January 2025

Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda

Project Paper No. 8

Ulaş Karakoç
Assistant Professor in Economics
Kadir Has University
ulas.karakoc@khas.edu.tr

Alp Erinç Yeldan
Professor in Economics
Kadir Has University
erinc.yeldan@khas.edu.tr

Role of Agriculture in Green Transition in Türkiye

Abstract

This paper evaluates the role of the agricultural sector in reinforcing green transition and green industrialization in Türkiye. Section 2 provides a long-run assessment of the structural change and agricultural transformation since the mid-twentieth century based on official statistics and novel historical data. Our estimates show that the sizable rural-urban migration, intensive land use, and technical change have gone hand in hand in the context of small-holder farming to the effect that the land and labor productivity increased until very recent times. However, Section 3 argues, these trends have slowed down since 2000, as arable land and demographic trends are unfavorable for further agricultural intensification. The recent policy framework set out to align with the EU's New Green Deal insufficiently addresses the underlying structural challenges. Section 4 runs several possible greening scenarios that simulate the effects of green transition on the agricultural output, as well as green-house gaseous emissions and macro effects, using a computable general equilibrium model. Our model simulation exercises suggest that a 50 percent decrease in chemical use and a 10 percent carbon tax have yet only limited adverse effects on the overall farm output, and a commensurate proportional reduction in the dependence on fossil fuels due to expanded renewables together with policies that enable further rise agricultural productivity can reverse such adverse effects.

Contents

KEYWORDS: Green Transition, Sustainable Agriculture, Computable General Equilibrium (CGE) modelling

Acknowledgements

This paper has been prepared under the UNCTAD project "Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda", funded by the 2030 Agenda for Sustainable Development Sub-Fund of UN Peace and Development Trust Fund of DESA. The author would like to thank UNCTAD staff for comments on earlier drafts. This paper represents the personal views of the authors only. The authors accept sole responsibility for any errors.

Introduction

The ongoing climate change and the upward trend in food prices in the world markets have recently put the agricultural sector at the front of economic policy debates. The war in Ukraine and other geopolitical conflicts compound food security concerns due to possible adverse effects on world trade. Also, in view of the substantial contribution of the current farming systems to carbon emissions, the green transition efforts, primarily in Europe and elsewhere, aim to push significant changes in the farming systems via the reduction in the use of chemical inputs and a marked increase in the land devoted to organic agriculture, sustainable practices, and biodiversity.(FAO 2017; 2018; Arata, Fabrizi, and Sckokai 2020) All these factors coincide with the ongoing downward trend in the amount of arable land, land degradation, the loss of soil nutrients, and the contamination of soil and water due to heavy amounts of chemicals, therefore, the conventional farming systems have increasingly been put into question.

On the other hand, countries face an increasingly urgent need to transform their domestic industrial sectors in line with their priorities to combat climate change, which set the stage for green transition. Facing domestic challenges, such as high unemployment and informality in the labor market, premature de-industrialization (UNCTAD 2016), and global competition, the efforts to decarbonize existing manufacturing capacities requires considering agricultural transformation, industrial restructuring, and structural change. Such a combined approach is particularly relevant for developing economies, such as Türkiye, as they have sizeable agricultural employment in the predominantly small and medium-scale family enterprises responsible for the bulk of the agricultural production. These countries also have sizable manufacturing capacities, with forward and backward linkages to agricultural production. Such challenges underline the importance of holistic solutions and integrated policy frameworks of industrial and agricultural policy at both local and global levels. At the national level, it is more imperative than ever for developing countries to adopt innovative and integrated policy strategies to pursue resilient, green, and transformative development. That said, governments of the developing countries are constrained by limited capacity to mobilize resources and lack of institutional and organizational capabilities.

Türkiye is home to more than a million of small and medium-scale farmers primarily producing for the domestic, and to a lesser extent, for export market. A sizable portion of vegetables and fruits are exported, mainly to Europe and the Middle East. In 2022, the share of agricultural exports in total agricultural production (including fishing and forestry) was about 4 percent. In 2021, agriculture, fishing and forestry were responsible for 6,3 percent of the Gross Domestic Product (GDP) and about one-fifth of the labor force. Despite the low productivity, the rural sector in Türkiye arguably plays a prominent role in the national safety net, as it absorbs the labor surplus and provides direct access to food for poorer or low-income communities. The different geographical features offer a variety of crops to be processed by the manufacturing sector. On the other hand, the recent downward trend in the arable land and the agricultural labor force can alarmingly be considered as signaling the low resilience level of the rural communities. What compounds this negative trend is that Türkiye is in a geographical zone expected to face significant warming, particularly the Mediterranean regions in the south.

While the agricultural practices, land use intensity, and carbon-based inputs vary from region to region, the areas currently producing the bulk of the produce are those intensively consuming fossil-fuel-related inputs, such as mineral fertilizers, chemicals, and oil. According to official estimates, Türkiye's total net greenhouse emission in 2021 was 564.1 MtCO2, and 12.3 percent of it was due to the agricultural sector[1], almost equal to direct industrial production emissions. The breakdown of the emissions of the agricultural sector in 2021 was 19.23 MtCO2 by enteric fermentation in animal husbandry, 5.14 MtCO2 by fertilizer consumption, 16.87 MtCO2 by the land use in farming (TCÇŞİDB, 2024). In line with increasing number of animals and the fertilizer use in the last decade, the emissions of the agricultural sector notably increased.

The ongoing efforts towards a more efficient rural economy and releasing lower carbon emissions are in the early stages; and admittedly, no systematic and robust policy framework exists. The government has recently passed several legislations towards aligning with the European Green Deal and EU's *Farm to Fork strategy*, setting up specific carbon emission targets. Yet, the ways such goals will be achieved, and the particular policy pathways remain uncertain.

The Farm to Fork Strategy[2] is, in the words of the *European Commission,* is at the heart of the so-called *European Green Deal*, aiming to make food systems *fair, healthy* and *environmentally friendly*. More formally, The Farm to Fork Strategy of the EU, aims to accelerate Europe's transition to a sustainable food system via

- stimulating a neutral or positive environmental impact
- mitigating climate change and reinvigorating adaption towards its impacts
- reversing the loss of biodiversity
- ensuring food security, nutrition and public health, making sure that everyone has access to sufficient, safe, nutritious, sustainable food
- preserving affordability of food while generating fairer economic returns, fostering competitiveness of the EU supply sector and promoting fair trade.

Against this backdrop, this article evaluates the role of the agricultural sector in reinforcing greemn transition and green industrialization in Türkiye. Section 2 provides a long-run assessment of the structural change and agricultural transformation since the mid-twentieth century based on official statistics and novel historical data. Our estimates show that the sizable rural-urban migration, intensive land use, and technical change have gone hand in hand in the context of small-holder farming to the effect that the land and labor productivity increased until very recent times. However, Section 3 argues, these trends have slowed down since 2000, as arable land and demographic trends are unfavorable for further agricultural intensification. The recent policy framework set out to align with the EU's New Green Deal insufficiently addresses the underlying structural challenges. Section 4 runs several possible greening scenarios that simulate the effects of green transition on the agricultural output, as well as green-house gaseous emissions and macro effects, using a computable general equilibrium model. Our model simulation exercises suggest that a 50 percent decrease in chemical use and a 10 percent carbon tax have yet only limited adverse effects on the overall farm output, and a commensurate proportional reduction in the dependence on fossil fuels due to expanded renewables together with policies that enable further rise agricultural productivity can reverse such adverse effects.

[1] TURKSTAT, Environmental Statistics, https://data.tuik.gov.tr/Kategori/GetKategori?p=cevre-ve-enerji-103
[2] https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

2. Long-run aggregate and regional trends of agricultural output, employment

This section outlines the leading indicators of the agricultural output and growth with a succinct historical overview. We discuss the share of agriculture in GDP and aggregate employment by combining the available official estimates with detailed long-run data. Second, we calculate the land and labor productivity in agriculture and discuss the shifts in crop composition by focusing on the major field crops produced in Türkiye. All these indicators are discussed at the national and regional level (NUTS2); therefore, we are able to assess the national as well as sub-national patterns, that are crucial to give a more accurate view of the long-run agricultural development and structural change that takes into account the considerable geographical and economic heterogeneity. Finally, in light of the long-run overview of the output, employment, and productivity, we touch upon the current challenges in further improving productivity in agriculture.

2.1 Aggregate long-run trends in agriculture

Türkiye's published official national income accounts go back to the 1920s, so the aggregated national output estimates with a sectoral breakdown are available for the republican period since 1923. Therefore, the share of agriculture, which includes farm production, animal husbandry, and forestry, in the national income is well documented. On the other hand, the official regional output estimates are relatively recent, as they are available for the years starting from the late 1980s.[3] This study's historical regional output estimates are based on the recent work of Aşık, Karakoç, and Pamuk (2023), presenting the novel, and the only available, output estimates for three main sectors (agriculture, industry, and services) since the onset of World War II at the spatial units that roughly correspond to current provincial borders. We aggregate these regional estimates into NUTS-2 regional classification so that the long-run output and employment data are consistent with the post-2000 classification of the regional data, which is only available at NUTS-2 level.

Figures 1 and 2 show the national trends of the share of agriculture in GDP since 1939, as well as indices of land and labor productivity, respectively. The downward trend in the share of agriculture of output and employment is evident and consistent over time. While the share of agriculture in the total output decreased from 40 to 7.5 percent between 1939 and 2020, its employment share declined even more dramatically from 81 to 27 percent. This order of magnitude points to a powerful structural transformation from agriculture towards industry and

[3] The official regional output estimates exist in two distinct series since 1988. The first series between 1988-2001 have the provincial breakdown, while the second one for the post-2004 are available at NUTS-2 level. See Aşık, Karakoç, and Pamuk (2023) for the details of the data sources and methodology of the construction of the regional output estimates. It has further to be noted, that the employment data for the years up to 2000 are obtained from the population censuses, which were not carried out after 2001. The aggregated census publications summarize the "sector of current economic activity" of working-age people, those over 12 years old, for each province. The sectoral breakdown in this series has 10 levels, which we categorize into agriculture, industry, and services. The definition of "current economic activity" does not perfectly conform with the modern definition of employment measures, as it indicates the sector of the economic activity of individuals regardless of the current employment status. However, for agriculture, in a country where smallholder farming is the dominant form of production, this measure is arguably more indicative than the current working status due to the seasonal character of the farming work and the fact that most farmers are smallholder farm owners rather than employees. Since 2000, however, we have used the official employment estimates provided at the national and regional levels by TUIK. As a result, the employment data before and after 2000 are not sufficiently consistent since the type of data source (population census vs. administrative labor force statistics) changed after 2000. When we present the share of agricultural employment instead of its levels, we directly use the available data for both periods without any manipulation, assuming that the sectoral share is comparable when working with two types of employment data. By contrast, when calculating labor productivity, we emphasize the difference in the underlying data types between pre- and post-2000.

services. Three main periods appear in comparing changes in the shares of output and employment over different subperiods. Between 1939 and 1970, agriculture was steadily responsible for around 40 percent of the national income; however, the share of agricultural employment started declining after 1950. The following period, 1970-1991, witnessed a rapid decline in the share of agricultural income, down to 12-13 percent, accompanied by a speedy decline in agricultural employment. Finally, since 1991, the third period, the agricultural income kept declining at a much slower rate, while the employment share has fallen rapidly.

