Quantifying the Economywide Impacts of Industrial Hemp Adoption in the U.S.

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Abstract

This study analyzes macro-economic aspects of industrial hemp adoption in the U.S. economy with a focus on fiber products. Hemp is currently not economically viable but we analyze potential policies for adoption of hemp using a general equilibrium model. Under a hypothetical three million acres of hemp production, fiber products could be widely integrated as intermediate inputs into production sectors involving fiber, paper, concrete, and building materials. The hemp-producing crops sector would increase in value by approximately four percent and would pull resources from other sectors of the economy. The model predicts that much hemp demand could be met by supply from outside the U.S., so expansion of domestic production is not guaranteed even if domestic demand is strong.

Keywords: industrial hemp, general equilibrium, agricultural policy

JEL Codes: C68, D58, Q17, Q18

Introduction

After decades of being illegal, hemp cultivation in the United States was authorized by the 2018 Farm Bill (Malone and Gomez, 2019). Since then, interest has grown among farmers, processors, and policymakers regarding hemp's viability as an alternative crop (Mark et al., 2020; Hamilton and Williams, 2019). For example, the U.S. Department of Agriculture is funding research to analyze the economic viability of hemp. Lobbying groups such as the American Farm Bureau Federation have supported moves toward increasing hemp production in the United States (Malone and Gomez, 2019). A potential advantage of hemp is its ability to thrive on marginal lands unsuitable for traditional agriculture. It can be incorporated into cropping rotations in some parts of the U.S. with only a modest loss in overall agricultural output, and has moderate pesticide and water requirements. By providing additional farm revenue, it could lead to improvements in farm profitability and rural economic activity (Scalabrin et al, 2024; Islam and Das, 2023).

Since U.S. hemp cultivation was illegal until recently, there's a scarcity of data and economic analysis on the potential of a hemp supply chain in the United States. The lack of historical data on hemp means that the costs, benefits, incentives to produce, and the potential economic impacts of its cultivation remain unclear. Hemp adoption by farmers has been limited by the viability of regular market channels for producers to sell into (Cho and Antle, 2024). Yet scientific research on potential end uses has progressed rapidly (Kemda et al., 2024; Islam and Das, 2023). Recent research on hemp's economic potential shows that hemp fiber production could help support rural economic growth if federal regulation of hemp were changed to reduce the costs imposed by existing regulations on producing, transporting, processing and marketing hemp fiber and related byproducts (Antle and Cho, 2025).

The purpose of this study is to analyze the economic plausibility and potential of hemp in the U.S. economy. We restrict our focus to hemp grown in open fields that is for fiber. We customize an applied general equilibrium model to represent scenarios under which hemp fiber are inputs to the production of other products. The scenarios we simulate include a mandate to incorporate hemp as an input in various production sectors, as well as border restrictions that favor domestic producers. A mandate is a government-imposed requirement that affects the allocation of resources in an economy to achieve an objective that might be non-economic in nature, like rural development or national economic self-reliance. No mandate for hemp is currently in place, but the United States has historically made interventions in markets to achieve non-economic objectives (Bhagwati, 1967). For example, the Renewable Fuel Standard (RFS) has been in place since 2006 and requires U.S. transportation fuel to contain a minimum volume of renewable fuels. Without the mandates implied by the RFS, renewable fuels would likely not be produced and consumed to the extent that they are within the U.S. (Gerveni, Hubbs, and Irwin, 2023).

Our model incorporates a social accounting matrix (SAM) that represents the supply chain, coupled with information on new uses for hemp products made from feed. The general equilibrium model builds on the SAM and can account for both the direct burden of policies such as a tax, as well as excess burden or deadweight loss, which is loss in economic efficiency when producers and consumers alter their decisions. The SAM traces tax data including taxes paid by production activities and factor use, by purchasers on sales of intermediate and retail goods, and income taxes. Taxes and tariffs influence the behavior of an economy's consumers and producers. They can generate tax revenue but can create an inefficient allocation of resources in the economy that adversely affect household welfare (Burfisher, 2021).

Our scenarios assume that hemp can be cultivated on three million acres in the U.S., a conservative estimate based upon the scaling up of projections in Antle and Cho (2025). A general equilibrium approach is employed so that we can consider farm-level decisions as well as transportation, processing, distribution, and end user markets. We model multiple economic sectors since their participation would be required to create a supply chain for hemp-based products.

Our work builds on prior studies such as Mark et al. (2020), who conduct an analysis of the viability of hemp. They find that hurdles exist towards making it viable, including competition from other crops with well-established markets, competition from global markets where hemp has been cultivated for years, as well as ongoing U.S. regulatory barriers. Yet other studies such as Cho and Antle (2024) and Antle and Cho (2025) find that hemp could be a profitable crop for many farmers, even at relatively low prices. One reason is that hemp can be incorporated into certain double-cropping systems, or into wheat-fallow rotations, with only moderate loss in overall crop output. In other systems there may be a one-to-one replacement, such that hemp displaces hay, to name one example. A theme in the literature has been that the increase in hemp production can occur through the intensification of current agricultural practices and more efficient use of existing arable land (Weyant, 2009).

The contribution of this work differs from earlier studies in that we analyze the economy-wide impact of hemp adoption, accounting for the interrelationships between the various sectors of the economy simultaneously. In a similar study, Reimer and Zheng (2017) quantified the impacts of replacing a portion of fossil fuels in the U.S. aviation industry with renewable energy derived from camelina oilseed. A similar approach was also used by Villoria et al. (2013), who used a general equilibrium model to assess the potential impacts of technological advancements in oil palm cultivation on the forest frontier in Asia.

