Chapter 13
The Role of Labor Markets in Determining the Efficacy and Distributional Impact of Sustainability Policies

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1 Introduction

Labor is a critical input in agriculture and an important determinant of rural household and community welfare in the wake of policies directed at the farm sector. In 2017, labor accounted for more than 30% of production costs in the agricultural sector globally and close to 60% in Sub-Saharan Africa (Aguiar et al. 2019). In the United States, average labor cost as a share of gross farm income (2017–2019) ranges from 25% to 35% for the production of fruits, nuts, vegetables, and other specialty crops (US Department of Agriculture (USDA) 2021). Thus, agriculture brings not only land and water resources but also human resources into the food system.

This chapter is a slightly revised version of a paper originally published as Ray, Srabashi, Iman Haqiqi, Alexandra E. Hill, J. Edward Taylor, and Thomas W. Hertel. 2023. Labor markets: A critical link between global-local shocks and their impact on agriculture. *Environmental Research Letters* 18: 035007. https://doi.org/10.1088/1748-9326/acb1c9.

Data availability statement: The files needed to replicate this application are available at https://gtap.agecon.purdue.edu/simple-g/.

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https://doi.org/10.1007/978-3-031-68054-0_13

Agricultural labour markets operate at a "meso" level that can shape the impacts of conservation policies (e.g., groundwater conservation) at the local level and feed back into national-level changes.[1] Several global modeling frameworks resolve processes with high spatial resolution (i.e., individual grid cells) (Lotze-Campen et al. 2008; Valin et al. 2013; Shin et al. 2016; Baldos et al. 2020). However, the meso level is also important when analyzing sustainability challenges (Johnson et al. 2023).

In this chapter, we highlight the critical role of labor markets in governing the effectiveness and distributional impacts of global food price shocks and local sustainability policies targeting land and water use in agriculture. We begin by reviewing the empirical literature on agricultural labor markets. We then offer insights from economic theory regarding the link between the functioning of labor markets and agricultural outcomes. Finally, we build these components into the SIMPLE-G model of US agriculture developed in Chap. 12 and demonstrate how labor market responses alter the impacts of global price shocks and local sustainability policies on agricultural production, employment, and land use.

Agricultural labor markets in the United States are complex, involving different types of labor with unique characteristics. In the United States, field crops such as maize, soy, and wheat are largely grown in the Midwest and Great Plains, where mechanization has permitted many farms to operate with small labor forces consisting primarily of family labor, supplemented by hired labor from local communities (USDA 2022). In contrast, in the Fruitful Rim, where the bulk of US fruit, vegetable, and horticultural (FVH) farms operate, immigrant labor—particularly from Mexico—is the main source of hired labor. The labor requirements for the FVH sector are highly seasonal. Follow-the-crop migration has traditionally facilitated agricultural production by redistributing agricultural workers across localities and seasons. However, farmworker mobility has decreased significantly over time (Fan et al. 2015), while the overall supply of farm workers from Mexico has declined (Charlton and Taylor 2016). Farms have therefore become more reliant on workers who have settled in nearby localities, and they are more likely to compete with nearby nonfarm businesses for scarce labor. These trends highlight the importance of representing labor markets in a global–local–global framework.

The growing reluctance of workers to relocate to new regions of the country means that wage differentials can emerge and persist across regions. This was evident in nonagricultural labor markets after China's accession to the World Trade Organization (WTO) and rapid growth in Chinese exports over the past two decades (Autor et al. 2016, 2021). Trade economists analyzing the impacts of WTO accession have paid little attention to labor markets (Bhattasali et al. 2004). As a result, few anticipated the slow adjustment of the US manufacturing sector and the depressed regional labor markets that emerged (Autor et al. 2021).

[1] The meso level refers to an intermediate scale arising between the aggregated global (or macro) scale and the local (or micro) scale.

We bring these recent labor market insights into the SIMPLE-G framework by explicitly accounting for agricultural workers' mobility. We illustrate the importance of labor market responsiveness by assessing the impacts of the recent commodity price boom and local conservation policies that withdraw overexploited resources from farming. The emphasis is on how labor market rigidities shape the responses to global and local shocks. While the focus here is on the United States, these issues are also relevant in developing countries, where agriculture is more labor intensive and labor market rigidities are prevalent (Campos and Nugent 2018; Konte et al. 2022).