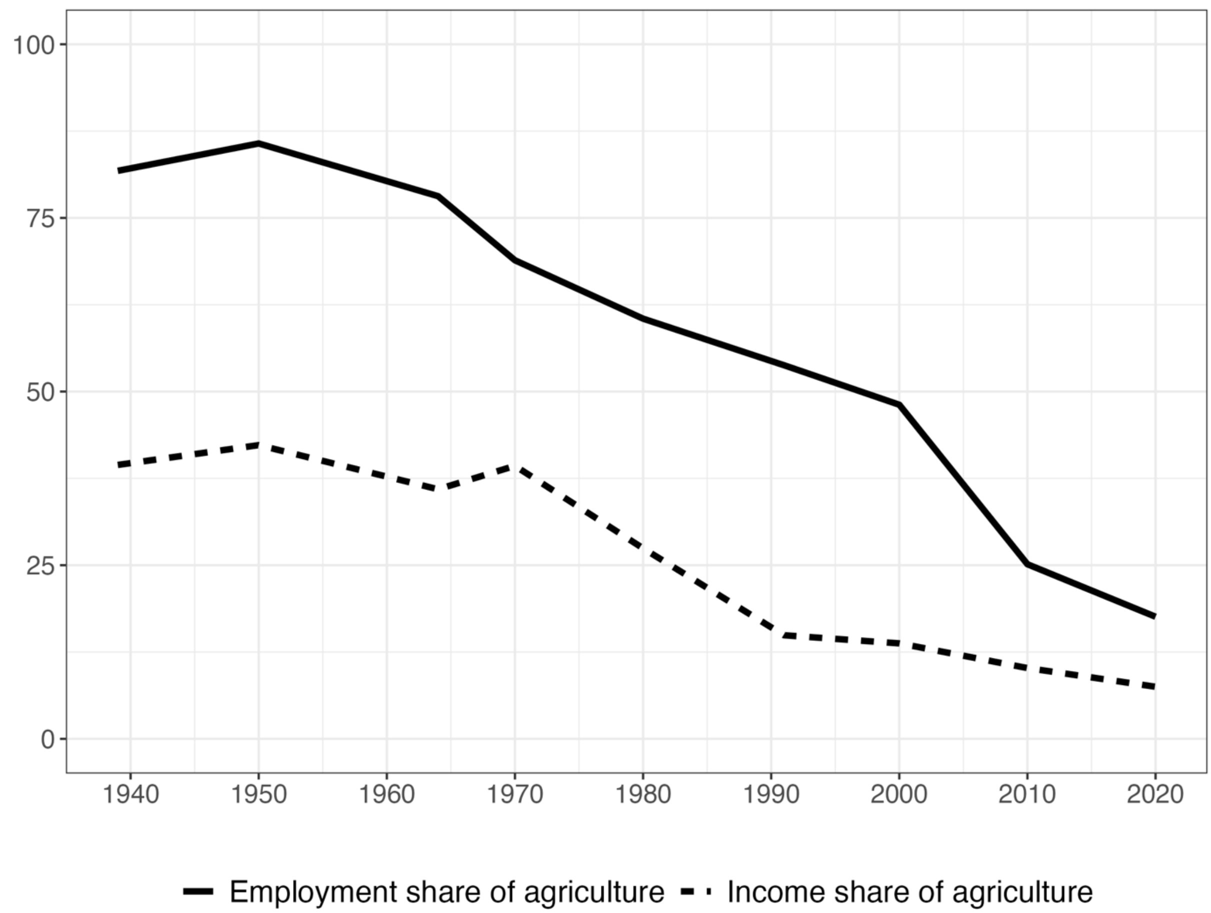

Figure 1 Share of agricultural output and employment (%)

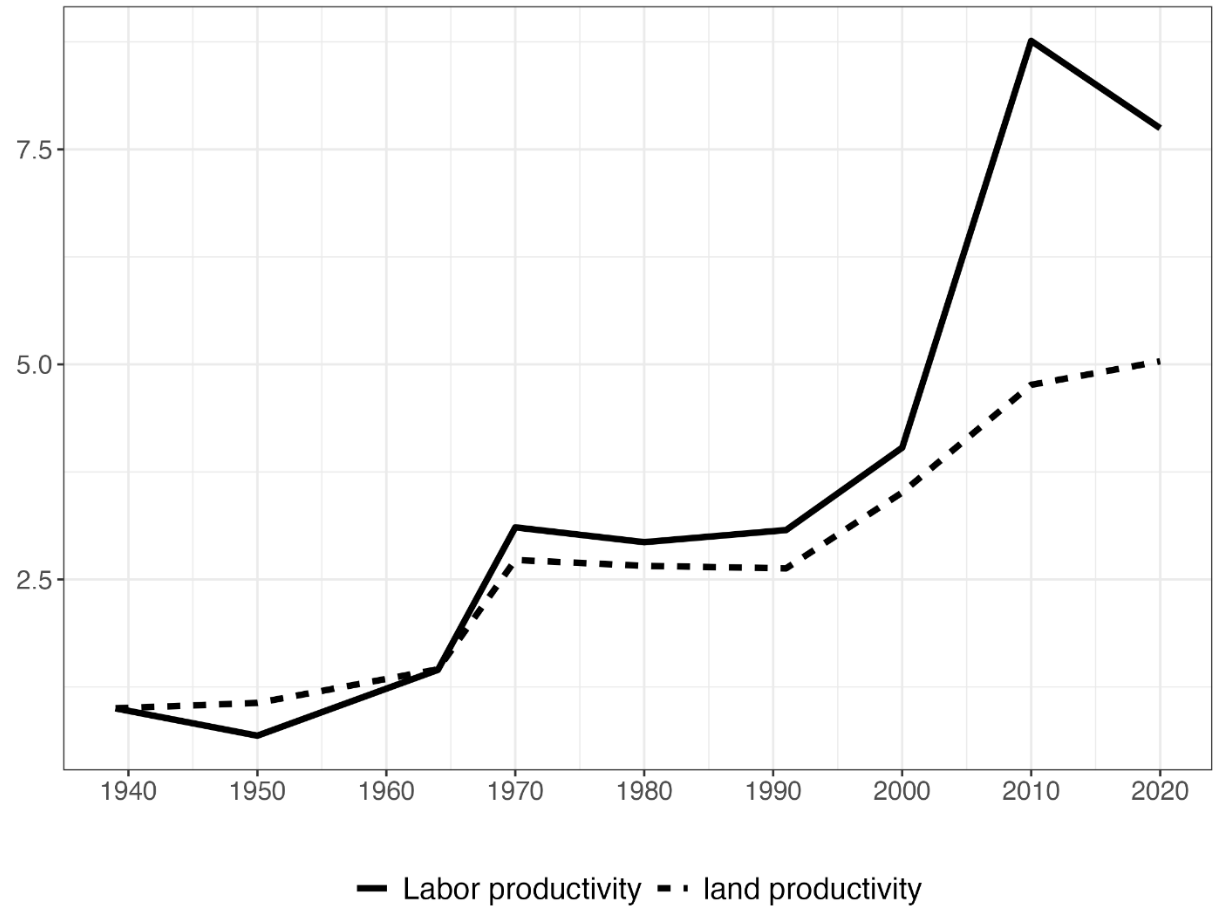

Figure 2 Indices of land and labor productivity

Behind these different trends in the share of output and employment lay, first of all, the rapid rural-urban migration that started in the 1950s and forcefully continued until 2010.[4] However, the last decade, 2010-2020, saw a decelerating decline in the employment share. Second, the increasing land productivity, particularly between 1950-1964 and 1991-2010, made it possible to keep food production stable despite the decline in the agricultural labor force. 1950s was the period when Marshall Plan was in action and provided stimulus to the adoption of tractors by farmers. As for the period 1991-2020, the continued investment in irrigation facilities, better seeds and the expanded use of fertilizers helped to boost the crop yields. Following the increase in land productivity and structural shifts of labor shift towards the non-agricultural sectors, agricultural output per person has followed chiefly the land productivity. Therefore, the structural transformation since the mid-century has been facilitated by a substantial labor shift away from agriculture and an increase in the land productivity. The combination of labor shift and technical change in agriculture made it possible to help industrial growth and services expansion throughout the second half of the 20th century. Simultaneously, however, due to the delays in aggregate gains in economic and technical productivity of the agricultural sector as a whole, the average

[4] For an evaluation off the changes in the national income and GDP decomposition in Türkiye during the 20th century, see Altug, Filiztekin, and Pamuk (2008). Pamuk (2018) provides an overview of the main contours of the economic history of the country in the last two centuries.

agricultural wages remained lower than the urban wages despite the improvements in the average agricultural incomes.

A set of factors has shaped this specific pattern of structural change. First, the relatively high wages in industry and services provided a decisive pull factor, which made millions of peasants in the countryside move to urban areas. This shift can be argued to be mostly due to a reflection of the *urban-bias* a la Lipton (1977), a concomitant pattern of the import-substitution industrialization strategy. When industrialization did not proceed steadily, and real wages eroded, such as in the 1990s, most people found service wages favorable, particularly after the 1990s.[5] Second, the direction of technical change in Turkish agriculture in the second half of the 20th century was mainly characterized by the relative scarcity of land. As Hansen (1991) argued, Türkiye had an open land frontier, and the land-labor ratio had been relatively high until the 1950s. The end of prospect for bringing more cultivable land into use at the mid-century and fast population growth kept demanding a particular type of technical change that could boost land productivity. Following the opportunities laid out by the Marshall Plan immediate after the World War II, the intensified mechanization in the 1950s (*tractorization*), the introduction of high-yielding wheat seeds in the 1960s and after that (*Green Revolution*), and the rise in public investment in irrigation after the 1980s all together led to the significant increase in land use intensity, multiple cropping, and large-scale use of chemical fertilizers and water. Yet, while the land productivity increased over time due to this specific pattern of technical change, the rural average incomes remained lower than the industrial and services wages as argued above. Therefore, the surplus rural labor kept moving towards the urban areas. These dynamics have remained strong until the first decade of the 2000s.

The rural-urban migration and structural change of this type have predominantly been market-driven, being shaped by the decisions of the market actors. However, the role of government has also been substantial. The technical change in agriculture, such as mechanization, development of seeds technology or irrigation investments have been mainly due to successive governments' efforts to increase rural incomes and keep food prices low for the sake of industrialization and urbanization. The different forms of *urbanism* characterized the public policy despite the occasional attempts to modernize farm production. However, millions of small peasant families have been the primary decision-makers regarding what to produce, how to produce, marketing, and allocating labor between locations and occupations. The policymakers or intellectuals discussed more radical rural reforms, such as land reform or regional planning, at times, but such reform plans have never materialized.

Another factor behind the increased land productivity has been the shift towards cultivating cash crops, which has brought higher profits. Farmers have adopted multiple cropping and industrial crops such as cotton, sugar beet, tea, and rice in the regions where soil fertility and water resources are favorable. Figure 3 shows the share of principal field crops in aggregate crop area. It appears that since the 1970s, the share of wheat decreased to 50 percent, whereas the share of major cash crops (cotton, maize, rice, sugar beet, and tobacco) increased progressively from 10 percent in 1939 to 18 percent in 2020. At the sub-national level, the most fertile agricultural regions increasingly became cultivated cash crops. For instance, cotton cultivation, a highly input-intensive crop, notably increased in the last three decades, partly because of the large-scale irrigation investments in the Southeast and mechanized harvesting, which came about in the early 2000s. Maize and rice, as well as other industrial crops, have seen a remarkable adoption, too.

[5] See Pamuk and Toprak (1988) for a discussion of the wide-ranging aspects of the transformation of the agricultural sector before 1980s.

While the relative food prices predominantly shape the year-to-year crop choices, the favorable animal feed prices also helped to increase the significant feed crops such as barley and oat. In short, the primary dynamics has been the rise of cash crops at the expense of legumes and seed crops such as broad beans, millet, rye, and sesame.

The agricultural support schemes were also responsible in driving the changes in crop composition. The scheme in place until the early 2000s depended on the floor prices determined by the government at the crop level and the direct support purchases, which aimed to stabilize the demand and supply. However, the early 2000s brought about significant changes in the support policies due to the adjustment to the Common Agricultural Policy. First, the role of crop premiums was reduced. Second, the decoupled direct payment scheme was introduced, in that farmers were paid a specific payment depending on the size of their land, regardless of the crop choices or the actual cultivation status of their farms. Today, the crop-specific payments remain in place, but their share in total support payments declined substantially. Overall, the new policy framework aims to reduce market-distorting policies. Therefore, the support schemes arguably affected the crop choices less than in the previous periods.