To give a preview of the results, we show that the hemp-producing crop sector would increase by 3.7% in value under increasing hemp use by end-user manufacturers. This expansion draws in capital and labor from other sectors. However, overall price and quantity effects are modest because much of the new hemp demand would be met by imports from countries that also grow hemp, such as Canada. In light of the fact that U.S. policymakers may want to encourage U.S. production, we find that a tariff of five percent would ensure that increased use of hemp fiber would be met by production within the United States. Since modeling assumptions underlie some of our results, attention is given to sensitivity analysis that allows for different assumptions about key elasticities, such as substitution between domestic and imported hemp, and elasticities between factors of production.

The study sheds light on the transition to a hemp-based economy envisioned by hemp industry observers, researchers, and policymakers. The current lack of information and market uncertainty for hemp presents a significant barrier to its adoption, meaning that it would take a mandate or other targeted incentive to encourage its integration into various sectors of the economy. Complementary policies such as a border restriction may be necessary if there is a non-economic objective being sought, such as U.S. economic self-reliance. Yet the analysis shows there will be small welfare losses for U.S. households if such policies would be adopted in the U.S. The model distinguishes household types based on secondary data sources to demonstrate how representative households are affected.

The next section of this study provides background on hemp production and then turns to an overview of the methods, scenario development, and the general equilibrium model.

Subsequent sections report results, results with a tariff, results under alternative factor market assumptions, and sensitivity analysis. The final sections concern limitations, conclusions, and potential for future work.

Background

Industrial hemp is a cultivar of the *Cannabis sativa* plant species that is cultivated for its fiber, grain or flowers, which can be processed into a wide array of products, including food, beverages, construction materials, textiles, bioplastics, cosmetics, animal feed, animal bedding, insulation materials, and biofuels (Kemda et al., 2024; Johnson, 2018). It is a fast-growing herbaceous annual crop that thrives in diverse agroecological conditions, performing best in temperate climates with average temperatures between 70°- 85°F (Scott, McDonald, and Scousen, 2020). With its ability to yield high biomass while requiring relatively low water and chemical inputs, hemp is both productive and resource-efficient (Parvez et al., 2021). Its extensive root system contributes to soil health by reducing erosion, breaking disease cycles, suppressing weeds, and improving soil aeration for subsequent crops, making it ideal for incorporation into crop rotation systems, especially with grains, oilseeds, and hay (Antle and Cho, 2025). Furthermore, its root system aids in the restoration of degraded soils by removing contaminants such as heavy metals (Rehman et al., 2021). When hemp is used in building materials such as hempcrete, it can lock away sequestered carbon, making it a good crop for environmental sustainability.

Existing research has mostly assessed the agronomics of hemp, analyzing suitable plant varieties for various purposes, optimal cultivation conditions, agricultural practices, as well as life cycle assessments (Fike et al., 2020; Mark et al., 2020). Schumacher, Pequito and Pazour

(2020) find that hemp produces three times more fiber per hectare cultivated than cotton. Phipps and Schluttenhofer (2022) outline other benefits of hemp, including its ability to suppress weeds, its ability to absorb toxic elements from the soil, its high biomass and minimal pesticide requirements. Finnan and Styles (2013) find that hemp could be a more efficient bioenergy source compared to certain energy crops.

In 2014, state departments of agriculture and research institutions were permitted to grow hemp under state pilot programs (Johnson, 2018; Mark et al., 2020). As a result, acreage under industrial hemp increased from zero to 90,000 between 2013 and 2018 (Mark et al., 2020). The pilot programs helped shed light on the challenges faced by growers of hemp including regulatory issues and insufficient information for decision-making. Some of these challenges were addressed in the 2018 Farm Bill, which legalized hemp and removed some of the restrictions that previously existed (Fike et al., 2020). For instance, the definition of hemp was separated from the definition of marijuana, meaning that hemp is no longer classified as a Schedule I controlled substance under the Controlled Substances Act of 1970 (Hamilton and Williams, 2019). Cultivation of industrial hemp is now permitted provided the tetrahydrocannabinol (THC) content of the plant is less than 0.3%. Previously, production and trade of all varieties of hemp as well as products derived from them was illegal regardless of their THC content. Following the legalization of hemp in 2018, production increased and in 2019, the U.S. was the third-largest producer of hemp worldwide after China and Canada. Some bottlenecks still remain with respect to cultivation and commercialization, such as background checks for the growers and ambiguity regarding the regulations by the federal government.

Methods overview

Figure 1 illustrates the overall methodology of the study. The top left box represents all the data needed for the study, including data on hemp production and processing, along with data on the rest of the economy including crop production. This data is compiled within a social accounting matrix (SAM) that numerically represents all trades and transfers between producers, buyers, households, and government, with links back to factors of production. The SAM represents the supply chain in a general equilibrium model.

The middle top box of Figure 1 represents the theoretical economic model, which is a mathematical representation of the behavioral objectives and responses of decision-makers as well as government. The theoretical model accounts for numerous economic features including taxes, subsidies, and other policy instruments. It is a modified version of Lofgren, Harris, and Robinson (2002) and Reimer, Weerasooriya, and West (2015), with multiple markets linked in supply-demand equilibrium through intermediate input use, factors of production, and consumer, demand, and price linkages. The top right box in Figure 1 shows that exogenously determined elasticity estimates are required reflecting technologies and preferences. These represent how different agents respond to price changes, including farmers, processors, distributors, traders, and consumers.

