green sector, wages are determined through Nash bargaining between workers and firms. The solution to the bargaining problem is:

$$\max_{w_g}(w_g - z)^{\theta}(y + \tau_g - w_g)^{1-\theta},$$
$$\implies \frac{\theta}{w_g - z} = \frac{1-\theta}{y + \tau_g - w_g},$$
$$\therefore w_g = \theta(y + \tau_g) + (1-\theta)z.$$

The wage in the green sector depends positively on the firm's productivity y and the green subsidy τ_g, while the worker's outside option is captured by z.

Non-Green Sector: In the non-green sector, the wage bargaining process is analogous, except for the presence of the tax τ imposed on firms. The resulting wage is:

$$\max_{w_n}(w_n - z)^{\theta}(y - \tau_n - w_n)^{1-\theta},$$
$$\implies \frac{\theta}{w_n - z} = \frac{1-\theta}{y - \tau_n - w_n},$$
$$\therefore w_n = \theta(y - \tau_n) + (1-\theta)z.$$

Here, the wage in the non-green sector is lower due to the tax burden τ on firms.

A.2 Interior Equilibrium with Both Sectors Operating

In equilibrium, firms and workers optimally choose their sectors. The endogenous variables are π, v_g, v_n, w_g, w_n, and τ. The system of equilibrium conditions is:

$$
\begin{aligned}
c &= \frac{\pi}{\pi + v_g}(y + \tau_g - w_g), \\
c &= \frac{1-\pi}{1-\pi+v_n}(y - \tau_n - w_n), \\
w_g &= \theta(y + \tau_g) + (1-\theta)z, \\
w_n &= \theta(y - \tau_n) + (1-\theta)z, \\
\tau_n \frac{(1-\pi)}{(1-\pi)+v_n}\, v_n \; &= \; \tau_g \frac{\pi}{\pi + v_g}\, v_g + s_g\, \pi\, \kappa_g, \\
\pi &= \begin{cases} 0 & \text{if } G < N, \\ \in (0,1) & \text{if G = N,} \\ 1 & \text{if } G > N. \end{cases}
\end{aligned}
$$

$$
G = -(1-s_g)\kappa_g + \frac{v_g}{\pi + v_g} w_g + \left(1 - \frac{v_g}{\pi + v_g}\right) z \quad \text{and} \quad N = \frac{v_n}{1-\pi+v_n} w_n + \left(1 - \frac{v_n}{1-\pi+v_n}\right) z.
$$

A.3 Corner Equilibria

The model also allows for corner equilibria where only one sector operates.

A.3.1 Corner Equilibrium: $\pi = 0$, $v_g = 0$

It must be the case that $v_g = 0$ iff $\pi = 0$. In this case, only non-green labor market operates with $v_n > 0$ and the matching probabilities become:$\alpha_{wg} = \alpha_{fg} = 0, \alpha_{wn} = \frac{v_n}{1+v_n}$, and $\alpha_{fn} = \frac{1}{1+v_n}$. The equilibrium conditions are:

$$
\begin{aligned}
v_g &= 0, \\
c &= \frac{1}{1+v_n}(y - \tau_n - w_n), \\
w_g &= \theta(y + \tau_g) + (1-\theta)z, \\
w_n &= \theta(y - \tau_n) + (1-\theta)z, \\
\tau_n &= \tau_g = 0, \\
\pi &= 0, \text{with } G < N,
\end{aligned}
$$

where G and N are the expected utilities in the green and non-green sectors, respectively:

$$G = -\kappa_g + z, \quad N = \frac{v_n}{1+v_n} w_n + \left(1 - \frac{v_n}{1+v_n}\right) z, \quad \text{and} \quad G - N = -(1-s_g)\kappa_g - \frac{v_n}{1+v_n}(w_n - z) < 0.$$