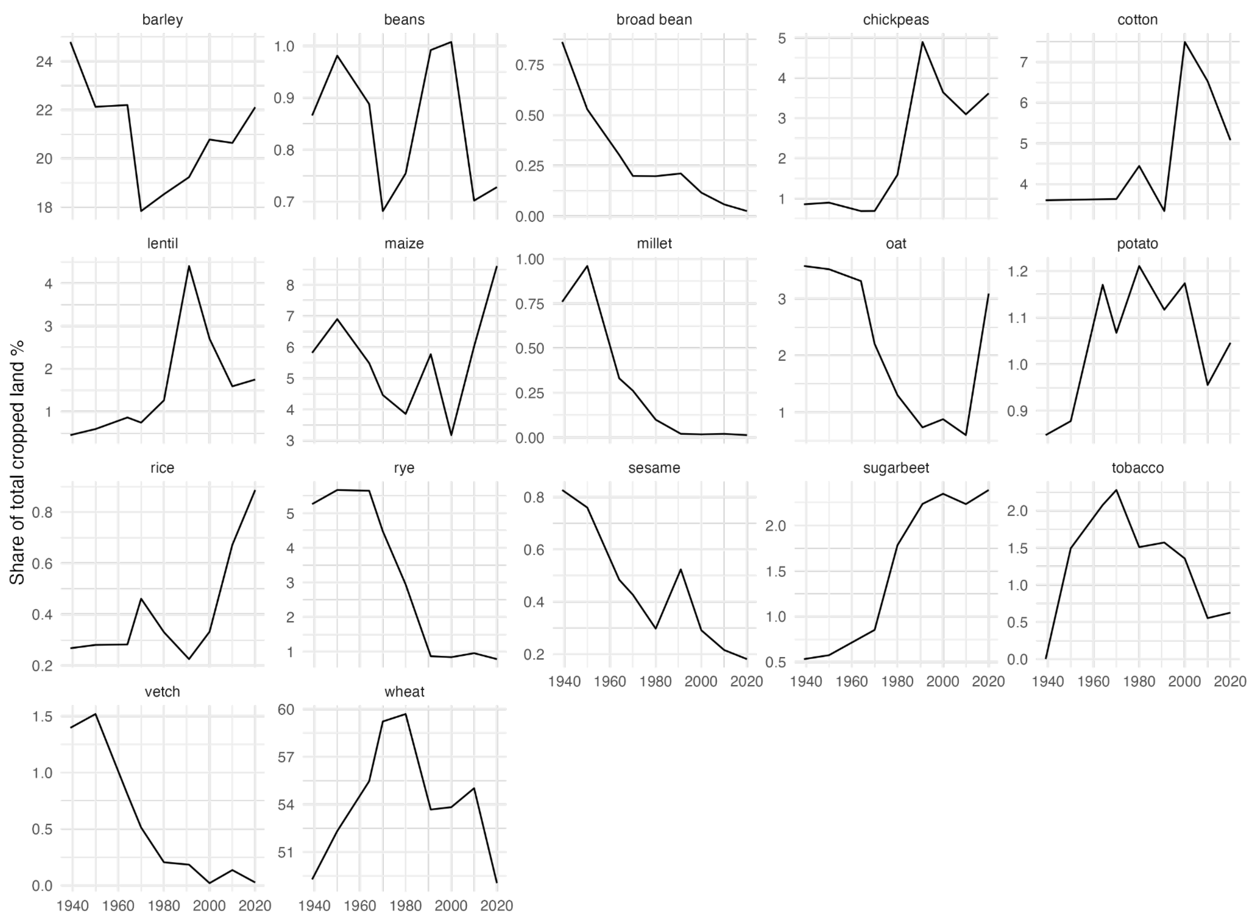

Figure 3 Changes in the share of crops in land under field crops

2.2 Regional long-run trends

The geography of Türkiye, characterized by a diverse landscape, exhibits distinctive climate and topographical features across regions, historically influencing varied cultivation practices. The northern and northeastern regions, primarily mountainous with a Black Sea climate, are not mostly suitable for large-scale farming due to a challenging topography, elevated altitudes, and climatic conditions. However, pockets of fertile valleys within these areas sustain localized agricultural activities. In contrast, the southeastern region, conducive to crop farming, has witnessed a significant surge in agricultural production after the implementation of damns, barrages, and irrigation projects after the 1990s. The arid or semi-arid inland central regions, and the rainfall-dependent small European portion are primarily responsible for the bulk of cereal production. Historically, the irrigated alleys in the western and southern parts of the country have stood out as fertile zones, specializing in cultivating fruits, vegetables, and cash crops such as cotton. These regions, well-connected to major ports and characterized by a Mediterranean climate, have provided an amenable environment for market development and, thus, are responsible for a substantial part of the country's food exports.

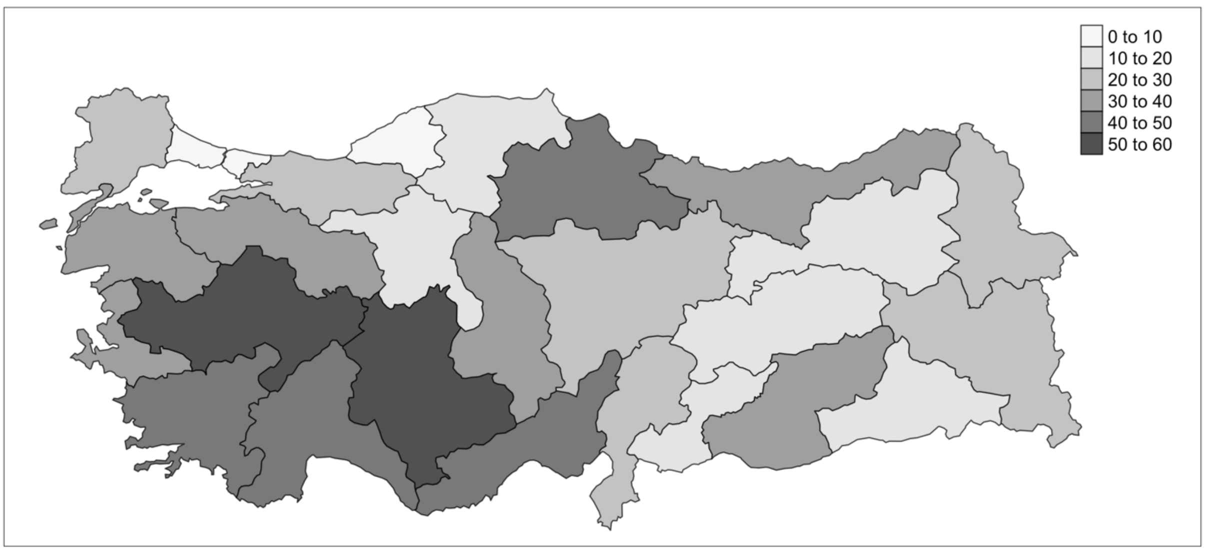

Figure 4 Regional distribution of agricultural output in 2020 (100 million TL)

Figures 4 and 5 shows the current regional dispersion of agricultural activities. Predominantly, the aggregate agricultural output is concentrated within the southwestern provinces. Beyond the demarcated area delineated by a line extending from the north-western sector (southern Marmara) to the central southern region (Adana and Mersin), notable agricultural production is also evident in several pockets, including the central Black Sea area and a limited section of the South-East. These regions outside the specified zone exhibit substantial agricultural productivity. On the other hand, the dispersion of cropped area shows a remarkably different picture, where the bulk of the agricultural land is in the inland central region and the Southeast. This contrasts with the importance of the South-Western zone that we observe in Figure 4. The difference reflects the differences in land productivity and crop composition. The southwestern regions have more restricted cropped land, are more suitable for cash crop production, fruits, and vegetables, while the farm production in the inland regions is more geared towards cereal production, which lowers land productivity.

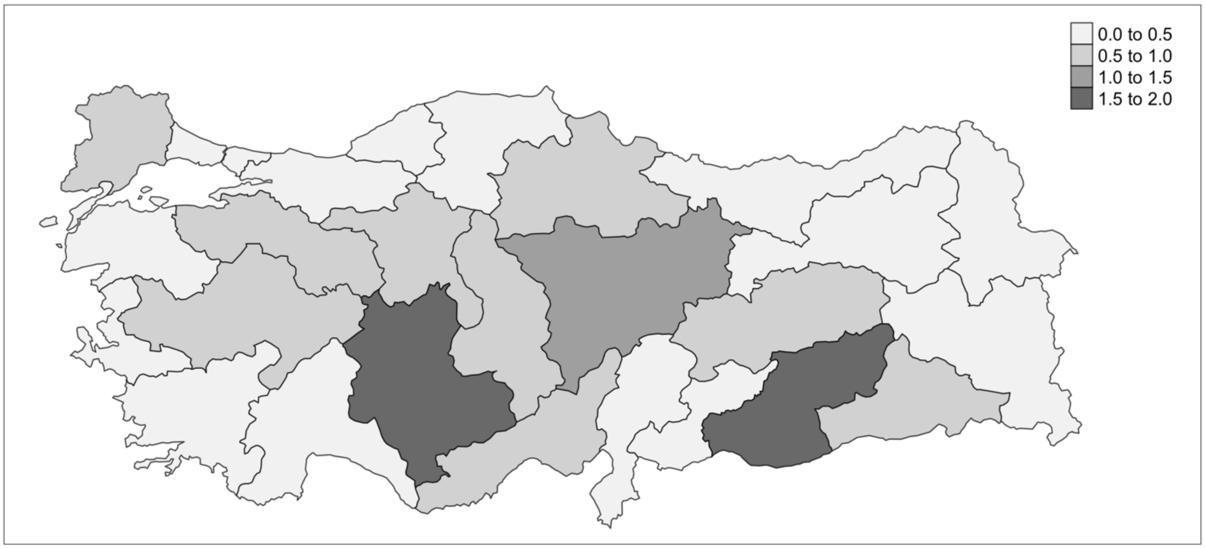

Figure 5 Regional distribution of cropped land in 2020 (million ha)

Figures 6 and 7 exhibit the percentage change between 1939 and 2020 in the share of agriculture in the provincial output and employment. Here we aggerate the provincial data into the NUTS-2 regions of Türkiye to be able to follow the regional trends in a coherent way, independent of the changes in the administrative borders. It appears that the most industrialized and urbanized regions currently, such as Istanbul, Eastern Marmara, and Ankara, are where the output share of agriculture decreased the fastest.[6] For instance, the output share in Ankara decreased from 36 to 2 percent between 1939 and 2020, from 45 to 3.4 percent in Kocaeli-Bolu (the East of Istanbul). Apart from the North-Western regions, the center-south region also witnessed a decline of agriculture in the local economy due to the rise of Adana and Gaziantep emerging as local manufacturing regional hubs. The relatively remarkable decline of regional output in the South-West can be linked to increased tourism. However, the case of the Eastern provinces (both in the North and South) is unclear since those regions have not witnessed significant urbanization and industrialization.

The employment share of agriculture in regional economies mainly moved in tandem with the output share. The employment share declined rapidly in Istanbul, Ankara, and the Eastern Marmara. On the other hand, regarding the decline of the employment share, the second-tier provinces appear mainly to be the Southern ones (except in the South-East). Notably, in most of the South-East, the employment share dropped less than the output share except in the fertile NUTS2 region TRC, including Şanlıurfa. Therefore, labor productivity increased in the West and Central Anatolia, whereas the East lagged. That is presumably because while the outmigration was substantial in these areas, the technical change in agriculture lagged as well, which in turn could be due in part to unfavorable geography (high altitude and less fertile land) and a slower rate of investment in agriculture (both public and private).

[6] Note that Istanbul and Ankara are here taken as the name of regional units of the NUTS-2 classification.