The middle box of Figure 1 denotes how the three elements above are combined to create a calibrated economic model. A model is considered calibrated if it can replicate the prices and quantities associated with the initial equilibrium when hemp is not widely adopted. We then employ simulations to generate new equilibrium values of all endogenous variables. The model establishes equilibrium with policies that would lead to production and consumption of hemp. The counterfactual equilibrium is the hemp-focused supply-chain scenario in the lowest box in

Figure 1. The values of key variables in the hemp-focused equilibrium are compared to the initial baseline values to evaluate different approaches. Measures such as GDP and equivalent variation can be calculated using standard economic theory.

Scenario development

Table 1 reports the status of hemp using data from the USDA National Hemp Report (USDA 2022). In 2021 there were about 12,700 acres grown in the United States with an average yield of 2,620 pounds per acre. The total output was 33,274,000 pounds with a utilized production of 27,610,000. With an estimated price of $1.50 per pound, the total value was $41,415,000. These are all estimates as hemp is still a very new commodity to the U.S., and information collection systems are not refined.

The counterfactual hemp-focused scenario is the rightmost column of Table 1 and is based on projections in recent studies, including Lacasse and Kolodinsky (2022), Cho and Antle (2024), and Antle and Cho (2025). The latter study demonstrates a plausible expansion of hemp to one million acres in the Pacific Northwest region, and this is extrapolated modestly to three million acres at the national level in light of agronomic requirements and the abundance of suitable land across the U.S. For comparison, the U.S. planted approximately 91.5 million acres of corn and 86.1 million acres of soybeans in 2024. Under our assumptions approximately $9,786,094,690 of hemp could be grown.

Hemp fiber can be processed into a wide array of products (Kemda et al., 2024; Johnson, 2018). In the scenarios below we represent how increased hemp production can be used in different sectors, in which certain sectors replace a portion of inputs in various sectors with substitutes derived from industrial hemp. The specific percentages for selected sectors are reported in Table 2, and correspond to our SAM. Looking at the rightmost column, raw materials comprise 10.36% of total costs in the concrete sector when there is no hemp mandate. When there is a hemp mandate, by contrast, 8.22% of total costs arise from non-hemp raw materials. Hemp replaces 2.14 percentage points of non-hemp raw materials in the concrete sector. The reader will note that the changes in Table 2 are conservative, as hemp contributes only 0.07 to 2.14 percentage points of overall total costs. The mandate under consideration is very modest and can be thought of providing a lower bound for the potential of hemp.

For the first simulation, there is no implicit assumption that hemp production needs to occur within the United States, as it could be imported. The model is run with the updated intermediate input ratios to simulate the economic impacts of the mandate. This scenario allows us to quantify sectoral adjustments, including shifts in resource allocation, as well as changes in output and prices.

The second simulation combines the above intermediate input mandate with a five percent tariff on hemp imports from the rest of the world. The tariff is designed to mimic an approach in which policymakers want to incentivize domestic production of hemp by making foreign imports more expensive. By discouraging imports, the tariff serves as a protective measure for the emerging U.S. hemp industry. This scenario helps us evaluate the complementary effects of stimulating domestic production while managing trade dynamics.

General equilibrium model

The applied general equilibrium model has great detail on supply chain relationships at an aggregate level, and recognizes that substitution of inputs in certain sectors draws resources from other sectors of the economy. If a tariff adds to state or federal revenues, for example, this would be accounted for as an increase in income within a final economic domestic product calculation. The behavior of producers and consumers is represented according to standard economic theory and available empirical evidence. Government and other institutions are represented with a fixed specification of behavior. Finally, price responses, cross-price effects and market clearing are accounted for because the prices for factors and commodities are determined endogenously and allow for substitution effects. The model is thus able to measure both direct and indirect feedbacks between agents in the economy, making it ideal for studying the effects of policies or shocks across countries or regions (Kretschmer and Peterson, 2010). This is in contrast with partial equilibrium models which focus on the analysis of a single market in isolation, leaving out feedback from other markets (Burfisher, 2021).

The approach disaggregates the U.S. economy into the 14 sectors (Table 2). The SAM is created from IMPLAN (2024) data based on U.S. government input-output tables, regional economic accounts, consumer expenditure surveys, county business patterns, the census of manufacturing, the census of employment, and the census of retail trade. The SAM is a square matrix that shows a summary of all the economic activities among agents in the economy, namely production sectors, households, factors of production, investors, the government and the rest of the world (ROW) region, thus providing a snapshot of the whole economy. The assumption is that these agents have optimized their behavior and the SAM shows the economy in equilibrium at that point (Lofgren, Harris, and Robinson, 2002).

The model captures the behavior and interactions of consumers, producers, and government, all in a competitive market setting. It is comprised of a system of linear and non-linear equations that represent demands and supplies resulting from the optimizing behavior of firms and consumers, as well as factor and commodity market clearing conditions. The equations are derived from constrained optimization of neoclassical production and consumption functions. Households are assumed to choose their preferred bundles of goods and services for consumption to maximize their utility according to a Stone-Geary utility function and subject to an expenditure constraint, allowing for quasi-homothetic preferences. This utility function gives rise to the Linear Expenditure System (LES) demand system (Lofgren, Harris, and Robinson, 2002).