2 Agricultural Labor Markets in the United States

Labor is a key input for planting, weeding, harvesting, and postharvest activities in agriculture. People's willingness to perform farm work at prevailing wages and to engage in follow-the-crop migration determines the availability of labor at particular geographic locations and seasons and thus are key determinants of agricultural production. Environmental stressors and economic conditions affect agricultural labor markets. For example, Jessoe et al. (2018) and Feng et al. (2012) show that environmental shocks on crop yields (i.e., rising temperatures and declining precipitation) cause out-migration from rural areas and decrease farm employment. Fan et al. (2016) show that agricultural wages rise during recessions due to a leftward shift in labor supply from decreased migration and an inelastic farm labor demand (because people must eat). This contrasts with labor market conditions in other industries with high proportions of immigrant workers (e.g., construction), in which both supply and demand are likely to decline during recessions. In the wake of new conservation policies, the optimal behavior of agricultural producers might be to contract and relocate production. However, producers' ability to make these changes depends on workers' mobility.

Historically, the US agricultural workforce has been characterized by a large number of migrant workers willing to travel long distances for employment. Today, fewer individuals are willing to work in agriculture, and those in the labor pool are more settled (Fan et al. 2015; Martin 2017). A variety of factors have contributed to the decline in farm labor supply. These include increases in immigration enforcement (Kostandini et al. 2014; Charlton and Taylor 2016), growing employment opportunities in nonfarm sectors (Richards and Patterson 1998; Martin 2017), and relative changes in economic conditions in the United States and Mexico (Taylor et al. 2012). These factors have contributed to the overall decline in labor supply from Mexico and a reduced willingness to work in US agriculture.

Migrant agricultural workers follow seasonal paths of crop production across large geographic regions. These paths are typically circular: Workers begin in the south early in the year, move northward, and then head south again, following the crop and weather patterns that dictate harvest times (Taylor 1937; Arnedo et al.

2011).[2] In recent years, however, agricultural workers have become less mobile (Fan et al. 2015). More people report being settled in a particular location and working nearby (Martin 2017). The specific causes of this transition to a more settled workforce are not immediately obvious, but the trend correlates with increases in immigration enforcement, which limits historic cross-border migration patterns and increases in the number of workers with families in the United States. It is also linked to the aging of the farm workforce (a consequence of decreasing immigration of young workers from Mexico); growing employment opportunities in nonfarm sectors, which reduce the need to move for employment (Martin 2017); and possibly to welfare policies (Green et al. 2003).

Combined, the decline in agricultural labor supply and reduced intra-US migration have led to a relative scarcity of agricultural labor and widespread reports of worker shortages (Hertz and Zahniser 2013; Bronars 2015; Richards 2018). The implications for US agricultural production are vast. In the short run, agricultural producers seeking to move or expand their production area might be unable to do so if their operations are not located near where many workers live. Moreover, to attract a sufficient workforce in the long run, job opportunities (e.g., wages, hours, and desired skills) must be enticing enough for workers to remain settled in the area.

In sum, employers face stickier labor markets and can no longer rely on having an elastic migrant workforce that arrives at the farm gate when and where they desire. Models that assume that the agricultural labor supply is highly (or perfectly) elastic are likely to present a biased picture of local and global agricultural and environmental impacts of policy interventions.

3 Insights About Labor Market Rigidities from Economic Theory

In Part II, we developed the two-input theoretical framework underlying the SIMPLE framework. Eqs. 3.5, 3.6, 3.7, 3.8, and 3.9 in Box 3.1 show the changes in input use, input prices, and overall production due to any exogenous shock. We can use these equations to understand how the impacts of a policy can vary under different assumptions about agricultural labor markets.

Agricultural labor is subsumed under human inputs in the two-input framework. When agricultural labor markets are assumed to be perfectly elastic, then $\nu_H \rightarrow \infty$. Under this condition, we can rewrite the changes in natural resource use (Eq. 13.1), human input use (Eq. 13.2), and total production (Eq. 13.3) as follows:

[2] In one historic route, West Coast agricultural laborers began in California's Imperial Valley, next to the Mexican border, harvesting truck crops in the winter, moved to the Los Angeles or San Bernardino County areas in the spring, then spent most of the summer and fall in central California near Bakersfield and Fresno (Taylor and Rowell 1938).

$$q_R = p^* \frac{v_R}{\theta_R} - \phi_R \tag{13.1}$$

$$q_H = v_R \frac{p^*}{\theta_R} + \sigma \frac{p^*}{\theta_R} - \phi_R \tag{13.2}$$

$$q = p^* \frac{v_R}{\theta_R} + p^* \frac{\sigma \theta_H}{\theta_R} - \phi_R \tag{13.3}$$

A comparison of these sets of equations shows that if we ignore labor markets, we are foregoing significant richness in our analysis. If we reintroduce labor market rigidities to Eq. 13.3 (i.e., the change in total production), we observe that both the extensive (v_R) and intensive ($\theta_H \sigma$) margin responses are modified by the terms Γ_R and Γ_σ in Eq. 3.9 in Box 3.1. Both the modifying terms are less than 1, indicating that labor market rigidities diminish the grid cell's responsiveness to commodity price changes. The "stickier" the labor market is, the smaller Γ_R and Γ_σ are, leading to a diminished production response. Intuitively, it is more expensive to hire workers in the relatively tight labor market required to manage the resources under production.