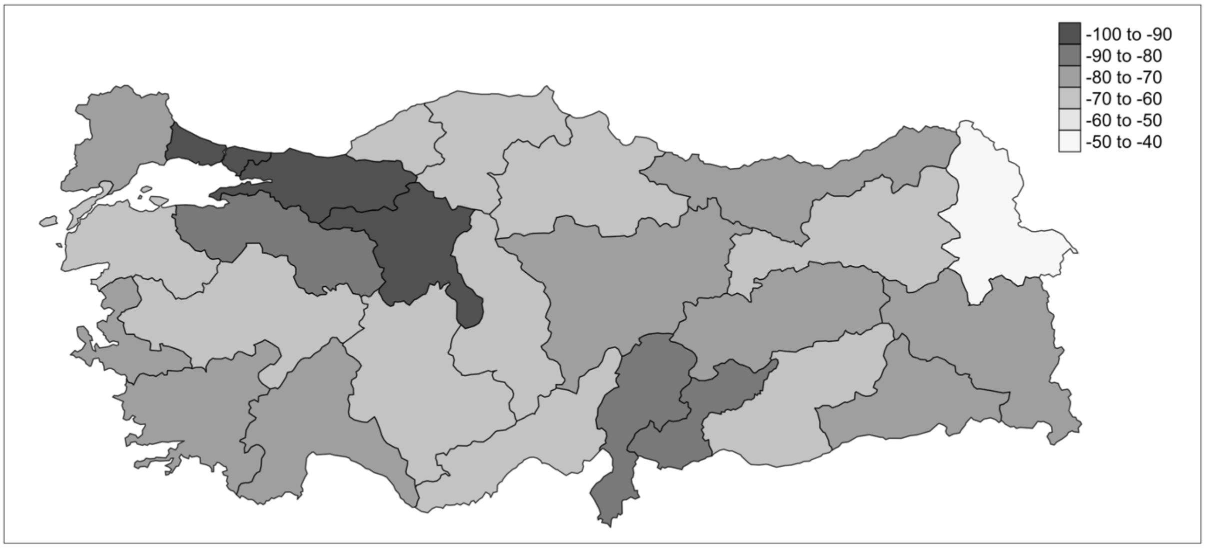

Figure 6 % change in the share agriculture in output by region between 1939-2020

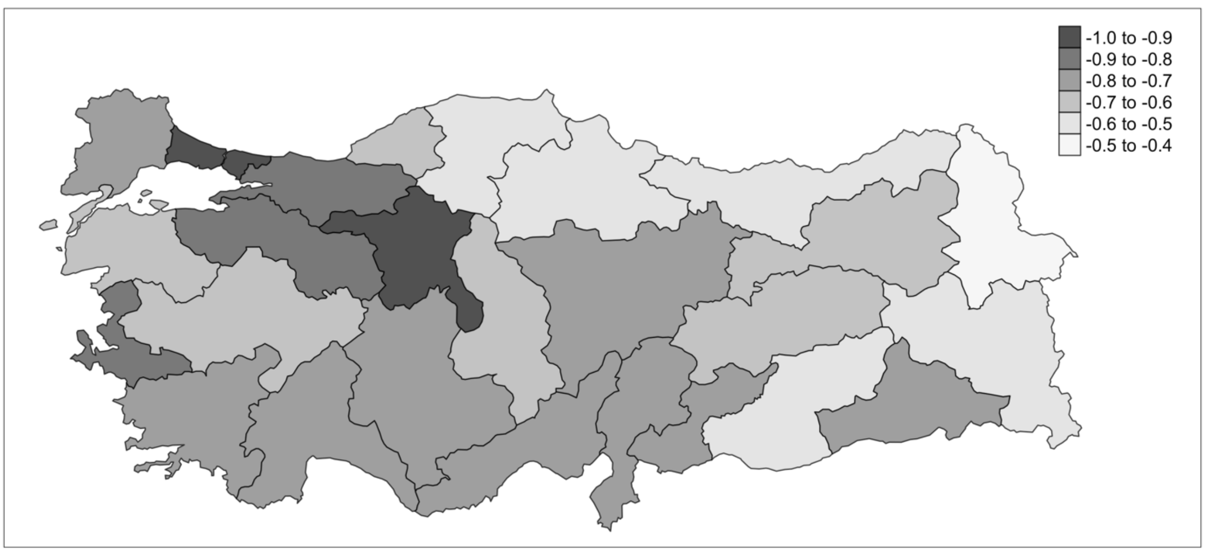

Figure 7 % change in the share of agriculture in employment by region between 1939-2020

3. Structural Challenges

3.1 Land, labor, and technological challenges

In light of its historical growth and ongoing structural changes, the agricultural sector now faces several interconnected challenges. These challenges can be broadly categorized into two areas: land, labor, and input use; and the organizational and institutional setting. Overcoming these challenges is essential for increasing land productivity, adapting to climate change, and achieving a green transition.

Even though the land and labor productivity in Türkiye has increased significantly since the mid-twentieth century, these trends seem to have slowed down, if not reversed, in the last decade, as seen in Figures 1 and 2. First, as Ağır, Karakoç, and Topal (2023) show using FAO data, both arable and cropped land have noticeably fallen since 2000. This pattern is in line with international trends in that many countries with agricultural sectors of comparable size. Italy, Spain, and Poland have also witnessed a non-negligible fall in arable land in recent decades.

The decline in land use for agricultural purposes is, on the one hand, the result of land loss, degradation, and land erosion.[7] The decline in cropped land in urban and semi-urban areas has been due to the expansion of non-farm activities at the expense of agricultural use, resulting in pressure on urban land, and higher land rent. While the residential areas have expanded with population growth, the agricultural regions in the periphery of the urban centers have eroded significantly (Keleş 2013). On the other hand, farmers are increasingly under the pressure of input prices. Thus, they seek to increase land efficiency by fully exploiting the fertile and irrigated lands so that low-quality lands are often left under-used or abandoned. Therefore, many parts of inland regions with low land productivity are the primary areas of land abandonment in Türkiye.

Another challenge is the unfavorable demographic transition in the countryside. The rural communities, mostly consisting of small medium-scale family enterprises, are aging, fragmented and vulnerable. As such, they can hardly respond to the challenges of climate change and green transition. When the new farmer registration system was introduced in the mid-2000s, the number of farmers stood around 2.7 million. The number, including the cooperatives and firms, has remained around 2.2 million since 2010. The farming community predominantly consists of small and medium-scale family farms.[8] The average farm size per family is approximately 150-200 acres if the data on total cropped land (23 million hectares) and actual number of farmers are considered[9]. A typical farmer family owns a plot of land and combines it with additional parcels rented from relatives or neighbors who do not reside in the countryside. Multiple sources estimate the average farmer age to be in early or mid-50s. Thus, the demographic change does not favor sustaining farm production, which aggravates the concerns about food security (Öztürk, Jongerden, and Hilton 2018). Even when urban wages are lower than average agricultural incomes, the lack of sufficient education, health, and social facilities in rural areas keeps encouraging the outflow of young people. Therefore, these trends in land use and demographic transition reinforce the fragility of farm production and stopping them requires a comprehensive reform of the farm economy and rural revitalization through social and physical infrastructure investment.

Against this backdrop, the sustainable transition of agricultural production crucially depends on the efficient use of inputs and technology or, broadly speaking, the sustainable technical change. The bulk of small and medium-scale farmers are under the strain of short-term price and cost pressure, restricting the choices of inputs and technology to short-term horizon. The urgency to keep debt service and sustain the immediate livelihood of the family, combined with insufficient access to long-term capital and market opportunities, force farmers to switch to crops with higher immediate returns, use fertilizers and pesticides as tools to maximize the short-term yields, invest in irrigation if possible, and thus largely ignore the sustainability of farming.

[7] See Atlı, Yıldırım, and Candaş (2021) for a recent survey of the soil of Türkiye. They argue that about 80 percent of agricultural land faces danger of soil erosion.
[8] The last agricultural census was undertaken in 2001. It was the last systematic and comprehensive source of information on the size distribution of farms. According to the census results, there were more than 3 million farmers in Türkiye, with 65 percent of them owning less than 49 acres. Such farms are typically considered as small in the local context.
[9] We assume the actual number of farmers are around 1/2-2/3 of those who are registered in the Farmer Registration System. This assumption reflects our educated guess based on our interviews with the local officials of the Ministry of Agriculture and Forestry.

The effects of climate change should be understood given this context. On the one hand, climate change brings about long-run changes in temperature, rainfall, and precipitation patterns. Farmers face changing patterns in many areas, so adaptation to the new patterns requires better knowledge, new techniques, capabilities, and a supportive organization and institutional environment.[10] On the other hand, the increasing intensity of extreme climate events, such as prolonged high temperatures, limited rainfall, or floods, require additional investment, new technologies, and enhanced adoption of the safety net. While facing such challenges inducing lower income and price risks, it is a typical response on the part of farmers to use more inputs (fostering intensive agriculture), including fertilizers, pesticides, and, when possible, water. Overall, the underlying structural problems and climate change reinforce the energy-intensive and fossil-based production patterns.[11]

Figure 8 remarkably shows, using the official estimates, that the energy consumption and fertilizer per unit of land increased by three and two-fold, respectively, in the last three decades. Most of the rise in energy consumption happened between 1990 and 2010, while fertilizer use expanded in the previous decade. While it is hard to make a definitive assessment, there are widespread concerns about the inefficient use of water and fertilizers. In principle, the effect of the excessive use of chemical fertilizers is the primary source of nutrient loss and water contamination. For instance, Üçler (2021) argues that an efficient use of chemical fertilizer can decrease the phosphate accumulation in the water by almost half in Konya, one of the central cereal-producing regions of the country. The international comparisons also show that while the level of fertilizer consumption in Türkiye is still lower than in France, Italy, and Poland, the gap is narrowing down since 2000 because while the consumption per area is declining in those countries, it has substantially increased in Türkiye (Ağır, Karakoç, and Topal 2023). Such observations and analyses suggest that it is possible in Türkiye to decrease fertilizer use, in line with the *Farm-to-Fork strategy*, by increasing fertilizer use efficiency via precision agriculture and the better use of biological methods without risking the physical output.

[10] T.C. TOB Tarım Reformu Genel Müdürlüğü (2021) presents a comprehensive report of how the climate change affects the farming conditions in major regions of Türkiye, based on expert views and discussions.
[11] For several projections of the effects of climate change on Turkish agriculture, see Sen et al. (2012); Vanli et al. (2019); Chandio et al. (2020); Dudu and Çakmak (2018).

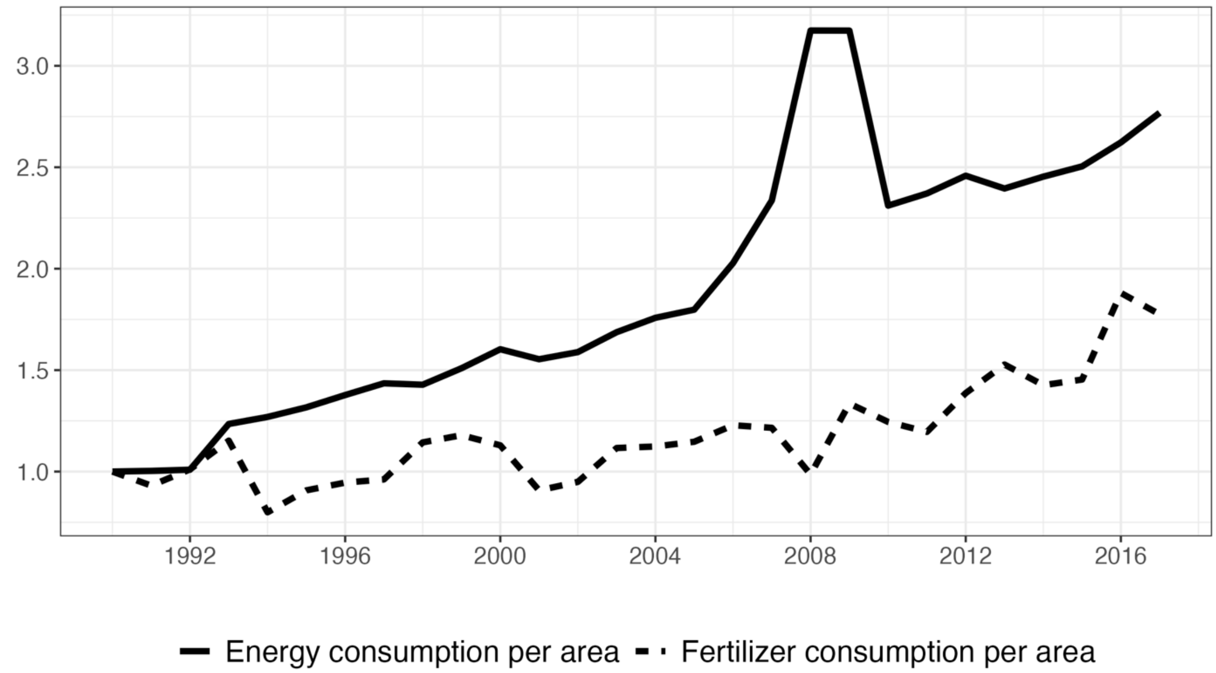

Figure 8 Indices of energy and fertilizer use per unit of area, 1990-2020 (1990=1)

The recent depreciation of TL against the US Dollar, and thus relative rise fertilizer cost made many farmers reduce fertilizer consumption.[12] Similarly, the relative rise of oil prices encourages farmers to decrease the cultivated area and reduce soil processing especially in the arid or semi-arid inland regions, which requires heavy use of tractors and other machinery. Indeed, increasing input costs are usually the main reason for reduced tillage and even land abandonment in some extreme cases (Ceylan, Karakoç, and Nizam 2021).