A.3.2 Corner Equilibrium: $\pi = 1$, $v_n = 0$

It must be the case that $v_n = 0$ iff $\pi = 1$. In this case, only green labor market operates with $v_g > 0$ and the matching probabilities become:$\alpha_{wn} = \alpha_{fn} = 0, \alpha_{wg} = \frac{v_g}{1+v_g}$, and $\alpha_{fn} = \frac{1}{1+v_g}$. The equilibrium conditions are:

$$\begin{aligned}
&v_n = 0, \\
&c = \frac{1}{1+v_g}(y + \tau_g - w_g), \\
&w_g = \theta(y + \tau_g) + (1-\theta)z, \\
&w_n = \theta(y - \tau_n) + (1-\theta)z, \\
&\tau_n = \tau_g = 0, \\
&\pi = 1, \text{with } G > N,
\end{aligned}$$

where G and N are the expected utilities in the green and non-green sectors, respectively:

$$G = -\kappa_g + \frac{v_g}{1+v_g} w_g + \left(1 - \frac{v_g}{1+v_g}\right) z, \quad N = z, \quad \text{and} \quad G - N = -(1-s_g)\kappa_g + \frac{v_g}{1+v_g}(w_g - z) > 0.$$

B Social Planner's Problem and Efficiency

B.1 Model Without Externality

We begin by considering a benchmark case without environmental externalities ($\phi = 0$), where the only difference between green and non-green sectors is that green-sector workers must pay an entry cost κ_g.

B.1.1 Social Planner's Problem

The social planner chooses the share of workers entering the green sector, π, and vacancies posted in each sector, $\{v_g, v_n\}$, to maximize the total flow surplus:

$$L(\pi, v_g, v_n) = \pi \frac{v_g}{\pi + v_g}(y - z) + (1-\pi)\frac{v_n}{(1-\pi) + v_n}(y - z) - c(v_g + v_n) - \pi\,\kappa_g. \tag{A.1}$$

The first two terms represent match surplus in green and non-green sectors, respectively; the third is the vacancy posting cost, and the last term is the total entry cost borne by green workers.

B.1.2 First-Order Conditions for Vacancies

For the green sector (holding π fixed), differentiating the relevant portion of (A.1) with respect to v_g yields:

$$\frac{\partial}{\partial v_g}\left[\pi\frac{v_g}{\pi+v_g}(y-z)-cv_g\right]=0 \quad \Rightarrow \quad \frac{\pi}{\pi+v_g}=\sqrt{\frac{c}{y-z}}.$$

By symmetry, the FOC for the non-green sector yields:

$$\frac{1-\pi}{(1-\pi)+v_n}=\sqrt{\frac{c}{y-z}}.$$

Hence, in the efficient allocation, the match probabilities are equal across sectors:

$$\frac{v_g}{\pi+v_g}=\frac{v_n}{(1-\pi)+v_n}.$$

B.1.3 First-Order Condition with Respect to π (Worker Allocation)

Using the envelope theorem and differentiating (A.1) with respect to π, we obtain:

$$\left(\frac{v_g}{\pi+v_g}\right)^2(y-z)-\left(\frac{v_n}{(1-\pi)+v_n}\right)^2(y-z)=\kappa_g.$$

This condition equates the marginal benefit of allocating an additional worker to green with its marginal cost κ_g. But if the match probabilities are equal across sectors (as shown above), the left-hand side equals zero, which contradicts $\kappa_g>0$. Thus, the planner never chooses an interior π.

B.1.4 Insight

In the absence of externalities, the planner always chooses a corner solution: no green workers if $\kappa_g>0$. This also implies that in competitive equilibrium, green jobs will not arise unless policy intervenes. Without a social benefit to green production, there's no rationale for reallocating workers toward green jobs.

B.2 Model With Positive Externality ($\phi > 0$)

We now introduce an environmental externality: each green match generates an additional benefit ϕ that accrues to all workers.

B.2.1 Planner's Objective with Externality

With $\phi > 0$, the planner's objective becomes:

$$\max_{\{\pi, v_g, v_n\}} L(\pi, v_g, v_n) = \underbrace{\pi \frac{v_g}{\pi + v_g} \left[(y - z) + \phi\right]}_{\text{Green matches with externality } \phi > 0} + \underbrace{(1 - \pi) \frac{v_n}{(1 - \pi) + v_n} (y - z)}_{\text{non-green matches}} - c\,(v_g + v_n) - \pi\,\kappa_g,$$

Vacancy Posting Conditions. Differentiating with respect to v_g and v_n, we obtain the efficient match probabilities:

$$\frac{v_g}{\pi + v_g} = 1 - \sqrt{\frac{c}{(y - z) + \phi}}, \quad \frac{v_n}{(1 - \pi) + v_n} = 1 - \sqrt{\frac{c}{y - z}}.$$

Worker Allocation Condition. The FOC with respect to π gives:

$$\left(\frac{v_g}{\pi + v_g}\right)^2 ((y - z) + \phi) - \left(\frac{v_n}{(1 - \pi) + v_n}\right)^2 (y - z) = \kappa_g.$$

This yields an interior solution as long as ϕ is large enough relative to κ_g.