Instead of presenting the complete model we present several key equations. Readers less interested in model technicalities can skip this section. Industries, or producers, are modeled as representative producers with constant elasticity of substitution CES-Leontief production technologies, as shown in Equation 1.

$$Y_i = \frac{\theta_i}{1 - tva_i - \sum_j ica_{ij}} \left(\sum_f \delta_{fi} \, F_{fi}^{-\rho_i} \right)^{-\frac{1}{\rho_i}}, \qquad (1)$$

where Y_i is the output of good i, θ_i is a shift parameter for the production function, tva_i is the value added tax rate for good i, ica_{ij} is the quantity of i used as an intermediate input per unit of good j, F_{fi} is the quantity of factor f demanded for good i, ρ_i is the exponent for the production function, and δ_{fi} is a share parameter for the production function.

The CES-Leontief production function allows for varying degrees of substitutability between inputs. Producers are assumed to choose their level of operation so as to maximize profits under constant returns to scale conditions. The firms combine the primary factor inputs as well as intermediate inputs to produce final goods. In many parts of the U.S., hemp can be incorporated into existing crop rotation systems, such as with grass or hay, rather than requiring the conversion of new land or displacing other crops. This implies an expansion at the intensive margin, meaning that the increase in hemp production will occur through the intensification of current agricultural practices and more efficient use of existing arable land (Weyant, 2009). Inputs are paid according to their respective marginal productivities. Equation 2 presents the factor demand equation, that equates the marginal cost of the factor in each activity to the marginal revenue product of the factor.

$$\tau_{fi} w_f = \frac{pva_i \theta_i}{1 - tva_i - \sum_j ica_{ij}} \left(\sum_f f \delta_{ffi} F_{ffi}^{-\rho_i} \right)^{-\frac{1}{\rho_i} - 1} \delta_{fi} F_{fi}^{-\rho_i - 1}, \qquad (2)$$

where τ_{fi} is the wage distortion factor for factor *f* in activity i, w_f is the rental rate for factor *f*, and pva_i is the value-added price (factor income per unit of activity) for good i.

For the main analysis a moderate-term scenario is simulated in which supplies of labor and capital are fixed and fully employed. These factors are mobile between sectors, and wages and rental rates are determined endogenously and adjust to ensure market equilibrium.

The elasticities are obtained from previous studies. For example following Reimer and Zheng (2017) we use a value of 1.447 for the elasticity of substitution between domestic and ROW imports of hemp. This value reflects moderate substitutability, implying that U.S.-produced hemp and imported hemp are reasonably interchangeable in production processes. However, some differences such as variations in quality, transportation costs, and regulatory requirements exist and may influence the degree of substitution. To check robustness, we perform sensitivity analyses below by testing a range of values for certain elasticities, allowing us to evaluate how different substitution assumptions affect the model outcomes, and the policy implications.

Results

Table 3 reports results for a scenario in which the building, fiber, agricultural, paper, and other sectors replace a portion of their intermediate inputs with hemp-based inputs, following the approach of Table 2. This increases demand for hemp, leading to a reallocation of resources within the economy. With the mandate alone, the price of domestic output increases slightly (0.155%) as demand rises. Meanwhile the price of imports decreases very slightly (-0.073%) as more comes in from the rest of the world. Domestic output rises by 3.712% as more land in the crop sector is devoted to hemp cultivation, supported by an inflow of labor and capital redirected from other sectors, particularly manufacturing. Yet much of the newfound demand for hemp is met by importers who increase hemp imports; they rise 4.287%. So the increased demand for hemp does not solely translate into domestic production, as imports from the rest of the world can fill a large part of the demand.

One of the rationales for promoting hemp is to encourage job growth in rural areas. In our model jobs can be inferred from how demand for labor changes throughout the economy. The model predicts 66,864 more jobs created in the hemp production sector, which is an increase of 4.094%. Meanwhile, demand for factors other than labor increase by 4.102%. This increase reflects the need for additional resources as farmers and processors expand output to enable hemp use in other sectors. Due to the assumption of fixed supplies of labor and capital in this scenario, factor returns (wages and rental rates) adjust downward to balance the market. Specifically, the returns to labor and capital decrease slightly, by 0.028% and 0.004%, respectively. These changes are negligible because the model's factor market closure assumes full employment (an assumption to be revisited below).

We can also examine the effects on society at large. While many arguments for hemp are economic in nature, there are also non-economic aspects that underlie hemp promotion. The mandate affects the production and consumption decisions of businesses and consumers, and therefore introduces economic inefficiencies into the national economy. Reallocation of factors of production from a relatively undistorted equilibrium into a somewhat more distorted one under the mandate results in a slight fall in gross domestic product (0.018%), which is $3,517 million (Table 3).

We also calculate the welfare effects on nine different groups of households that are distinguished within the SAM. The households are distinguished by level of income, how they spend their money on different goods, and by the composition of income, specifically, the extent to which income comes from labor, capital, or transfers from other households or government. We calculate equivalent variation, which is the change in income that would have the same effect as the change in utility that arises because of a new scenario. Table 3 presents the results for three of the nine representative households distinguished in the model. These three are sufficient to represent low income, middle income, and high income households in a general sense. Equivalent variation is -$10.60 per household per year for households with income $40,000 to $50,000, -$23.10 for households with income $70,000 to $100,000, and -$143.20 for households with income exceeding $200,000. This suggests that a hemp-focused mandate would reduce household welfare. These measures reflect not just changes in income and transfers among households and government, but also behavioral responses, and efficiency changes for the economy as a whole. They result from the distortionary effects of the policy mandate and are well suited to evaluation within a general equilibrium framework (Bhagwati, 1967).