Until very recently, the agricultural policies in Türkiye have heavily been shaped by a market-oriented perspective that emphasizes the need for maximizing efficiency and switching to high-value-added products. The new policy agenda, however, recently developed to align with European Green Deal, also brings into focus an additional environmental perspective. It remains unclear whether the current organizational and institutional framework within the agricultural sector can effectively support the implementation of the intended policy mix, which strives to achieve both efficiency and sustainability.

The farming community comprises, presumably, 1-1.5 million farmers with limited access to credit, knowledge, and human capital, and ongoing demographic trends are unsupportive. The farmers' organizations, for instance, the Union of Farmer Chambers, have long been far from being a powerful lobbying force for farming interests, and other non-state organizations do not have a solid political and economic presence. This organizational and institutional vacuum is being complicated by the varied effects of climate change in different parts of the country.

[12] See (TAGEM 2018) or a detailed analysis of fertilizer market in Türkiye.

Sustainable agriculture practices have been proposed to support agriculture's green transition (TÜSİAD 2020, TOB 2021).[13] The share of organic agriculture in total arable land is about 2.5 percent, which is way lower than the average of the EU. Organic food production is mostly shaped by the exports of fruits, dried fruits, and nuts, where the domestic market is limited. Organic production is regulated by various controls and certification mechanisms, and the organic farmers also receive government support. In line with the *Farm-to-Fork* objectives, it is possible and realistic to increase the organic lands relatively fast. Also, expanding organic areas, as in the EU, would help decrease the use of chemicals and increase soil nutrients, thus helping decarbonize agriculture. On the other hand, any significant increase in the organic production will put pressure on the food supply and food prices, as estimated by several studies that focus on European agriculture (Beckman 2020, Bareiro et.al 2021) Second, as Karapinar et al. (2020) argues, organic farming can potentially increase the demand for labor, which can be a strong binding constraint regionally. Therefore, any greening policy-target, including organic agriculture, should set out a cautious action plan.

In addition to organic agriculture, a specific support instrument *("iyi tarım"- "good agriculture")* aims to promote environmentally sound and healthy practices. The Ministry of Agriculture and Forestry has regulated the practices that conform to the legal definition of *"iyi tarım"* via a certification system since 2004. In 2021, about 10 thousand farmers were involved in the program, which covered a 400-thousand-hectare area.[14] *"Iyi tarım"* thus, remains a small program, as is evident by the number of registered farmers.

Apart from organic and *"iyi tarim*", there is no separate government support program or certification process for sustainable agriculture practices. The lack of systematic data on such practices prevents a coherent evaluation, but the partial evidence indicates that several initiatives and programs where NGOs, experts, and food industry actors have been actively developing testing, educational, and propagation activities. Such activities range from regenerative agriculture, conservation agriculture, or agroecology and permaculture. Their focus varies from reduced tillage or soil disturbance, green cover crops, and crop rotations to the more holistic generative approaches. The no-tillage program run by WWF-Türkiye in the wheat-producing inland regions and the "Better Cotton" project of the local partners of the Better Cotton Initiative are prime examples of sustainable agriculture where the different aspects of sustainable agriculture are tested.[15] These remain as isolated attempts aimed at propagating sustainable methods without substantial support from the government (Ceylan, Karakoç, and Nizam 2021; Ceylan, Karakoç, and Kutman 2023)

Therefore, it appears that there are significant structural challenges in developing sustainable agriculture and green transition. The underlying patterns of land and labor use and the widespread small-holder farming provide major barriers. Yet, the current attempts at sustainable agriculture remain small, isolated, though exemplary, incidences, which can hardly be expanded without

[13] Among the leading NGOs working towards the adaptation and mitigation in agriculture are World Wildlife Fund-Turkey (https://www.wwf.org.tr/#) and Nature Conservation Center (https://dkm.org.tr/en). Their published policy reports and research can be followed on their websites.

[14] https://www.tarimorman.gov.tr/Konular/Bitkisel-Uretim/Iyi-Tarim-Uygulamalari

[15] WWF-Turkey has implemented the no-tillage program under the heading of "healthy soil movement", with the financial support of one of the biggest food firms ETI-BURCAK. The objective of the program was to study the implementation of the no-tillage agriculture in the wheat-producing areas and to explore ways to promote the farmers' adoption.
https://www.wwf.org.tr/kesfet/gida/saglikli_toprak_hareketi/
BCI's local partner in Türkiye. IPUD (*İyi Pamuk Uygulamaları Derneği*) has been implementing Better Cotton certification program in major cotton-producing areas, such as Söke and Harran. The program mainly aims to reduce the use of certain pesticides and promote the efficient water use and fertilizers. Better Cotton now covers more than 10 percent of the total cotton production of the country.

public support. The ongoing climate change aggravates the difficulties by creating a fast-changing environment, so the adaptation and transformation action becomes more urgent. The unfavorable land use and demographic patterns require both the adoption of new digital technologies and sustainable holistic approaches such as regenerative agriculture, which can substantially reduce the consumption of fossil-based inputs, improve soil health, and increase biodiversity.

3.2 Policy framework to address decarbonization in agriculture

The policy framework for green transition and decarbonization is relatively new and still in progress. The ratification of the Paris Agreement, signed by the government in 2016 by the parliament, was completed as late as 2021. The development of the legal framework speeded up with the EU's New Green Deal. In 2021, the Ministry of Commerce drew up an Action Plan for the Green Deal.[16] The Action Plan was announced as a roadmap enabling green investments that will contribute to transforming the global value chains in line with the green transitions worldwide. Such a definition emphasizes the need for adjustment to the EU Green Deal and for increasing the competitiveness of Türkiye in the emerging new global markets.

There are few studies attempting to estimate the possible effects of the *Farm-to-Fork* strategies on the food output, prices and trade in and outside the EU. The general equilibrium effects on the output and trade of EU and its trade partners are hard to pin down due to the indirect price and welfare effects, so these studies are indicative of direct immediate effects. Beckman et. al (2020) focuses on the effects of *Farm-to-Fork* on the output and price of a number of agricultural products for several countries. In the base scenario of *Farm-to-Fork* being only implemented in the EU, Türkiye's cereals production is expected to increase by around 10-20 percent with comparable increase in prices, while the fruits-vegetables output will fall slightly. In the second scenario where *Farm-to-Fork* policies are implemented in both the EU and its major trade partners, the wheat production in Türkiye will decrease, while the fruits and vegetables production will increase by 20 percent together with significant price increases. The partial equilibrium estimates of this kind, however, rely on strong assumptions. For instance, one key aspect of the relationship between *Farm-to-Fork* and foreign trade will be the implementation of Carbon Border Adjustment Mechanism. For instance, Türkiye needs to invest considerable organizational and technical resources into adapting to CBAM adjustments, especially to reduce pesticides in exported fruits and vegetables. Second, as argued by Ağır, Karakoç and Topal (2023), the effects of the climate change on Turkish agriculture will compound the complexity of forecasts. In particular, the Mediterranean region is expected to witness to switch to the semi-arid climate, according to the many climate change scenarios, and it is also the very region where Türkiye's exported fruits and vegetables are grown.

The Action Plan mainly follows the EU's *Farm-to-Fork* objectives, indicating that the strategic objectives will be to reduce the use of pesticides, fertilizers, and antimicrobials, expand organic production, and improve biodiversity. More specifically, it also adds to the list of objectives, continuing the land consolidation, more extensive use of geothermal resources as alternative energy sources, supporting renewable energy production, reducing food waste, and preventing land degradation. The Plan also outlined a schedule for the specific laws and regulations. On the other hand, among these policy objectives, the specific concrete plans were only laid out for the investment in geothermal and land consolidation. The plan did not specify clear targets for the most immediate objectives of *Farm-to-Fork*, such as organic agriculture, pesticide, and fertilizer use.

[16] https://ticaret.gov.tr/data/60f1200013b876eb28421b23/MUTABAKAT%20YE%C5%9E%C4%B0L.pdf

On the other hand, the Ministry of Agriculture and Forestry expanded on the Action Plan by outlining the specifics of the section of agriculture of the Action Plan with the Strategic Plan for 2019-2023 (TOB 2022). The Strategic Plan announced seven main targets and, corresponding to each, 16 performance targets. However, the relationships between the quantitative targets and strategic objectives remain unclear, and the specific mechanisms for realizing these targets have yet to be determined.

The 2022 Progress Report, announced by the European Commission regarding the ongoing membership status of Türkiye, provides an evaluation of the progress made in the specific policy areas of agriculture and rural development, food security, and environment and climate change.[17] The report states that no progress has been made on climate change, and there were crucial gaps between the EU policies and Türkiye’s stance concerning food security. More specifically, even though the objectives of the green transition have been identified, concrete targets need to be specified with a clear policy agenda to foster policy implementation. Second, there are still ambiguities about the agricultural policy priorities and immediate actions to be taken. Third, the organizational structures and coordination at the level of ministries and local institutions, which are required for effective implementation, are missing. Also, an effective information system must be developed to monitor the policy actions and evaluate their impacts. Although sustainability has been the main objective of agricultural policies, there is no comprehensive database of sustainable practices. Finally, and perhaps more importantly, while *Farm to Fork* and related policies about the Common Agricultural Policy in the EU are developed jointly, how such policy targets and Action Plans are integrated into the existing agricultural policies in Türkiye remains unknown.

While recent policy initiatives in Türkiye aim to align with the EU's ambitious *Farm-to-Fork*, they appear more focused on short-term adjustments than a comprehensive long-term strategy. There are overlaps between the government's stated goals and the *Farm-to-Fork* strategy highlights, though, the implementation path for these objectives remains unclear. The coming years will likely see new regulations emerge mirroring the EU's approach. However, the absence of a cohesive framework that tackles the structural issues within the Turkish agricultural sector presents the most significant challenge.

4. Macroeconomics of greening the agricultural sector

This section aims to pursue the foundations of a green and interconnected industrial policy framework with exclusive attention on generating increased efficiency in agriculture towards reduced chemicals and energy dependence and inducing sustainable patterns of green agricultural growth. To this end, we use an applied dynamic macroeconomic model and investigate alternative strategic policies towards an efficient and well-balanced green agricultural economy. Our results suggest that pursuing an integrated green agricultural abatement policy capable of enhanced agricultural efficiency can achieve a more robust and vigorous transition towards a more balanced egalitarian economy with reduced fossil fuel and chemical dependency. A coherent industrial policy encompassing strategic backward and forward inter-linkages together with agricultural transition was indeed the cornerstone concept of the traditional development literature of the so-called *Golden Age* –depicting the *grand theories of development* a la Lewis, Ranis and Fei, Hirschman, Nurkse, Singer, Kaldor, and Rosenstein-Rodan, among others. The

[17] https://www.ab.gov.tr/siteimages/birimler/kpb/2022_turkiye_report_tr_27.11.2022_22.05.pdf

concept was discredited and fell out of fashion in the policy debates in line with the rising conservatism of the neoliberal arena after the 1980s. From the mid-2000s onward, however, the literature witnessed an intensified call for (*new*) industrial and agricultural policy instruments, whose justifications are based on externalities and spill-over effects, and a renewed appreciation of green public policy towards achieving transition to a green, decarbonized pathway.