Further examination of the terms Γ_R and Γ_σ reveals the crucial role that the labor supply elasticity, v_H, plays in governing local responses to a commodity price boom, particularly the size of this elasticity relative to the supply response of natural inputs, v_R. Given the geographic immobility of natural resources, we expect v_R to be lower than the labor supply response; therefore, $v_H > v_R$. The greater the difference in the supply elasticities of the two inputs, the larger the intensification component of the supply response. If the factor supply elasticities are equal (i.e., $v_H = v_R$), there is no incentive to intensify production in response to the commodity price hike. In this case, both input demands will rise proportionately with output.

When commodity prices increase, the returns to both inputs increase. We expect land and water resources to capture a greater share of the increase in crop prices (i.e., $p_H < p_R$) because producers are willing to pay a higher price for the relatively scarce input. Thus, the relative price elasticity of supply for labor versus natural resources determines the distribution of gains from a higher crop price between the two inputs. In the extreme case of perfect labor mobility—as assumed in most integrated assessment models (IAMs)—labor supply is perfectly elastic, and wages are constant despite increased production. In this case, all of the gains accrue to landowners.

In the case of the groundwater policy shock, as with the commodity market boom, the presence of inelastic labor markets mediates the production impact of this resource conservation policy. Eq. 13.3 shows that the maximum impact of the policy would be realized under perfect labor mobility ($\Gamma_H \rightarrow 1$ as $v_H \rightarrow \infty$). We saw that the production impact of the crop price boom is smaller when labor market rigidities are introduced. However, in the case of a groundwater conservation policy, the ramifications of ignoring imperfect labor mobility are ambiguous. The direct impact of the policy shock on production is negative (i.e., land and water are forced out of production in targeted grid cells), but the spillover effects are positive (i.e., labor moves from targeted to untargeted cells). Both these effects are overestimated when we ignore labor market rigidities. Therefore, whether ignoring labor market rigidities causes the aggregate effect of the groundwater policy to be over- or underestimated varies by grid cell, depending on the grid-level parameters.

From the theoretical model, it is clear that we need to explicitly model agricultural labor markets to accurately capture the policy impacts, distributional consequences, and—importantly—the effectiveness of the policy in terms of the resources conserved. In the SIMPLE-G-CZ model, we address this problem by considering a range of long-run labor supply elasticity estimates that are supported by the literature (Hill et al. 2021). Shifting migration patterns are also pivotal elements in agricultural labor markets' role in mediating farms' ability to respond to stressors. We expect the decline in the mobility of the agricultural workforce to alter the optimal producer response to crop price shocks and groundwater sustainability policies. The extent to which producers expand or relocate production in response to these shocks will be mediated by the availability of workers at specific locations. Thus, models that assume perfect labor mobility are likely to be biased. Informed by studies of agricultural labor-supply elasticity (Hill et al. 2021), we geographically restrict labor mobility to areas, or laborsheds, in which modern farmworkers are willing to work and compare the results with those under an assumption of perfect labor mobility.[3]

4 SIMPLE-G Version Employed for This Study

In this chapter, we use the SIMPLE-G-CZ (Ray et al. 2023) model (Fig. 13.1), which builds on the foundation of the SIMPLE-G framework outlined in Part III of this book and incorporates rigidities in agricultural labor markets. Specifically, the model in Fig. 13.1 elaborates on the version of SIMPLE-G used in the previous chapter of this book (Chap. 12) by disaggregating the agricultural labor input and introducing geographically limited "laborsheds."

There are multiple empirical and conceptual challenges to defining the geographic extent of agricultural labor markets. The three most widely used geographic delineations of US labor markets are the Office of Management and Budget's core-based statistical areas (CBSAs), the USDA Economic Research Service's commuting zones (CZs), and the Bureau of Economic Analysis's economic areas (EAs). Fowler and Jensen (2020) compare these methods on the extent to which labor markets represent core EAs, the degree of economic connectivity within areas, and the degree to which individuals live and work within the same areas. They conclude that no existing labor market delineation is adequate; geographic delineations must be tailored to the problem at hand.

[3] One can think of agricultural labor markets as "laborsheds" in much the same way as hydrologists think about watersheds. Watersheds are shaped by geological features; laborsheds are shaped by farm workers' willingness to move from one place to another in response to changing labor demands.