Results with a tariff

Given that policymakers may seek to encourage domestic production, a five percent tariff on hemp imports is considered within the analysis. Tariffs receive little support within the economics literature since they are generally an inefficient way to achieve non-economic objectives; they distort both production and consumption decisions. However given the recent evolution of the U.S. political environment, in which tariffs are a major part of contemporary economic policies, this scenario is designed to mimic what might happen if policymakers seek to protect and stimulate the U.S. hemp industry. By making imports costlier this policy ensures that a higher share of hemp economic activity remains within the U.S. economy.

Table 3 shows that with a tariff the results change substantially in terms of creating more U.S. production, but get worse in terms of GDP and household welfare. With the tariff, the price of domestic output increases by 0.245% instead of 0.155%, reflecting higher production costs associated with reallocating resources to meet the increased demand for hemp domestically. The price of imports by themselves increase 4.887% instead of decreasing very slightly (-0.073%), due to the tariff. Domestic output rises by more than before, 4.724% instead of 3.712%, since fewer imports come in due to their being less cost-competitive. With the tariff, imports decrease by 1.626% instead of increasing by 4.287%.

Since firms adjust their input sourcing decisions in response to changes in relative prices, factor usage is also affected. The expansion of the hemp industry creates 85,142 jobs instead of 66,864 jobs, which is a 5.214% increase instead of a 4.094% increase. Similarly, more capital is drawn in than before (5.220% vs. 4.102%).

The tariff decreases gross domestic product slightly more (0.032% versus 0.018%) with a fall of $6,500 million instead of $3,517 million. With the tariff, equivalent variation worsens to -

$18.8 instead of -$10.6 per household per year for households with income $40,000 to $50,000, -$39.7 instead of -$23.1 for households with income $70,000 to $100,000, and -$246.8 instead of -$143.2 for households with income exceeding $200,000. Results for the other six households are similar to these magnitudes. Tariffs are more distorting than a production subsidy, for example, because tariffs affect both production and consumption decisions within the model. The change in welfare comes from the deadweight loss.

Together, the mandate and tariff demonstrate a complementary approach to stimulating domestic hemp production. While the mandate drives initial demand and resource reallocation, the tariff ensures that the benefits of this increased demand are captured within the U.S. economy, rather than being distributed to foreign suppliers. By raising the relative cost of imported goods, this approach curtails imports and supports domestic producers. However, this comes at a cost of economic efficiency and household welfare.

The findings are driven in part by the model's equilibrium closure mechanisms. Capital and labor are held fixed in supply, and adjustments in factor returns take place to ensure the market attains equilibrium. The changes in wages and capital returns are minimal, since they are set at the national level and are assumed to be fully employed in this particular scenario. To make sure our results aren't driven too much by the assumptions, we consider different closures in the alternative assumptions below.

Alternative assumptions: Factor market closure rules

To assess the impact of varying factor market closures on the outcomes of the policies aimed at stimulating hemp production, we run the analysis with the mandate and tariff scenario under other closure rules as shown in Table 4. These differ in the assumptions about availability and mobility of capital and labor, as well as the possibility of unemployment in the labor market. In a sense they approximate what a long run equilibrium may look like, relative to the earlier results.

Table 4 shows that greater flexibility in the U.S. economy implies there is less need to import hemp, because it is easier to increase domestic supplies. Imports from the rest of world decline by 4.082 to 4.092% instead of the 1.626% decline in Table 3 when a five percent tariff is in place. Domestic output increases by 4.828 to 4.832%, slightly higher than the 4.724% in Table 3. This greater reliance on domestic output is possible because capital and labor can be substituted more easily across sectors of the economy. The greater flexibility in this scenario is exhibited in factor market responsiveness. Labor and capital demand increases by approximately 5.8% across all scenarios, as compared to approximately 5.2% in Table 3.

The Table 4 results are consistent with expectations, which is that across a longer time horizon firms can enter and exit in different sectors according to market incentives. Some firms may enter hemp-related activities while others have more flexibility to adopt hemp-based products. In a long term horizon there is greater time to reallocate resources in response to market signals.

Sensitivity Analysis: Substitution elasticities for domestic vs. imported hemp

We can also test the sensitivity of the results to varying elasticities of substitution between domestically-produced and imported hemp. We run the simulation using a range of elasticities of between 0.5 and 5.0 and use these to plot confidence intervals. The results are in Figure 2 and illustrate the extreme upper- and lower-bounds of individual results. There is little variation in the likely outcome range for most variables, except in the case of import quantities.

Table 5 presents a more detailed examination, showing results of the simulation for with the elasticities between 50% and 150% of 1.447, which is the value used in the main simulation. The lower-bound elasticity value implies limited substitutability between domestic and imported hemp. In this case the increase in domestic output is more modest at 4.127%, and imports from the rest of the world rise slightly by 0.965%. This suggests that with lower substitutability, firms find it harder to switch from imported to domestic hemp, leading to a moderate increase in domestic production and a small rise in imports. The upper bound elasticity value of 2.171 implies greater substitutability between domestic and imported hemp. In this case the domestic output increases somewhat more (5.288%) and imports from the rest of the world decrease by 4.076%. This reflects a stronger shift towards domestic production as firms respond more flexibly to incentives, substituting away from imports to meet the increased demand domestically. Under the higher elasticity, the domestic price of output rises more under lower substitutability (0.273% compared to 0.215%) and the value of output sold increases 5.329% compared to 4.171%. These changes are consistent with a higher responsiveness to policy measures when hemp is more substitutable, leading to greater production and sales in the domestic market.