A number of critical developments in the global economy, along with advances in empirics-driven policy work, further enabled the understanding of the need for *industrial development policy*: (1) an increased concern for the environment, especially mitigation of the climate crisis via sustained pathways of decarbonized growth; (2) increased awareness of deepened polarization, social exclusion, and fragmented income strata through the works of Piketty (2014), Milanovic (2023), Atkinson (2015); (3) appreciation of a more holistic approach towards a more inclusive development strategy that is capable of capturing the externalities of interlinkages among the strategic sectors, *viz*. industry and agriculture; (4) raising awareness of the importance of sound institutions and the strategic role of the state in combatting the climate crisis. OECD (2014), for instance, emphasizes that two essential reasons for its bleak prognostication regarding the dynamics of the global economy rest with (i) duality and unevenness of income distribution across functional and regional sense with a consequent rise of social exclusion and conflict and (ii) environmental degradation due to the threat of climate change.

Hence, an underlying theme of the come-back of the *green agro-industrial policy* was the recognition that *development* itself is by no means a linear, harmonious process but is interwoven with interdependencies, unintended external effects that involve both positive spillovers and negative dualistic gaps with structural bottlenecks (Andreoni 2014; Andreoni and Chang 2019). All of this was further marred by the threat of climate change and the deepening of the ecological footprint on the resources of our fragile planet. In its 2019 *Trade and Development Report*, UNCTAD (2019) cautions, for instance, that

> "The *global economy does not serve all people equally. Under the current configuration of policies, rules, market dynamics, and corporate power, economic gaps are likely to increase, and environmental degradation intensifies*"; and "*decarbonizing the global economy will require a significant rise in public investment especially in clean transport, energy, and food systems. This will need to be supported by effective industrial policies, with targeted subsidies, tax incentives, loans, and guarantees, as well as accelerated investments in research, development, and technological adaptation*".

Aghion, Boulanger, and Cohen (2011) further remark that the threat of climate change invited us to rethink agro-industrial policy since, "*without government intervention to encourage clean production and clean innovation, global warming will intensify and generate negative externalities (droughts, deforestation, migration, conflict) worldwide*."

All these calls lead us to think more carefully towards the design of a more balanced and inclusive development strategy based on strengthening *green agriculture–industry interconnectivity* and with due attention to the warrants of a green pathway to mitigate global warming and to reverse the unsustainable rate of exploitation of our planetary resources.

To this end, we develop and use a multi-region, multi-sector applied (Walrasian) general equilibrium model of the computable general equilibrium (CGE) tradition. The model is applied to the economy of Türkiye to assess the impact of a selected number of *green* policy instruments and public policy intervention mechanisms, including market-based incentives designed to discuss ways to reduce its energy and chemical dependence on agriculture. We pay particular attention to constructing a consistent dataset that reflects the decomposition of the national economy into its empirically observed fossil fuel energy dependency. The study is based on the 2014 macroeconomic balances of the Turkish economy, with a detailed focus on carbon emissions from energy combustion in agriculture and industrial sectors and the relevant market instruments of abatement. We first introduce the salient characteristics of this analytical model.

4.1 An applied general equilibrium model to study green policy alternatives in agriculture

TRGQMA (Türkiye General Equilibrium Model for Agriculture Impact) is an applied general equilibrium modeling framework. TRGQMA is a national, comparative, static, Walrasian general equilibrium model designed to cover the agricultural sector of Türkiye. It is based on the Global Trade Analysis Project (GTAP) with Türkiye-focused as a direct separate entity against the rest of the world's global system of accounts.[18]

TRGQMA encompasses thirty sectors, twenty-one of which consist of agricultural activities.[19] A number of sectors directly refer to crop production, such as cereals, fruits, vegetables, and animal products. Oil, coal, and their products, as well as chemical products, including fertilizers, comprise the second group of sectors. Finally, manufacturing and services are represented as the broader sectoral categories. Crucially, TRGQMA separates the "fossil fuel" energy sources exclusively and accommodates land, capital, and labor to produce sectorial output along given neoclassical production functions.

The model that is utilized in this paper relies on the background works to the Rio+20 conference laid by Bouzaher, Şahin, and Yeldan (2015) and the WWF-IPC 2015 Report that was submitted to the COP21 Paris meetings (Voyvoda and Yeldan 2015). Antecedents of the model rest on the seminal contributions of the CGE analyses on gaseous pollutants, energy utilization, and economics of climate change for Türkiye, as narrated by Acar, Voyvoda, and Yeldan (2018; Acar and Yeldan (2016); Telli, Voyvoda, and Yeldan (2008). Among many other innovations in production technology and environmental pollution specification, a prominent distinguishing feature of our approach is its accommodation of a detailed agricultural sub-sectorial structure with explicit recognition of chemical and fossil fuel dependency in the agricultural economy.

We distinguish labor, capital, and a composite of energy inputs (electricity, petroleum gas, and coal), together with other intermediate inputs, as the main factors of production. Emissions arising from production and consumption activities are modeled within the specification of the economic sectors. Another essential characteristic of the model is its accommodation of rigidity and fragmentation, consistent with broad stylized facts of today's Turkish labor markets (Telli, Voyvoda, and Yeldan 2008). This adds to the cost of adjusting environmental tax measures and

[18] https://www.gtap.agecon.purdue.edu

[19] Agriculture sector includes: *pdr* (Paddy rice), *wht* (Wheat), *gro* (Cereal grains), *V_f* (Vegetables, fruit, nuts), *osd* (Oil seeds), *c_b* (Sugar cane, sugar beet), *pfb* (Plant-based fibers), and *ocr* (Crops nec). Animal products sector comprises: *ctl*(Bovine cattle, sheep, goats), *oap* (Animal products nec), *rmk* (Raw milk), and *wol* (Wool, silk-worm cocoons). Forestry sector has *frs* (Forestry), while Fishing sector includes *fsh* (Fishing). Energy sector consists of: *coa* (Coal), *oil* (Oil), *gas*(Gas), and *P_c* (Petroleum, coal products). Food processing sector encompasses: *meat* (Meat products), *vol* (Vegetable oils and fats), *mil* (Dairy products), *pcr* (Processed rice), *Sgr* (Sugar), *Ofd* (Food products nec), and *B_t* (Beverages and tobacco products). The remaining sectors are: Chemicals with *Chm* (Chemical products), Electricity with *ely* (Electricity), Gas sector with *gdt* (Gas manufacture, distribution), Manufacturing with *Manuf* (Manufacturing), and Services sector with *ser* (Services).

strengthens the case for following a coordinated portfolio of environment and growth measures for green growth, as discussed below. The basic model features are discussed below.

Production Technology and Emissions: The production structure in each sector is specified using a nested production technology. Here, at the *top stage*, gross output is produced through an augmented Cobb-Douglas technology defining capital (*K*), labor (*L*), and intermediate inputs, along with fossil-fuel-based primary energy composite (*ENG*) as factors of production. In addition to these, the model accommodates *land aggregate* as an additional composite factor of production in agriculture. Agricultural land aggregate is further decomposed as a CES function of *irrigated* and *rain-fed land*. This decomposition is responsive to rental rates of the type of land respectively, and the model endogenously solves the relative land use.

We distinguish mainly gaseous emissions from energy combustion (regarding CO_2 equivalents) for environmental pollution and climate change indicators. TRGQMA calculates indicators for the agricultural (non-CO2) GHG emissions in the form of nitrous oxide, methane, and CO2 emissions. Indicators for non-CO2 emissions are based on input use and outputs from production activities.

***Income Generation and Consumption*:** The private sector is aggregated as one representative household. Given her preferences and budget, the representative household is assumed to choose a bundle of consumption goods that maximizes her utility. Household income comprises returns to labor input (net of social security taxes for formal labor), land rental income, and remittances of profits from the enterprise sector, including the payments to renewables used for electricity production.

Government: As for the government accounts, the model closely follows fiscal budget constraints. We regard the government transfer items to the households, enterprises, and social security system as fixed ratios to government revenues net of interest payments. Then, under a pre-determined primary surplus/GDP ratio, public investment demand is settled as a residual variable out of the general fiscal accounts.

In terms of the components of environmental policy, we assume that pollutant tax serves as one of the instruments and is introduced per tons of carbon dioxide emitted on production, intermediate input usage, and consumption, respectively. The revenues are directed into the revenue pool of the government budget.

Equilibrium: With wages being fixed in each period, equilibrium in the formal labor market is sustained through employment adjustments. The overall model is brought into equilibrium through endogenous adjustments of product prices to clear the commodity markets and balance the payment accounts. The actual exchange rate serves as the numeraire of the system.

Dataset: We utilize the latest 2012 I/O table produced by the Turkish Statistical Institute (Turkstat) as the base for constructing and expanding our data set with the GTAP I/O database. The base year of the model economy is 2014, against which the comparative static policy scenarios are conducted. This consistent dataset of the 'base year' is further utilized to 'calibrate' the analytical model's micro/sectorial and macroeconomic balances to the existing data. In so doing, we obtain values of structural parameters and exogenous variables of our algebraic equations.

For the base year, we derive GHG emissions (in CO_2 equivalent terms) from sectoral production activities and fossil fuel input demand. Nationwide, a total of 451 million tons of CO_2e is reported by TurkStat for 2014. This aggregate contains emissions due to energy combustion (260.1 million tons). We explicitly calculated the agriculture's share in this total through *direct (scope 1)* emissions and *indirect emissions* through inputs from the other sectors (*scope 2+ 3 emissions*). Our calculations reveal that the agricultural sectors as a whole were responsible for the following:

Scope 1_Emissions (Mt CO2e)	47.6434
Scope 2_Emissions (Mt CO2e)	1.0585
Scope 3_Emissions (Mt CO2e)	1.8975

Table 1 provides the detailed outcome of this sum and allocates total emissions into sectoral activities induced by demand from agriculture.

Table 1 Aggregate (Direct + Indirect) CO2(e) Emissions (million tons) induced by the agricultural sector

	Agriculture	Rest of the Economy	Total
AG: Agriculture	47.643	26.997	74.641
MI: Mining	0.031	2.358	2.389
FO: Food Processing	0.102	5.145	5.247
TE: Textiles, Clothing	0.001	0.567	0.568
OE: Other Economy	0.036	4.342	4.378
PA: Paper Products	0.008	1.010	1.017
PE: Petroleum Products	0.191	6.472	6.663
CH: Chemicals	0.347	9.798	10.145
CE: Cement	0.299	74.819	75.119
IS: Iron and Steel	0.024	17.565	17.589
MW: Machinery, White Goods	0.010	5.814	5.824
AU: Automative	0.000	0.174	0.174
EL: Electricity	1.059	153.884	154.942
CN: Construction	0.004	3.029	3.033
RT: Retail trade	0.007	1.038	1.045
TR: Transportation	0.815	80.842	81.657
AT: Air Transport	0.014	3.752	3.765
PS: Postal and Courier Services	0.001	0.165	0.166
AF: Accomodation and Food	0.000	0.267	0.267
PR: Professional Services	0.004	0.701	0.705
FS: Financial and Real Estate Services	0.004	1.199	1.203
TS: Tourism	0.000	0.158	0.158
ES: Education Services	0.000	0.266	0.267
HE: Health Services	0.000	0.311	0.311
SUM_SECTORS	**50.599**	**400.672**	**451.271**

Source: TurkStat, Environmental Statistics, GTAP database, UNFCCC and authors' calculations. The aggregate figures are the sum of direct and indirect emissions induced by demand pulls from agriculture.