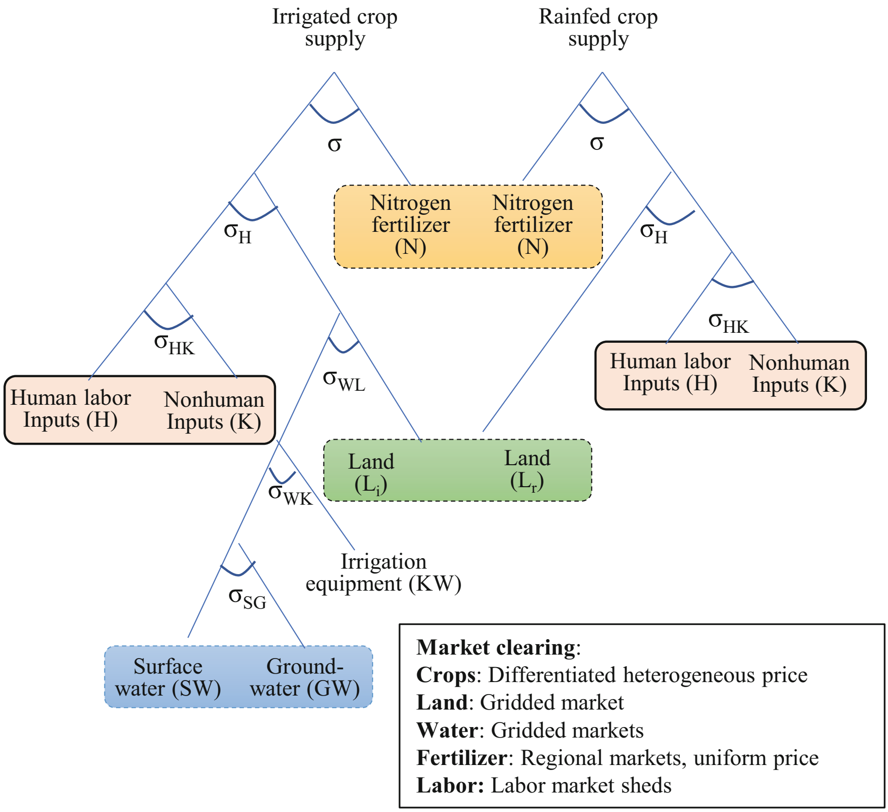

Fig. 13.1 Structure of crop production in SIMPLE-G-CZ
The SIMPLE-G-CZ model is based on SIMPLE-G-US (Baldos et al. 2020). In SIMPLE-G-CZ, "other Inputs" are split into human labor inputs (*H*) and nonhuman inputs (*K*), which comprise capital and other production inputs (e.g., seeds and chemicals). Human labor refers to all types of labor, including hired, migrant, and family labor. The SIMPLE-G-CZ model introduces spatially explicit markets for the labor input using the concept of commuting zones (CZs) (Fowler et al. 2016). Each CZ has a labor supply curve parameterized based on the extensive margin labor supply elasticity reported by Hill et al. (2021). Labor demand is determined by profit-maximizing producers in each grid cell. The allocation of labor within a CZ is determined by a quantity-preserving CET function, which determines the equilibrium wages at local laborsheds (i.e., commuting zones). The elasticity of substitution parameters is shown by σ, indexed by the relevant inputs

The SIMPLE-G-CZ model employed in this chapter builds on the literature on CZs (Fowler et al. 2016; Fowler and Jensen 2020). The SIMPLE-G-CZ model incorporates labor market rigidities in the SIMPLE-G framework using estimates of agricultural labor supply elasticity from Hill et al. (2021). In the SIMPLE-G-CZ model, labor markets are clear and wages are determined at the CZ level. We also incorporate within-CZ frictions across grid cells.

We use CZs as the geographical areas over which we delineate the pool of available workers because, among existing labor market delineations, they are most consistent with our research objectives. The CZ methodology, which was first developed by Tolbert and Sizer (1996), is based on central place theory, which assigns counties to nodes based on a hierarchical cluster algorithm that groups counties with strong commuting ties (Carpenter et al. 2022). CZs are widely used in population and labor economic analyses of areas sharing a common labor market as an alternative to counties (which are problematic because they are largely arbitrary political units) and metropolitan statistical areas or CBSAs (which by definition *exclude* nonmetropolitan places and do not span the entire United States). Agricultural workers often cross county and state lines, and the CZ approach is well suited to address this mobility.

5 Experimental Design: Global Change Scenarios

Our experiments consider two cases that allow us to highlight the significance of labor markets in a multiscale, integrated socioeconomic–biophysical framework. The first case examines a global commodity price boom. The second case considers a local sustainable groundwater policy. We simulate the impacts of these two shocks on both local and national production, wages, and employment. For each case, we consider two labor market scenarios: (1) perfect labor mobility across the United States, in keeping with traditional IAMs, and (2) restricted mobility, as discussed in Sect. 2.