With regard to factor demands, the demand for both labor and capital increases more significantly in the higher elasticity scenario: 5.836% compared to 4.555%. This indicates that more resources are mobilized to expand domestic production, reflecting higher economic activity in response to the policy. The returns to labor wages and capital are slightly negative in both scenarios, with a slightly larger decline in the higher elasticity case, with a 0.049% decline in wages and a 0.014% decline in capital returns.

The overall results underscore the importance of elasticity choice in determining the effectiveness of policies aimed at stimulating domestic production and reducing import reliance. We find that there are small differences depending on what elasticity is chosen, but the overall results from Table 3 do not change in a significant way. This adds confidence that the main results are reasonably robust to changes in elasticity assumptions.

Limitations

There are a number of issues that this analysis has left unexamined that should be acknowledged. First, many model parameters were calibrated using data before the counterfactual was in place, implying that certain parameters could have been different. The implication is that the results are not necessarily of the standard of an actual forecast. This is a common problem of trying to estimate the effects of economic policy with a model that relies upon historical data (Lucas, 1976).

Second, while the analysis has good detail in terms of inter-industry relations, the analysis is at an aggregated level geographically. Some of the more nuanced inter-industry linkages are only quantifiable if one looks at the U.S. as a whole. In addition, the model does not account for land scarcity, variations in land productivity, or the potential environmental implications of expanding hemp production on different types of land. The scenarios were designed to reflect land scarcity, but this is an area for future improvement. Adding these factors might increase the degree of resolution, but would not likely change the overall results that are provided to the literature. Future research could examine individual regions and give a more nuanced understanding of how land-related factors affect the economics of hemp adoption.

A third general observation is that the environmental benefits of transitioning to a hemp-based economy could be analyzed in future research. Translating the economic findings into environmental metrics, such as reductions in greenhouse gas emissions, reductions in carbon footprint, and improvements in soil health, could make the results more relevant to environmentalists and policymakers focused on sustainability. This is beyond the scope of the current study.

In conclusion, by focusing this study at larger scales and carrying out a macro-level analysis, we have foregone some richness and possible realism. However, we have captured broad economy-wide impacts that have not yet been considered in any other economic study.

Conclusions

The purpose of this study was to analyze selected macro-economic aspects of increasing hemp production and hemp-product consumption in the U.S. We consider in broad terms a mandate that would result in hemp adoption in a variety of sectors for which it is plausible given existing technology in hemp-based product research and development. The mandate we have considered is modest in scope and can be thought of providing a lower bound for the potential of hemp for the U.S. We find that under reasonable assumptions about land availability and cropping rotations, the value of the crops sector could increase by 3.7 to 4.7% under a policy mandate in which a variety of sectors attain a share of their raw material needs with hemp fiber. We estimate that 66,864 to 85,142 jobs could be created in hemp-related production and processing under such a scenario. The increase in U.S.-related economic activity is bigger if the mandate is accompanied by a border restriction such as a tariff. Otherwise much of the demand for hemp could be met with imports.

The overall economic impact of the policy experiment considered in this study is very small when viewed through national aggregates such as GDP, which declines by 0.018 to 0.032%. However, the effects on individual sectors are relatively large, particularly the hemp production and processing sectors. The policies modeled in this study lead to significant increases in output, labor demand, and capital investment in the hemp production sector. These changes can result in meaningful economic benefits for farmers and agribusinesses, as well as improved job opportunities and wages for workers. This indicates that while the policies to promote hemp production might lead to sector-specific gains, the overall economic impact is very modest. In the absence of environmental benefits (not examined here) there is little reason to enact such a policy, as the main effect is to divert resources from non-agricultural sectors to the agricultural economy.

Due to the altered incentives for production and consumption decisions under a mandate, such a policy approach slightly reduces household welfare for the typical U.S. household who is not actively receiving income from increased hemp production and usage. The adverse effect increases with the income of the household because (even under full employment of productive factors) a tariff drives a wedge between producer and consumer prices, leading to small distortions in the economy. This is the excess burden of the policy instrument, and accounting for it is one of the contributions of this study to the literature on the economics of hemp.

The adverse effects are modest, however, and the analysis does not account for potential non-economic benefits of increased hemp production and use. Production and use of hemp products can have environmental benefits, as hemp can be sustainable with a lower environmental footprint compared to other materials. Therefore, promoting hemp cultivation may not only offer economic advantages but could also be part of a broader strategy to enhance the sustainability of U.S. agriculture. These goals are consistent with the recent Farm Bill objectives of promoting sustainable agricultural practices and fostering rural development. Hemp production can stimulate economic activity in rural areas, providing new income streams for farmers and creating jobs, thereby contributing to rural economic development. Part of the push towards hemp adoption in the U.S. may also be due to an objective of domestic self sufficiency, which is to say less reliance on imports.

We have not quantified these latter types of potential benefits because they are non-economic aspects, and as such are beyond the scope of this study's general equilibrium model. Future work could evaluate a more comprehensive set of tradeoffs involved in hemp production and consumption, and address some of the limitations of our approach that were addressed above.