B.2.2 Competitive Market with Policy Instruments

In the decentralized equilibrium, workers are indifferent between sectors if:

$$-(1 - s_g)\kappa_g + \frac{v_g}{\pi + v_g}(w_g - z) = \frac{v_n}{(1 - \pi) + v_n}(w_n - z),$$

where s_g is a subsidy offsetting green entry costs. Wages are determined via Nash bargaining:

$$w_g = \theta(y + \tau_g) + (1 - \theta)z, \quad w_n = \theta(y - \tau_n) + (1 - \theta)z.$$

Firms enter until expected profits equal the posting cost c:

$$c = \frac{\pi}{\pi + v_g}(y + \tau_g - w_g), \quad c = \frac{1 - \pi}{(1 - \pi) + v_n}(y - \tau_n - w_n).$$

Solving these conditions yields the match probabilities and equilibrium green employment:

$$E_g = \pi \left(\frac{v_g}{\pi + v_g} \right) = \pi \left(1 - \frac{c}{(1-\theta)(y + \tau_g - z)} \right).$$

Solving for the share of workers entering the green sector π^* in the competitive market yields the key relation with only policy variables but no externality term ϕ:

$$\pi^* : \kappa_g = \frac{\theta(\tau_n + \tau_g)}{1 - s_g}.$$

Discussion

Since the external benefit ϕE_g is common to both employed and unemployed payoffs, it cancels out in worker decision-making. Consequently, the competitive equilibrium does not fully internalize the externality, leading to underinvestment in green jobs. A Pigouvian policy, involving subsidies s_g for workers and τ_g for firms, is needed to align the competitive equilibrium with the socially optimal allocation.

B.2.3 Efficiency Conditions: Comparing Planner vs. Market

To decentralize the planner's solution, the competitive equilibrium must replicate the planner's allocation $\{\pi^*, v_g^*, v_n^*\}$. We compare the worker and firm indifference conditions under both frameworks.

1. Firm Indifference Condition

Planner's condition:

$$c = \left[\frac{\pi}{\pi + v_g} \left(1 - \frac{v_g}{\pi + v_g} \right) - \frac{1 - \pi}{1 - \pi + v_n} \left(1 - \frac{v_n}{1 - \pi + v_n} \right) \right] (y - z) + \phi \cdot \frac{\pi}{\pi + v_g} \left(1 - \frac{v_g}{\pi + v_g} \right) = 0.$$

Market condition:

$$c = \left[\frac{\pi}{\pi + v_g}(1 - \theta) - \frac{1 - \pi}{1 - \pi + v_n}(1 - \theta) \right] (y - z) + \frac{\pi}{\pi + v_g}\tau_g + \frac{1 - \pi}{1 - \pi + v_n}\tau = 0.$$

2. Worker Indifference Condition

Planner's condition:

$$\kappa_g = \left[\left(\frac{v_g}{\pi + v_g} \right)^2 ((y - z)) - \left(\frac{v_n}{(1 - \pi) + v_n} \right)^2 (y - z) \right] + \phi \cdot \left(\frac{v_g}{\pi + v_g} \right)^2.$$

Market condition:

$$\kappa_g = \frac{\theta(\tau + \tau_g)}{1 - s_g}.$$

Conditions for Decentralization

To ensure efficiency (i.e., the planner's allocation is a competitive equilibrium), we require both the workers and firms indifference condition to concide and the conditions are:

1. Hosois condition in both sector: $\eta^{g*} = \frac{v_g^*}{\pi^* + v_g^*} = \eta^{n*} = \frac{v_n^*}{1-\pi^* + v_n^*} = \theta$.
2. Firm-side alignment: $\phi = \frac{\tau_g + \tau_n}{1-\theta}$.
3. Workers-side alignment: $\phi = \frac{\tau + \tau^g}{\theta(1-s^g)}$.