5.1 Global Commodity Boom

Agricultural commodity prices are notably volatile, and crop producers must continually form expectations about prices prior to harvest. Commodity prices began to rise sharply at the onset of the Ukraine conflict in early 2022. This was particularly notable for wheat and oilseeds, for which Ukraine and Russia account for a large share of global exports. Due to substitutability in use as well as in production, crop commodities tend to move in tandem, and the prices of other crops also rose during this period. While they have subsequently declined, agricultural commodity prices remain above the level forecast prior to the conflict, and the future for agricultural prices is uncertain. Similar shocks to the global food system occurred in the 2006–2013 period when a combination of rapid growth in biofuel demand, low commodity stocks, and adverse weather events resulted in a series of commodity price spikes (Abbott et al. 2008). Of course, the price that matters for producer profits is the one prevailing at the time of sale, but this price is unknown at the time of planting, hence the importance of expectations. For longer-term decision-making, prices in subsequent years are also relevant. For example, the price of maize prevailing in the spring of 2022 was 19% higher than it had been in the spring of 2021 (World Bank 2022). Price increases vary by crop, and it is unclear whether farmers understood these increases to signal persistently higher prices. For this reason, we study the effect of a commodity price boom using a stylized 10% price hike.

5.2 Sustainable Groundwater Policy in the Western United States

In this chapter, we implement the same groundwater sustainability shock discussed in Chap. 12. Water scarcity is one of the major challenges facing states in the Western United States, where there is widespread unsustainable use of groundwater. As in Chap. 12, we implement a groundwater sustainability policy that restricts groundwater extraction rates to average recharge rates in each grid cell. This policy ensures that the groundwater table does not decline further over the long run. Viewed from a local perspective, the implications of this policy are dramatic, implying up to a 90% reduction in groundwater pumping in some locations. In total, the policy imposes a 66.7% reduction in total groundwater withdrawals in the United States (Haqiqi et al. 2023). Restrictions on groundwater extraction have local and regional economic impacts, and labor markets may play a critical role in transmitting impacts across grid cells. We quantify the consequences of such policies for agricultural production, employment, and land use at local and regional scales.

6 Results

In the cases of both policy shocks, we assume that the perturbation to the system is permanent, as the model is designed to elicit long-run equilibrium responses to shocks. Thus, producers assume that the groundwater sustainability policy will not be reversed, despite the political pressures that inevitably emerge following such policies. In the case of the commodity price boom, we assume that there are structural features causing prices to be persistently higher relative to baseline expectations so that farmers adjust their land, water, and labor usage accordingly. If the commodity price boom is perceived as temporary (as is typical for commodity booms), then the supply response will be smaller than that shown here.

6.1 Impacts of an Agricultural Commodity Price Boom

The price boom has an expansionary effect on national crop output and on all underlying inputs used (Table 13.1). However, the extent of the expansionary effect is starkly different depending on agricultural labor mobility. When labor is perfectly

Table 13.1 National change (%) in crop production, employment, wages, land use, groundwater use, and crop price in the United States

Percentage change in	Perfect labor mobility (SIMPLE-G model)	Restricted labor markets (SIMPLE-G-CZ)
Crop price boom		
Crop production	35.3	9.2
Employment	12.7	4.8
Wages	0	18.6
Land use	1.9	1.3
Groundwater use	9.1	6.4
Sustainable groundwater policy		
Crop production	−2.9	−2.7
Employment	−3.7	0.9
Wages	0	−0.26
Land use	0.3	0.2
Groundwater use	−41.9	−41.5
Crop price	2.2	2.1

mobile, the 10% crop price increase leads to a 35.3% increase in total crop production and a 12.7% increase in employment in the United States. The local-level increase in employment ranges from 12% to 25% across the West and Midwestern United States and rises to more than 25% in the South and Southeastern United States (Fig. 13.2). This supply response to a 10% global price shock is implausibly large, considering estimates in the literature (Lee and Helmberger 1985; Keeney and Hertel 2009). In contrast, total crop production and employment increase by 9.2% and 4.8%, respectively, when labor market rigidities are included in the model. Local-level increases in employment range from 2% to 12% (Fig. 13.2).

Under the imperfect labor mobility scenario, land use expands along the margins of the Corn Belt as well as parts of the Southern and Eastern United States, where agriculture is less reliant on scarce groundwater than in the Western United States (Fig. 13.2f). This is consistent with recent observations in the wake of the biofuel boom (Lark et al. 2015). In contrast, there is almost no change in cropland use in the Western United States.