4.2 Policy scenarios towards a green agriculture

Policy scenario 1: Reduced use of chemicals in agriculture

In line with the discussions carried out in the introductory sections above, we first study a green agriculture scenario to highlight the input dependence of the agricultural economy on chemicals - fertilizers in particular. To this end, we simulate a scenario where chemicals used in agricultural sectors are reduced by 50%. The reduction of chemicals used in agriculture is well-discussed and articulated in the European Green Deal offered by the EU Commission. For instance, the two pillars of the EU's agricultural policy framework Farm-to-Fork and a Biodiversity Strategy for 2030 (BDS) envision major adaptations along the whole food chain, from farming and processing to transportation and retail sectors. Specifically, they aim to achieve by 2030 a reduction of the sales of antimicrobials for farmed animals and chemical pesticides, nutrient losses in the environment by 50%, an increase of the agricultural land under organic farming by at least 25%, and a reduction of the use of chemical fertilizers by at least 20 percent (JRC-European Commission 2021).

Thus, following the targets of Farm-to-Fork policy set, we consider an extension of this policy agenda to Turkish agriculture, and implement a technical analysis of limiting chemical use by 50%. This target should be considered as a medium-run ambitious policy for the context of the Turkish agriculture. The ways such as major reduction in the use of chemicals can be achieved is beyond the confines of this study. However, we would like to note that 50 percent reduction in the use of chemical fertilizers alone would mean to go back to the level of 1990 for Türkiye in fertilizers per unit of cropped area (Figure 8).

Table 2 presents the main results of the model simulations under three scenarios. Assuming that the policy is implemented in full, the model solutions suggest a 1.7% reduction in aggregate actual agricultural output relative to the base solution (a decrease from 55,241 million US$ to 54,279 million US$ (in 2014 fixed prices) (Figures 9 and 10). On the other hand, the scenario does not predict any significant impact on the industrial sector (Tables 2-5). One major reason of that is that Türkiye is a significant importer of fertilizers, and domestic industrial activity is thus minimally affected from the decline of fertilizer demand. However, across the agricultural sub-sectorial activities, we observe substantial variations in output responses (Table 3). Among the agricultural sectors, constraining the chemical input usage by a quota resulted in output reductions of 6% in crops, 4.8% in wool, 3.6% in vegetables, and 7.3% in plant-based fibers. Output reductions in the remaining the output of agricultural goods range around 1.5-2%.

Similar adjustments in labor employment accompany the downward adjustments in sectorial output. The employment results are displayed in Table 4. In line with the sectorial output responses, the most significant employment loss is observed in crops (5.3%), wool (4%), plant-based fivers (3.3%) and vegetables (2.2%). The range of predicted responses is comparable to those for the output responses.

Table 2 Sectoral Output Responses under Alternative Policy Scenarios

Index of Output In Ag-Sectors	Base Equilibrium	Scenario 1	Scenario 2	Scenario 3
Paddy rice	100.000	98.128	96.809	113.329
Wheat	100.000	98.810	97.993	111.436
Cereal grains nec	100.000	98.256	96.825	108.313
Vegetables, fruit, nuts	100.000	96.481	94.055	113.263
Oil seeds	100.000	97.832	96.383	116.692
Sugar cane, sugar beet	100.000	98.303	97.158	105.446
Plant-based fibers	100.000	92.778	87.374	95.620
Crops nec	100.000	94.078	91.045	212.197
Bovine cattle, sheep and goats	100.000	99.591	98.914	116.920
Animal products nec	100.000	99.546	99.007	114.638
Raw milk	100.000	99.562	99.126	108.561
Wool, silk-worm cocoons	100.000	95.284	84.903	166.712
Forestry	100.000	99.789	98.885	107.167
Fishing	100.000	99.841	97.704	108.908

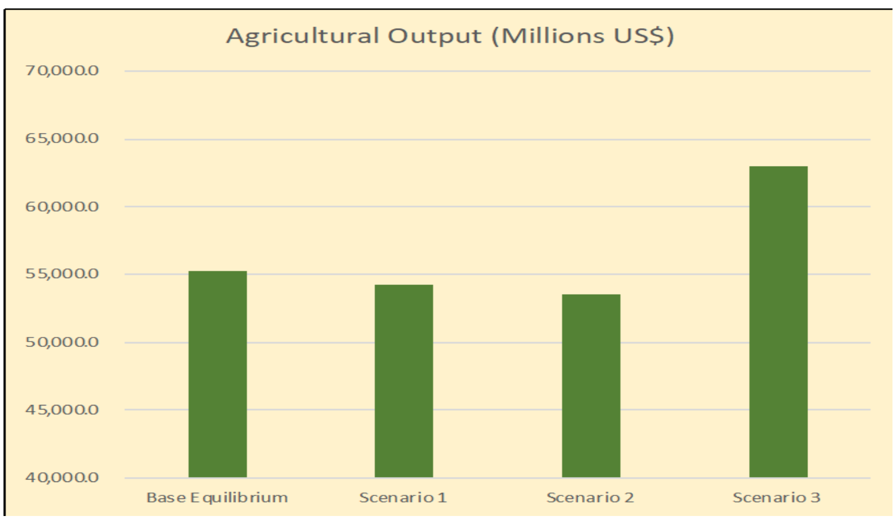

Figure 9 Agricultural Output (Millions of US$) under Alternative Policy Scenarios

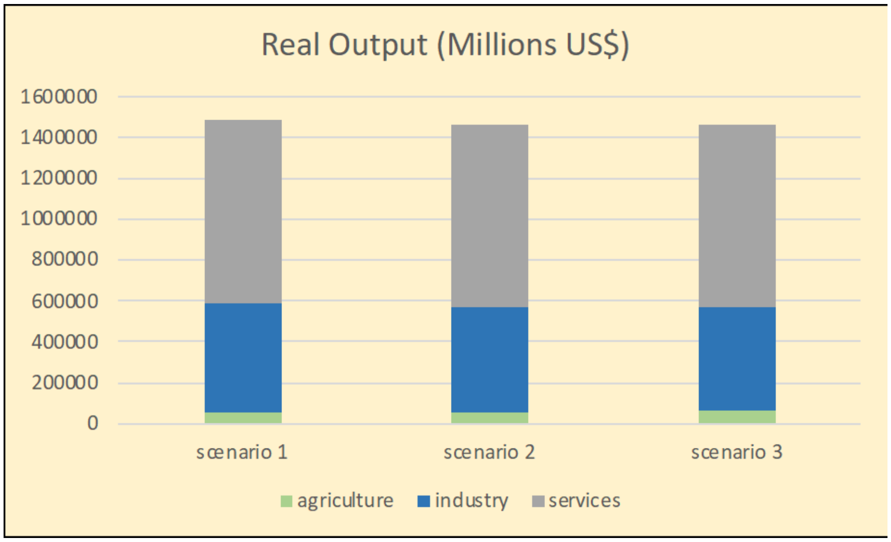

Figure 10 Sectoral Output Under Alternative Policy Scenarios (Millions of US$)

Table 3 Sectoral Employment Responses under Alternative Policy Scenarios

Paddy rice	100.000	99.425	99.340	104.424
Wheat	100.000	99.741	100.056	103.462
Cereal grains nec	100.000	99.660	99.795	103.178
Vegetables, fruit, nuts	100.000	97.880	96.910	108.823
Oil seeds	100.000	98.748	98.373	110.542
Sugar cane, sugar beet	100.000	99.995	100.487	100.828
Plant-based fibers	100.000	96.758	94.496	97.853
Crops nec	100.000	94.691	92.469	202.946
Bovine cattle, sheep and goats	100.000	100.052	100.487	101.844
Animal products nec	100.000	99.969	100.364	105.330
Raw milk	100.000	100.105	100.693	100.670
Wool, silk-worm cocoons	100.000	96.042	87.301	157.325
Forestry	100.000	100.041	99.740	99.834
Fishing	100.000	100.074	99.976	103.313

Legend:

Scenario 1: Reduce Chemicals use in Agricultural Sectors by half

Scenario 2: Scenario 1 + Introduce a carbon tax on fossil fuels at 10%

Scenario 3: Scenarios 1 & 2 + Reduce Fossil Fuel use in the economy and increase productivity in Agriculture

Table 4 Environmental Indicators under Alternative Policy Scenarios

Environmantal Indicators				
	Base Equilibrium	**Scenario 1**	**Scenario 2**	**Scenario 3**
Index of Chemicals Use In Ag-Sectors	100.00	50.00	50.00	50.00
Total CO2 Energy Related (Mill Tons)	260.183	259.575	227.929	216.368
Total CO2/GDP(kg/$GDP)	325.825	325.162	285.503	269.463
CO2 Emissions in Agriculture (Mill tons)	9.937	9.793	8.250	7.933
CO2 Emissions in Industry&Services (Mill tons)	250.246	249.782	219.680	208.435
CO2 Emissions Intensity in Agriculture (kg/$)	179.9	180.4	154.3	125.9
CO2 Emissions Intensity in Industry&Services (kg/$)	174.2	174.1	155.7	148.9
Total CO2 Taxes (Millions US$)			6,252.43	5,901.411
Total CO2 Taxes to GDP			0.008	0.007
Marginal Abatement Cost of CO2 taxes in US$ per ton			0.194	0.135

Policy scenario 2: Scenario 1 + Introduction of a carbon tax on fossil fuels at 10%

The impact of the above policy scenario on aggregate CO2 emissions is found to be negligible. Table 3-6 below discloses that in response to the binding quota on chemical use in agriculture, the aggregate emissions in energy combustion are reduced by only 1 million tons, from 260 to 259 million tons. To ensure reductions of gaseous emissions, we need to implement a more effective intervention in the domestic economy. We consider this by introducing an explicit carbon tax on CO2 polluters. In the model, the tax is imposed on an *ad valorem* basis as a ratio of the demand for fossil fuels (coal, oil, petroleum, gas, and gas manufacturing) as differentiated by the energy users. We administer the tax rate as 10% of the value of (fossil fuel-based) energy input demanded.

Table 5 Total CO2 Emissions from Fossil Energy (Million Tones) under Alternative Policy Scenarios

Total CO2 Emissions from Fossil Energy (Million Tonnes)				
		Ratios to Base Equilibrium		
	Base Equilibrium	**Scenario 1**	**Scenario 2**	**Scenario 3**
Coal	107,145.34	0.998	0.895	0.874
Oil	266.01	0.998	0.895	0.876
Gas	68,579.01	0.997	0.888	0.865
Petroleum, coal products	78,838.17	0.997	0.838	0.742
Gas manufacture, distribution	5,354.54	0.999	0.895	0.872
Totals	**260,183.1**	**259,575.0**	**227,929.5**	**216,368.2**

Scenario 1: Reduce chemicals used in agricultural sectors by half
Scenario 2: Scenario 1 + Introduce a carbon tax on fossil fuels at 10%
Scenario 3: Scenarios 1 & 2 + Reduce fossil fuel use in the economy and increase productivity in agriculture

The tax policy reduces aggregate energy-related emissions by 10% from 250 to 227 mill tones. The significant bulk of this reduction originates from the non-agricultural sectors (by 12.4%). However, coupled with the quota on chemicals inherited from the previous scenario, agricultural output continues to decline along with rural employment. Output falls by 16% now in *wool*, 9.5% in *crops*, and 13% in *plant-based fibers*. Overall, aggregate output is reduced by 3.2% in *agriculture* and 4% in *industry* (see Table 3-8 below).

Table 3-6 reveals that CO2 emissions intensity is reduced from 180 kg/$ to 154 kg/$ in agriculture and from 174 kg/$ to 155 kg/$ in industry. The model foresees that the carbon tax to be collected will amount to, on average, 0.88% of the GDP. The *marginal abatement cost* (MAC)[20] is calculated at 19.4 cents per ton of CO2 reduced due to the carbon tax. Table 3-7 and Figure 11 show that coal and gas combustion emissions are reduced by 10.2% each, from 107 to 95 mill tons in coal and from 68 to 60 mill tons in gas.