In addition to the standard hosois condition, we now also have alignment conditions for both firms and workers. These conditions must be satisfied for a feasible set of policy instruments (τ, τ_g, s_g) to decentralize the efficient allocation. Importantly, note that the policy parameters are interdependent and not all combinations are feasible.

B.3 Government Budget Constraint

In steady state, total taxes collected from non-green-sector matches must cover the cost of green subsidies:

$$\tau_n \cdot \frac{(1-\pi)}{(1-\pi) + v_n} v_n = \tau_g \cdot \frac{\pi}{\pi + v_g} v_g + s_g \, \pi \, \kappa_g.$$

This constraint ties together the fiscal viability of the subsidy design with the labor market allocation.

C Bargaining Problem in the Dynamic Model

C.1 Bargaining Problem in non-green Jobs

Proof. The bargaining problem in non-green jobs is: $(1-\eta)(W_n - U_n) = \eta J_n$.

C.1.1 Derivation of the wage in the non-green sector w_n

Let's start with the value function of unemployed workers in the non-green sector U_n from equation (14):

$$U_n = z + \beta \left[\alpha_{wn} W_n + (1-\alpha_{wn}) U_n\right] \implies U_n = \frac{z}{1-\beta(1-\alpha_{wn})} + \frac{\beta \alpha_{wn} W_n}{1-\beta(1-\alpha_{wn})} \quad \text{(A.2)}$$

Not, let's turn to the value function of employed workers in the non-green sector W_n from equation (16):

$$
\begin{aligned}
&W_n = w_n + \beta\left[(1-\lambda)W_n + \lambda U_n\right] \\
&\implies \left[1-\beta(1-\lambda)\right]W_n = w_n + \beta\lambda U_n \\
&\implies \left[1-\beta(1-\lambda)\right]W_n = w_n + \beta\lambda\left[\frac{z}{1-\beta(1-\alpha_{wn})} + \frac{\beta\alpha_{wn}W_n}{1-\beta(1-\alpha_{wn})}\right] \\
&\implies W_n = \frac{w_n}{1-\beta(1-\lambda)} + \frac{\beta\lambda}{1-\beta(1-\lambda)}\left[\frac{z}{1-\beta(1-\alpha_{wn})} + \frac{\beta\alpha_{wn}W_n}{1-\beta(1-\alpha_{wn})}\right] \\
&\implies W_n\left[1 - \frac{\beta^2\lambda\alpha_{wn}}{(1-\beta(1-\lambda))(1-\beta(1-\alpha_{wn}))}\right] = \frac{w_n}{1-\beta(1-\lambda)} + \frac{\beta\lambda}{1-\beta(1-\lambda)}\left[\frac{z}{1-\beta(1-\alpha_{wn})}\right] \\
&\implies W_n\left[\frac{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}{(1-\beta(1-\lambda))(1-\beta(1-\alpha_{wn}))}\right] = \frac{w_n}{1-\beta(1-\lambda)} + \frac{\beta\lambda}{1-\beta(1-\lambda)}\left[\frac{z}{1-\beta(1-\alpha_{wn})}\right] \\
&\implies W_n = \frac{w_n(1-\beta(1-\alpha_{wn})) + \beta\lambda z}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}
\end{aligned}
$$

Now, let's plug this back to the equation (A.2):

$$
\begin{aligned}
&U_n = \frac{z}{1-\beta(1-\alpha_{wn})} + \frac{\beta\alpha_{wn}W_n}{1-\beta(1-\alpha_{wn})} \\
&= \frac{z}{1-\beta(1-\alpha_{wn})} + \frac{\beta\alpha_{wn}}{1-\beta(1-\alpha_{wn})}\left[\frac{w_n(1-\beta(1-\alpha_{wn})) + \beta\lambda z}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}\right] \\
&= \frac{z}{1-\beta(1-\alpha_{wn})} + \frac{\beta\alpha_{wn}w_n}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))} \\
&+ \frac{\beta^2\lambda\alpha_{wn}z}{(1-\beta)(1-\beta(1-\alpha_{wn}))(1-\beta(1-\alpha_{wn}-\lambda))} \\
&= \frac{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda)) + \beta^2\lambda\alpha_{wn}}{(1-\beta)(1-\beta(1-\alpha_{wn}))(1-\beta(1-\alpha_{wn}-\lambda))}\cdot z + \frac{\beta\alpha_{wn}}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}\cdot w_n \\
&= \frac{(1-\beta(1-\lambda))(1-\beta(1-\alpha_{wn}))}{(1-\beta)(1-\beta(1-\alpha_{wn}))(1-\beta(1-\alpha_{wn}-\lambda))}\cdot z + \frac{\beta\alpha_{wn}}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}\cdot w_n \\
&\implies U_n = \frac{(1-\beta(1-\lambda))\cdot z + \beta\alpha_{wn}\cdot w_n}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}
\end{aligned}
$$