Under restricted labor mobility, the smaller increase in land use in response to the commodity price hike is associated with a smaller increase in groundwater use: 6.4%, compared with 9.1% under perfect labor mobility (Fig. 13.3). Differences in land use between the two labor market scenarios are small compared with differences in production and employment because—based on empirical estimates—both models limit the mobility of land across uses (Villoria and Liu 2018).

Agricultural labor markets mediate the regional impacts of the global crop price boom on agricultural workers. With perfect labor mobility, agricultural wages do not change, whereas wage increases are evident given more realistic, sticky labor market assumptions. In the presence of sticky labor markets, national agricultural wages increase by 18.6%. However, the CZs in the Corn Belt that respond to the global

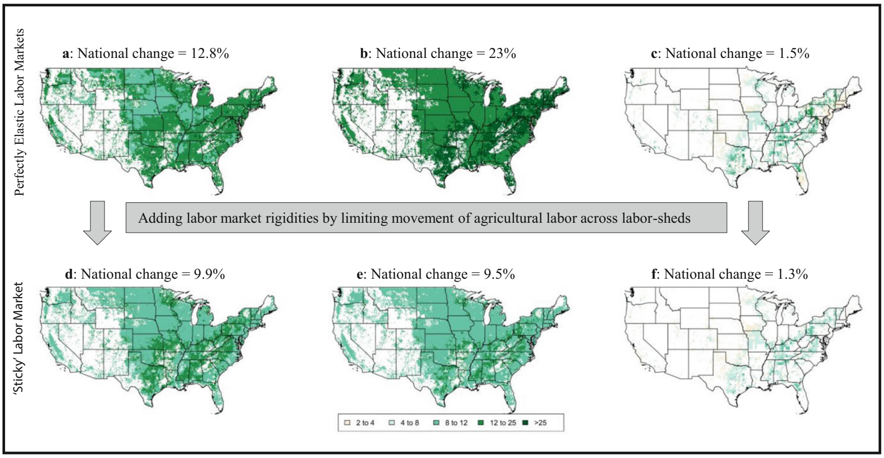

Fig. 13.2 Grid-cell level response to a permanent 10% price hike as a percentage change in (**a**) production, (**b**) employment, and (**c**) land use under a perfectly elastic labor market contrasted with responses in (**d**) production, (**e**) employment, and (**f**) land use under restricted labor mobility

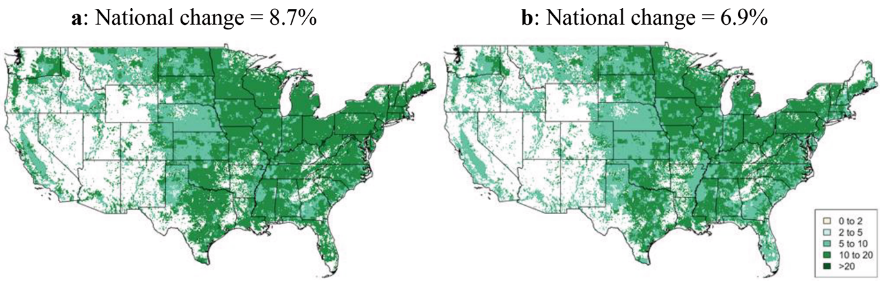

Fig. 13.3 Changes in groundwater use due to a global price shock in (**a**) perfectly elastic and (**b**) "sticky" labor markets

price shock with the strongest increases in crop production experience a wage increase of 20–30% (Fig. 13.4). The structure of agricultural labor markets plays a significant role in determining the impacts of global shocks on local-level farmworkers.

6.2 Impacts of a Sustainable Groundwater Conservation Policy

The sustainable groundwater policy affects primarily the Western United States, where irrigated agriculture relies on severely overexploited groundwater resources. The aggregate impacts of the policy in terms of reduction in crop production

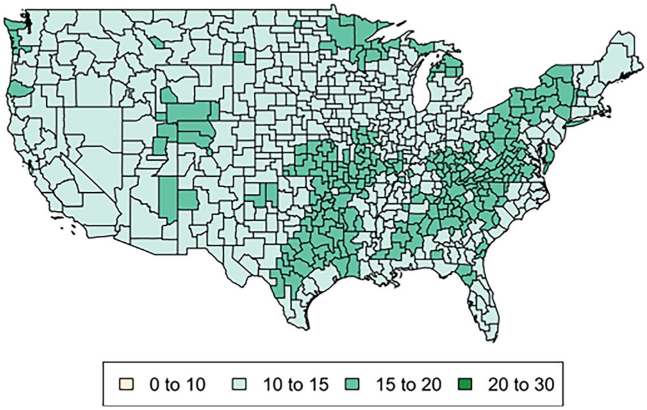

Fig. 13.4 Impact of crop price shock on wages at the commuting zone level (restricted labor mobility model)
Note that the change in wages is concentrated in the Corn Belt, with a relatively smaller impact in the western United States, where agriculture is relatively more reliant on overexploited groundwater

(2.7–2.9%) and the change in land use (an increase of less than 1%) are comparable across the two assumptions about the structure of agricultural labor markets. However, if we ignore labor market rigidities, the national-level reduction in employment is overestimated: 3.7% compared with 0.9% (Table 13.1).