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Table 1. Baseline and counterfactual data for hemp grown for fiber

Variable	Unit	Baseline	Hemp mandate
Acreage	acres	12,700	3,000,121
Average yield	pounds/acre	2,620	2,620
Total output	pounds	33,274,000	7,860,317,020
Utilized production	pounds	27,610,000	6,524,063,127
Price	$/pound	1.50	1.50
Total value	$	41,415,000	9,786,094,690

Source: National Hemp Report (USDA 2022)

Table 2. Replacement of non-hemp raw materials with hemp, selected sectors

	Building materials and related industries	Fiber products and related industries	Paper products and related industries	Concrete products and related industries
Percent that raw materials have of total costs in this sector (no hemp mandate)	15.78	28.05	18.54	10.36
Percent that raw materials have in total costs of this sector (with hemp mandate)	15.71	26.46	18.12	8.22
Percentage points of non-hemp raw materials that have been replaced with hemp	0.07	1.59	0.42	2.14
Total production costs (millions)	$1,865,833	$81,956	$308,697	$60,996

Note: In addition to the hemp and crop production sectors and those above, the following sectors are distinguished: Other farming, Ag and food processing, Food and drinks away from home, alcohol, tobacco; Energy; Mining; All other manufacturing; Wholesale and retail trade; Transportation; and Housing and services.

Table 3. Primary results by scenario

Variable	Mandate	Mandate plus 5% tariff
Change in crops sector:		
Price change: domestic output	0.155%	0.245%
Price change: imports	-0.073%	4.887%
Quantity change: domestic output	3.712%	4.724%
Quantity change: imports	4.287%	-1.626%
Change in demand for labor in this sector	66,864 jobs (4.094%)	85,142 jobs (5.214%)
Change in demand for capital in this sector (inclusive of land)	4.102%	5.220%
Societal impacts:		
Change in U.S. GDP	-$3,517 million (-0.018%)	-$6,500 million (-0.032%)
Equivalent variation for U.S. household with income $40–50,000	-$10.6	-$18.8
Equivalent variation for U.S. household with income $70–100,000	-$23.10	-$39.7
Equivalent variation for U.S. household with income exceeding $200,000	-$143.2	-$246.8

Table 4. Change in crops sector under different factor market closures (%)

Variable	Capital is mobile & fixed, labor is mobile & variable	Capital is mobile & fixed, labor is mobile, variable (unemployment possible)	Capital is mobile and variable, labor is mobile and variable	Capital is variable, labor is mobile (unemployment possible)
Price change: domestic output	0.271	0.269	0.271	0.270
Price change: imports	4.832	4.831	4.830	4.828
Quantity change: domestic output	5.282	5.279	5.273	5.265
Quantity change: imports	-4.082	-4.086	-4.086	-4.092
Change in demand for labor in this sector	5.821	5.812	5.814	5.797
Change in demand for capital in this sector	5.835	5.838	5.828	5.822

Note: Scenario concerns a hemp-focused mandate coupled with a five percent tariff.

Table 5. Change in crops sector under different elasticities of substitution

	Change (%)	
	Elasticity=0.732	Elasticity=2.171
Price change: domestic output	0.215	0.273
Price change: imports	4.944	4.834
Quantity change: domestic output	4.127	5.288
Quantity change: imports	0.965	-4.076
Change in demand for labor in this sector	4.555	5.836
Change in demand for capital in this sector	4.561	5.843

Note: Concerns the exogenously specified constant elasticity of substitution between domestic and imported hemp. Scenario concerns a hemp-focused mandate plus a five percent tariff.