Subtracting U_n from W_n above, we get:

$$
\begin{aligned}
&\implies W_n - U_n = \left[\frac{w_n(1-\beta(1-\alpha_{wn})) + \beta\lambda z}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}\right] - \left[\frac{(1-\beta(1-\lambda))\cdot z + \beta\alpha_{wn}\cdot w_n}{(1-\beta)(1-\beta(1-\alpha_{wn}-\lambda))}\right] \\
&\therefore W_n - U_n = \left[\frac{w_n - z}{1-\beta(1-\alpha_{wn}-\lambda)}\right].
\end{aligned}
$$

Going back to the bargaining problem,

$$(1-\eta)(W_n - U_n) = \eta J_n$$

Plugging in the equations from above and plugging the value of J_n from (12), we get:

$$
\begin{aligned}
&(1-\eta)\left[\frac{w_n - z}{1-\beta(1-\alpha_{wn}-\lambda)}\right] = \eta\frac{p-\tau_n-w_n}{1-\beta(1-\lambda)} \\
&\implies w_n\left[\frac{1-\eta}{1-\beta(1-\alpha_{wn}-\lambda)} + \frac{\eta}{1-\beta(1-\lambda)}\right] = \frac{\eta(p-\tau_n)}{1-\beta(1-\lambda)} + \frac{(1-\eta)z}{1-\beta(1-\alpha_{wn}-\lambda)} \\
&\implies w_n = \frac{(1-\eta)z[1-\beta(1-\lambda)] + \eta(p-\tau_n)[1-\beta(1-\lambda-\alpha_{wn})]}{[1-\beta(1-\lambda-\eta\alpha_{wn})]}
\end{aligned}
$$

i.e. $\tau_n \uparrow \implies w_n \downarrow$. □

C.2 Bargaining Problem in Green Jobs

Proof. The bargaining problem in green jobs is: $(1-\eta)(W_g - U_g) = \eta J_g$.

C.2.1 Derivation of the wage in the green sector w_g

Let's start with the value function of unemployed workers in the green sector U_g from equation (13):

$$U_g = z - (1-s_g)\kappa_g + \beta\left[\alpha_{wg}W_g + (1-\alpha_{wg})U_g\right] \implies U_g = \frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})} + \frac{\beta\alpha_{wg}W_g}{1-\beta(1-\alpha_{wg})} \tag{A.3}$$

Not, let's turn to the value function of employed workers in the green sector W_g from equation (15):

$$
\begin{aligned}
& W_g = w_g + \beta\left[(1-\lambda)W_g + \lambda U_g\right] \\
& \implies \left[1-\beta(1-\lambda)\right] W_g = w_g + \beta\lambda U_g \\
& \implies \left[1-\beta(1-\lambda)\right] W_g = w_g + \beta\lambda\left[\frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})} + \frac{\beta\alpha_{wg}W_g}{1-\beta(1-\alpha_{wg})}\right] \\
& \implies W_g = \frac{w_g}{1-\beta(1-\lambda)} + \frac{\beta\lambda}{1-\beta(1-\lambda)}\left[\frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})} + \frac{\beta\alpha_{wg}W_g}{1-\beta(1-\alpha_{wg})}\right] \\
& \implies W_g\left[1 - \frac{\beta^2\lambda\alpha_{wg}}{(1-\beta(1-\lambda))(1-\beta(1-\alpha_{wg}))}\right] = \frac{w_g}{1-\beta(1-\lambda)} + \frac{\beta\lambda}{1-\beta(1-\lambda)}\left[\frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})}\right] \\
& \implies W_g\left[\frac{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}{(1-\beta(1-\lambda))(1-\beta(1-\alpha_{wg}))}\right] = \frac{w_g}{1-\beta(1-\lambda)} + \frac{\beta\lambda}{1-\beta(1-\lambda)}\left[\frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})}\right] \\
& \implies W_g = \frac{w_g(1-\beta(1-\alpha_{wg})) + \beta\lambda(z-(1-s_g)\kappa_g)}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}
\end{aligned}
$$