Due to the reduction in national crop production following the groundwater conservation policy, US crop prices increase by roughly 2% under both policies. This increase affects all producers, leading to spillover effects in grids that are not directly targeted by the policy. These spillover effects could contribute to the overexploitation of groundwater resources in the nontargeted regions. (We do not explore this overexploitation here.) The national impact of this policy on groundwater use under both labor market scenarios is a 42% reduction in national groundwater use. While the simulation reduces groundwater withdrawals by 66.7% in the directly affected cells, the increase in national crop prices stimulates an increase in groundwater use in locations not targeted by the policy. Thus, the net reduction in groundwater use, accounting for the spillover effects, is lower: just 42%.

As in the case of the global price shock, the local impacts of a groundwater conservation policy can vary significantly from what appears to be small impacts at the national level. In the directly affected regions of the Central Valley of California, crop production falls by up to 50% and employment decreases significantly (Fig. 13.5). The magnitude of the policy impact on employment depends on the structure of the local agricultural labor markets. Under perfect labor mobility, the fall in employment closely matches the corresponding fall in grid-level production. However, under restricted labor mobility, employment falls by up to 15% in California's Central Valley (Fig. 13.5).

The spillover effects, on both production and employment, in the indirectly affected grid cells are also overestimated under the assumption of perfect labor

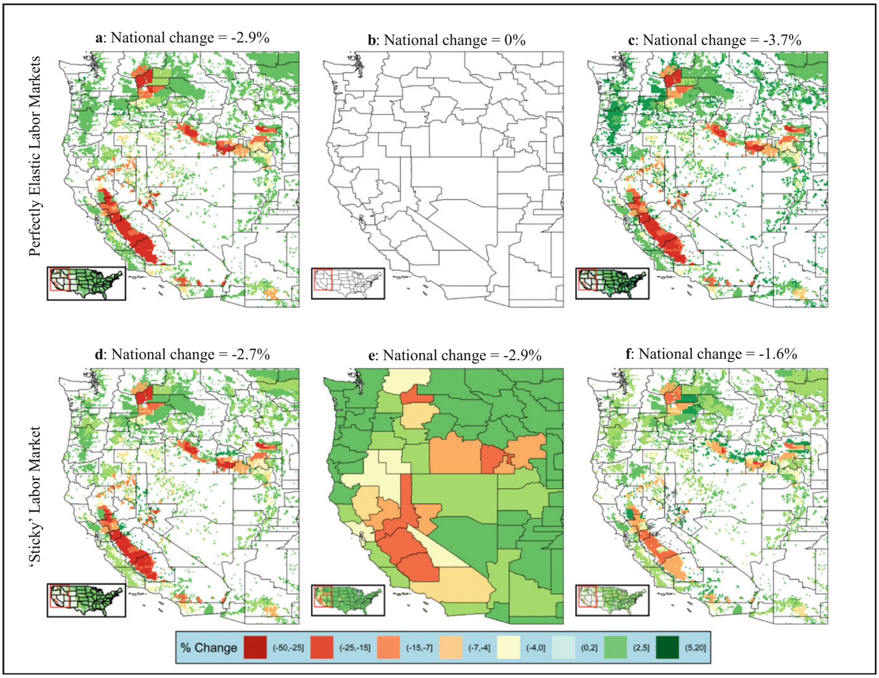

Fig. 13.5 Impact of US sustainable groundwater policy shock as a percentage change in (**a**) crop production, (**b**) employment, and (**c**) wages in the western United States under perfect mobility versus impact on (**d**) crop production, (**e**) employment, and (**f**) wages under restricted labor mobility Figure **b** is blank because there is no change in wages in this scenario. Borders within the wage change maps show the commuting zone delineations across the western United States

mobility. Grids that are not directly targeted by the groundwater policy in a CZ expand production due to the higher crop prices. These increases in production also lead to an increase in employment. When we consider labor market rigidities, the spillover effects on employment generate up to a 5% increase in employment in most grids (Fig. 13.5). This effect is estimated to reach 20% under perfect labor mobility. The spillover effects of a conservation policy give farmworkers the opportunity to find employment in neighboring grid cells. If farmworkers' mobility is restricted, the spillover effects are also limited.