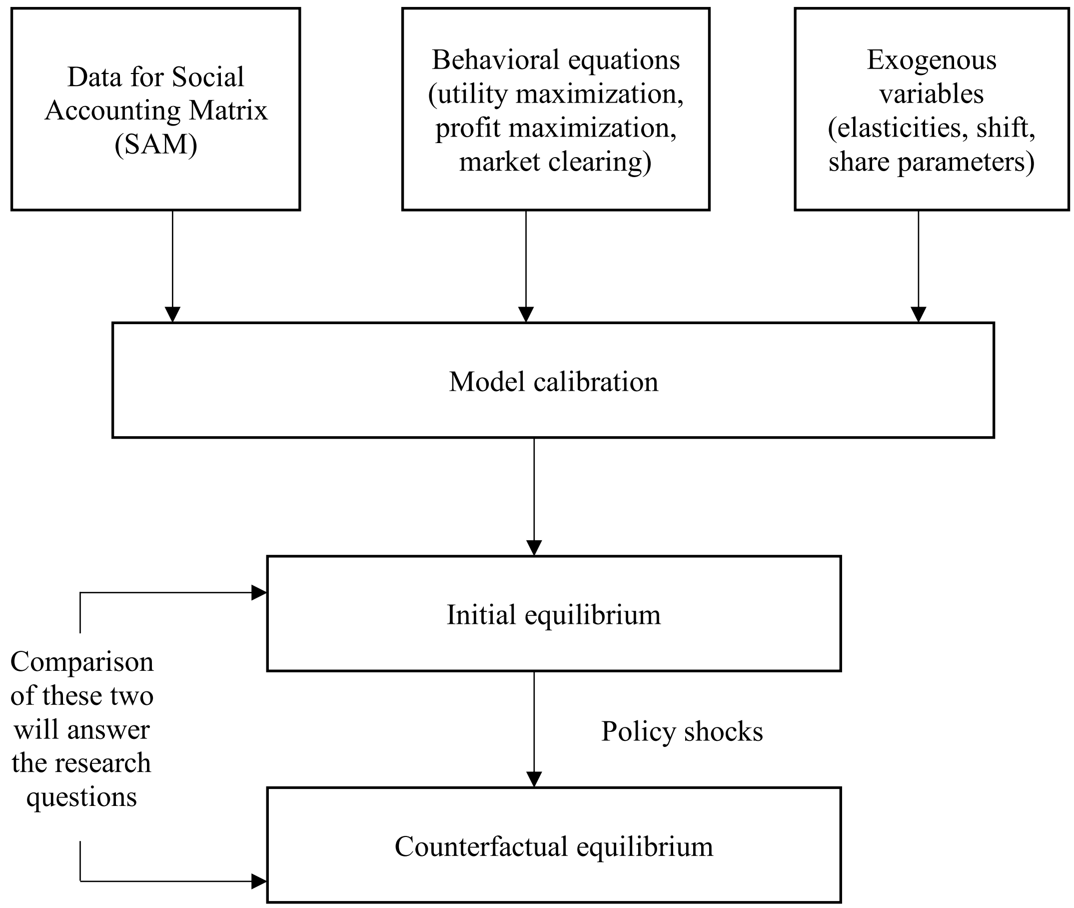

Figure 1. Overview of methodology

Source: Author illustration.

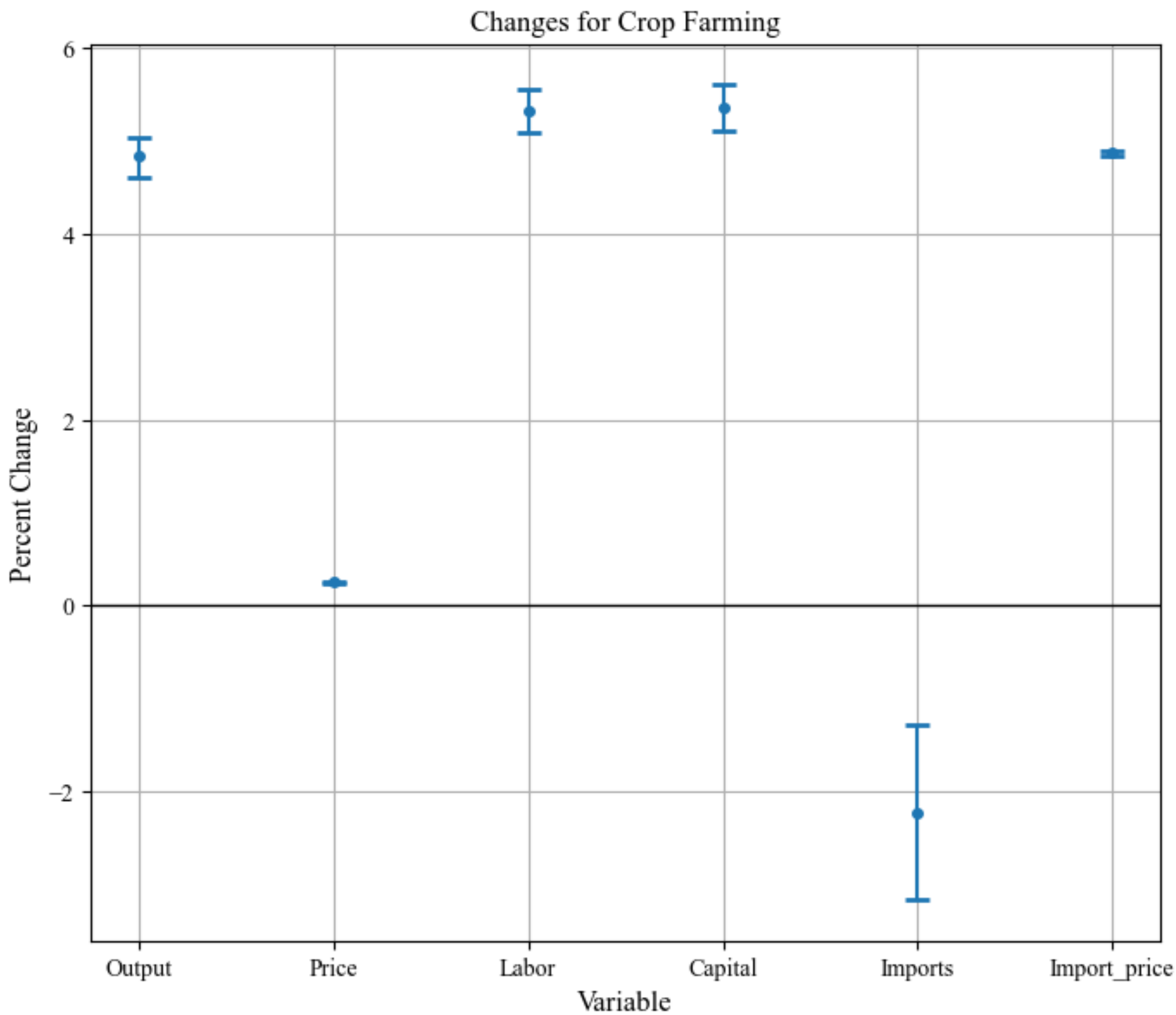

Figure 2. Confidence intervals around variable changes for hemp production sector

Source: Model simulation results for a hemp-focused mandate coupled with a five percent tariff.