Now, let's plug this back to the equation (A.3):

$$
\begin{aligned}
U_g &= \frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})} + \frac{\beta\alpha_{wg}W_g}{1-\beta(1-\alpha_{wg})} \\
&= \frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})} + \frac{\beta\alpha_{wg}}{1-\beta(1-\alpha_{wg})}\left[\frac{w_g(1-\beta(1-\alpha_{wg})) + \beta\lambda(z-(1-s_g)\kappa_g)}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}\right] \\
&= \frac{z-(1-s_g)\kappa_g}{1-\beta(1-\alpha_{wg})} + \frac{\beta\alpha_{wg}w_g}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))} \\
&+ \frac{\beta^2\lambda\alpha_{wg}(z-(1-s_g)\kappa_g)}{(1-\beta)(1-\beta(1-\alpha_{wg}))(1-\beta(1-\alpha_{wg}-\lambda))}
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda)) + \beta^2\lambda\alpha_{wg}}{(1-\beta)(1-\beta(1-\alpha_{wg}))(1-\beta(1-\alpha_{wg}-\lambda))}\cdot(z-(1-s_g)\kappa_g) \\
&+ \frac{\beta\alpha_{wg}}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}\cdot w_g \\
&= \frac{(1-\beta(1-\lambda))(1-\beta(1-\alpha_{wg}))}{(1-\beta)(1-\beta(1-\alpha_{wg}))(1-\beta(1-\alpha_{wg}-\lambda))}\cdot(z-(1-s_g)\kappa_g) \\
&+ \frac{\beta\alpha_{wg}}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}\cdot w_g \\
&\implies U_g = \frac{(1-\beta(1-\lambda))\cdot(z-(1-s_g)\kappa_g) + \beta\alpha_{wg}\cdot w_g}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}
\end{aligned}
$$

Subtracting U_g from W_g, we get:

$$\implies W_g - U_g = \left[\frac{w_g(1-\beta(1-\alpha_{wg})) + \beta\lambda(z-(1-s_g)\kappa_g)}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}\right]$$
$$-\left[\frac{(1-\beta(1-\lambda))\cdot(z-(1-s_g)\kappa_g) + \beta\alpha_{wg}\cdot w_g}{(1-\beta)(1-\beta(1-\alpha_{wg}-\lambda))}\right]$$
$$\therefore W_g - U_g = \left[\frac{w_g-(z-(1-s_g)\kappa_g)}{1-\beta(1-\alpha_{wg}-\lambda)}\right].$$

Going back to the bargaining problem:

$$(1-\eta)(W_g - U_g) = \eta J_g.$$

Plugging in the equations from above and plugging the value of J_g from (11), we get:

$$(1-\eta)\left[\frac{w_g-(z-(1-s_g)\kappa_g)}{1-\beta(1-\alpha_{wg}-\lambda)}\right] = \eta\frac{p+\tau_g-w_g}{1-\beta(1-\lambda)}$$
$$\implies w_g\left[\frac{1-\eta}{1-\beta(1-\alpha_{wg}-\lambda)} + \frac{\eta}{1-\beta(1-\lambda)}\right] = \frac{\eta(p+\tau_g)}{1-\beta(1-\lambda)} + \frac{(1-\eta)(z-(1-s_g)\kappa_g)}{1-\beta(1-\alpha_{wg}-\lambda)}$$
$$\implies w_g = \frac{(1-\eta)(z-(1-s_g)\kappa_g)[1-\beta(1-\lambda)] + \eta(p+\tau_g)[1-\beta(1-\lambda-\alpha_{wg})]}{[1-\beta(1-\lambda-\eta\alpha_{wg})]}.$$

i.e. $\tau_g \uparrow \implies w_g \uparrow$, $s_g \uparrow \implies w_g \uparrow$ and $\kappa_g \uparrow \implies w_g \downarrow$. □