By assumption, the perfect labor mobility case completely overlooks the potential wage impacts (Fig. 13.5b) of conservation policies. Figure 13.5e shows that agricultural wages decrease by 7–50% in the Central Valley and parts of the Snake River Basin, where the groundwater conservation policy is targeted. Farmworkers who lose their jobs when unsustainable use of natural resources is restricted are likely to absorb wage cuts if alternative opportunities for employment are limited.

7 Discussion

This chapter documents an important first step toward integrating labor markets into multiscale sustainability analyses. We detail conceptually why agricultural labor markets are increasingly likely to influence agriculture's ability to respond to a variety of factors, including changes in global commodity prices and local conservation policies. In recent years, US agricultural workers have become less mobile, contributing to geographically smaller and more contained laborsheds. Our simulations demonstrate how assumptions about labor market mobility shape the impacts of market and policy changes. Labor markets can be crucial determinants of how agricultural production changes over time and across space in response to economy-wide, sectoral, or regional shocks.

Incorporating labor market responses can improve the accuracy and utility of multiscale models of the economy and environment (e.g., SIMPLE-G). However, challenges remain, and future research should be directed toward addressing them. A top priority is to develop better estimates of the underlying parameters used in the model. Given the importance of factor supply responses within this framework, estimating the agricultural labor supply response within and across laborsheds is a priority for future research. There are few reliable agricultural labor-supply elasticity estimates (Hill et al. 2021), and land and groundwater supply elasticities can also be improved. Work is currently underway to estimate cropland supply elasticities at the grid cell level and use those elasticities to validate the model's predictions over a historical period (Villoria et al. 2022). This will be an important advance.

An important adaptation to groundwater restrictions involves changes in crop mix that imply changes in the labor intensity of production. Although incorporating dozens of crops into a gridded model of agriculture would be appealing, the absence of necessary data and parameters would pose major challenges to such an endeavor. However, the proposed framework approximates the interplay between multiple crop types with different water needs by estimating an aggregate relationship between the water intensity of all crops grown in a given region and water availability. Crop mix also plays a role on the demand side of this analysis, where we have assumed a single, national crop price. Chap. 5 and other chapters of this book develop an approach that allows for the differentiation of the composite crop by the USDA production region. This is also an important advance.

There are potential limitations to using CZs as geographical restrictions on labor mobility. The CZ methodology is based on commuting patterns for the general US population, the majority of whom do not regularly move for employment throughout the year. Most workers commute from their homes to nearby workplaces (e.g., living in a suburb and commuting to a city center). The CZ methodology is not designed to depict the movements of follow-the-crop migrants. While this type of worker movement has become less common in recent years, follow-the-crop migrants still represent an important subset of the agricultural workforce and are crucial for ensuring a sufficient labor supply when and where it is needed. One emerging solution to the decline in migrant workers is the H-2A visa program for temporary agricultural workers. H-2A visa holders are beholden to specific agricultural employers for a duration that is agreed upon prior to the workers' arrival. As these workers cannot move from employer to employer, we omit them from our current analysis; in effect, their labor market area encompasses the home country and a single US employer (usually a farmer or farmer association, but in some cases a labor contractor). All of these constraints point to the need for future work to build on our framework and explore the implications of richer delineations of agricultural labor markets.

In summary, we believe that there is great potential for the explicit modeling of agricultural labor markets to contribute to our understanding of the impacts of global food price shocks as well as current debates over the agriculture–environment interface and the equity implications of conservation policies. The results of this study show that the assumption of a less than perfectly elastic labor supply can significantly alter conclusions from multiscale sustainability modeling regarding the effectiveness and distributional consequences of global shocks as well as local conservation policies. We see this work as a first step toward understanding how labor markets mediate between local and global economies, thereby enabling the refinement of integrated assessment models with richer representations of labor markets.

Acknowledgments and Competing Interests The authors acknowledge support from USDA-AFRI grants #NIFA-2022-67023-36403, "Labor Markets and the Impacts of Environmental Stresses and Conservation Policies on US Agriculture," and #2019-67023-29679, "Economic Foundations of Long Run Agricultural Sustainability," and the National Science Foundation INFEWS award #1855937, "Identifying Sustainability Solutions through Global-Local-Global Analysis of a Coupled Water-Agriculture-Bioenergy System."

The findings and conclusions presented in this chapter are those of the authors and should not be construed to represent any official determination or policy of the US Department of Agriculture (USDA), or the National Science Foundation (NSF). Furthermore, we declare that there is no conflict of interest related to this work.

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