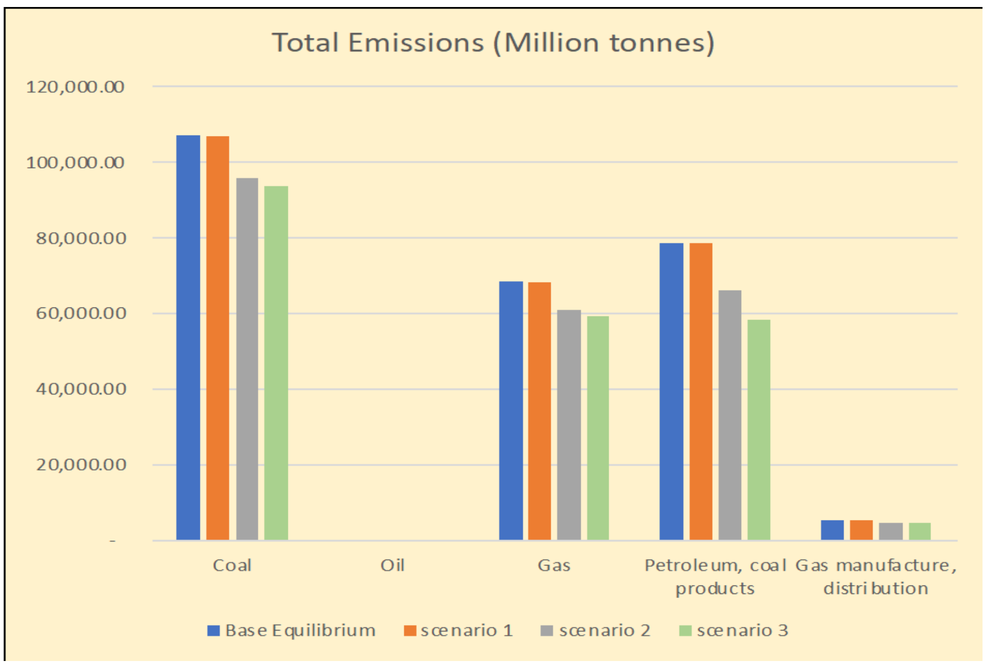

Figure 11 Total Emissions Under Alternative Policy Scenarios (Million tons)

Policy scenario 3: Scenario 2 + Reduction of fossil fuel use in the economy + Increase in the agricultural productivity

Under the expanded policy scenario, we look at the gains in efficiency and production. We increase agricultural technical efficiency by 1%, which can be achieved by a combination of land and labor-saving technical change such as precision agriculture, use of digital tools and the better organization of the farming economy. We must note that increasing efficiency by reducing the waste of inputs or improving the organizational structures is a more realistic viable strategy in

[20] MAC calculates the cost to the domestic economy (as a result of imposition of the carbon tax in US$) due to 1 ton of reduction achieved in aggregate emissions.

developing economies, such as Türkiye, since the efficiency level is already lower than, for instance, in the EU.

Additionally, in this scenario, we further reduce the energy emissions by 1%. This is foreseen as a return to increased utilization of the renewables sectors and has been borrowed from the findings of Kat *et.al.* (2022). Such a reduction in energy emissions can be achieved by a reasonable amount of investment in renewable wind and solar energy in agriculture. Also, the expansion of reduced tillage in arid regions can substantially contribute to the fall in energy emissions, without major disruptions in the agricultural output.

As expected, the effects of the Policy Scenario 3 on sectoral production turn out to be positive in agriculture. The most vibrant gainers are *crops* (112%) and *wool* (66%). Overall, the agricultural economy expands by 14%, pulling in an extra employment gain of 7%. Expansion of the agricultural sector pulls resources out of non-agriculture into the rural economy, thereby reducing opportunities in industry in the short run (upon impact).

The gains on the environmental front via the green policy package are observable in Table 5. Our results reveal that the total emissions of GHGs and emissions from CO_2 continue to decrease as the enactment of the package proceeds. Here, total GHG emissions fall to 216 million tons (by 13% over the base value). The significant savings on this front come from changes in the composition of the energy mix. The demand for fossil fuels falls considerably thanks to the carbon taxation scheme, which generates revenues at 0.7% of GDP, reaching 5.9 billion US$. The accompanying decline in the domestic product's emissions content (from energy) (down to 125 kg/$ from 179 kg/$ of value added in agriculture and 148 kg/$ from 248 kg/$ in industry) indicates enhanced abatement efficiency.

We display macroeconomic aggregates under Table 6. First, we observe that, except for scenario 3, the effects of the policy interventions do not significantly affect the GDP level. In contrast, increased efficiency gains in agriculture lead to a rise of the GDP by 0.6% upon impact (in the short run) over the base equilibrium. Agricultural activity rises by 14%. Continued implementation of the carbon tax (that asymmetrically affects industry) and diversion of scarce resources into the rural economy in the short run leads to a decline in industrial output. This suggests that a targeted *new industrial strategy* should be on the policy agenda in the medium to long run to complement gains in the agricultural economy.

Second, the wage and profit rates are minimally affected even though aggregate private disposable income and private consumption (which can be taken as a “neoclassical” indicator of *social welfare*) rise by 0.7% over the base equilibrium.

Finally, the foreign economy shrinks, as exports fall 4.7% and imports 3.6%. This is primarily due to the decline in industrial activity due to its more openness.

Table 6 Macroeconomic Aggregates (Millions of US$) under Alternative Policy Scenarios

Macroeconomic Aggregates (Millions US$)				
		Ratios to Base Equilibrium		
	Base Equilibrium	**Scenario 1**	**Scenario 2**	**Scenario 3**
Real Output (Millions US$)				
Agriculture	55,241.0	0.983	0.968	1.141
Industry	538,025.7	0.997	0.960	0.945
Services	898,400.7	0.999	0.996	0.992
Index Total Employment (Thousand persons)				
Agriculture	100.00	98.96	98.71	107.95
Industry	100.00	99.99	98.70	97.31
Services	100.00	100.10	100.47	99.96
Total Rural Income (Millions US$)	31,657.8	1.016	1.006	1.107
Average Wage Rate Index	1.00	1.00	0.99	1.00
Average Profit Rate Index	1.00	1.00	0.99	1.00
Total GDP	798,536.3	1.000	1.000	1.006
Pivate Disposable Income	672,666.4	1.000	1.000	1.006
Aggregate Investment	165,487.5	1.000	1.000	1.004
Aggregate Private Consumption	566,472.8	0.999	0.995	0.999
Aggregate Government Consumption	125,869.9	1.000	0.998	1.007
Public Sector Revenues	280,476.9	0.999	1.016	1.018
Exports	155,812.7	0.995	0.952	0.953
Imports	245,119.5	0.997	0.969	0.965

Legend:
Scenario 1: Reduce Chemicals use in Agricultural Sectors by half
Scenario 2: Scenario 1 + Introduce a carbon tax on fossil fuels at 10%
Scenario 3: Scenarios 1 & 2 + Reduce Fossil Fuel use in the economy and increase productivity in Agriculture

4.3 Towards an Integrated Strategy of New Agro-Industrialization

This section presents the viable agricultural abatement policies enhanced with a deliberate environmental focus on green growth. Our findings indicate that an exclusive policy of *green agricultural policy* interventions would create robust and conducive returns for the farming sectors. Re-switching to reduced dependence on chemical input use, pricing carbon emissions with an introduction of taxation, and increased technical efficiency are likely to yield significant positive outcomes regarding agricultural output and abatement without risking the food supply with possible income improvements for the farming community.

However, many caveats do remain. Reducing the productivity gap between the industrial and agricultural sectors and within the farming sector would require widespread diffusion of new technologies. The concept of *green agriculture* offers a range of channels through which productivity gains could be obtained both within agriculture and in the downstream and upstream sectors to which it is linked, such as food processing, transportation and logistics, and machinery. For instance, the reduced dependence on chemicals via regenerative agriculture, reduced tillage and moving in the direction of organic agriculture require the development of new machinery and tools, use of digital technologies, and advancement of technical skills and organizational capabilities to foster the transition. Such a change would create demand for agro-industrial sectors such as machinery sector (both traditional and digital).

An example is the case of no-till agriculture mentioned above. The increase in the no-till practices in inland regions of Türkiye was achieved in the 2010s (Ceylan, Karakoç and Nizam, 2002). The no-till agriculture builds upon direct seeding with special seeders, combined with crop rotations, leaving the crop residues on the field and the use of cover crops. The new practices were promoted by a small number of agricultural experts, activists, government officials and the farmer organizations. However, one of the binding constraints towards the expanded use of no-till was the insufficient number of the no-till seeders. Eventually, the adaptation of the seeders to the local soil and farm conditions and for specific crops were achieved by the local industrialists and machinery experts, with the help of the imitation of the foreign machinery. Therefore, there are currently the producers of the no-till seeders in Konya, Izmir and Edirne, which are able to supply the required seeds in case of the larger demand. It is remarkable that the agricultural machinery sector in Türkiye was already developed, and they producers were able to adapt to the demand for the new products via combination of imitation, small adjustments, trial and error and the expert-industrialist coordination. This trend in no-till agriculture has slowed down recently since the government financial support for the no-till machineries were disrupted.

This example is emblematic of the nature of the agricultural innovations: the adaptation of the green agriculture practices, as often pointed out in the literature on regenerative agriculture, often requires the development of new techniques and tools in the light of the local soil type, climate conditions and the specific needs of farmers. Unlike the case of conventional fertilizer-high energy-based agriculture, the sustainable practices rejects the one-size-fits-all solutions, and can only be built in innovative environments. The technical innovations thus revive the agro-industrial sector by way of switching of the existing industrial capacity towards the demand of the sustainable agriculture.

It has, nevertheless, to be noted that under the current realm of the global markets suffering from persistent stagnation and disequilibria, invigoration of a new leap-forward based on investments to attain green transitions will be no easy task. Apart from the vested interests of fossil fuel-based energy transnationals preventing phasing out of brown industries, dogmatic constraints of neoliberal superstitions favoring an eternal state of austerity and non-intervention severely hamper the implementation of new ideas of innovation and creativity for a just and sustainable system of governance of the global economy.

In what follows, we trace out our findings above within the Turkish context to offer the main steps of such a transition: First and foremost, the developing economies of the global South need *fiscal space* and indigenous instruments of fiscal governance to be able to pursue an expansionary stance favoring green transition. *Re-orientation* away from a fossil fuel-driven energy economy necessitates development of new investment channels towards renewables with unavoidable fixed installation costs as well as removal of direct and implicit subsidization of the fossil-based sources of energy, in particular coal.

Key elements of such a framework were already laid out by UNCTAD as early as in its 2019 TDR, where a *Green Bretton Woods Movement* had been called for, emphasizing:

- Policy space and coordination, initiated at the minimum with revising FTAs and supporting capital controls.

- Clamping down on corporate tax avoidance; installing a common unitary taxation system with global minimum tax rate set at 20–25 per cent, (the current average global nominal rates).

- A new debt jubilee: a huge programme of debt relief and new rules to help debt distressed states in the future.

- A properly funded global climate bank to support green transitions all over the world but particularly in the South.

- A Green Marshall Plan; technology transfer plus specific adaption funds for developing countries different funding mechanisms.

- Encouraging and initiating new regional trade and financial arrangements.

Such a shift of focus will serve as the basis for breaking the impasse of faltering productivity gains and rising structural unemployment along the global economy, developed and less-developed alike. One of the major reasons for this outcome is known to be associated with hyper-financialization episodes of the late 20th century where investment expenditures on fixed capital stagnated as the scarce saving funds had been diverted towards speculative whims and caprices of financial arbitrageurs.

Industrial labor productivity growth is reportedly nil in Latin America (Palma, 2011), while East Asia continuously reports significantly volatile and erratic rates of labor productivity growth. These observations had been projected to be endured over the next several decades in an OECD 2014 Policy Paper, where it is argued that the global economy will likely slowdown from its annual average of 3.6% over 2014-2030 to 2.7% over 2030-2060; and that the growth rate of today's developed world will slow down to as much as 0.5% by 2060. Authors of the OECD 2014 Report claim that two of the major reasons behind this projection are (1) intensified threats of the climate crisis and (2) increased threats of social exclusion and global inequalities. In the words of Acar *et.al.* (2018) "*Informalization, fragmentation and social exclusion are observed to be the indispensable outcomes of modern enclaves; in short, modern/formal centers of growth have simultaneously created their informal bases; fragmented informal structures were produced and sustained by their modern, formal counterparts*" (p.17).

Consequently, in what follows, "*in the contextual realm of Turkey, the modern Istanbul not only retains and produces backwardness in Urfa, but also generates further Urfas within its geographical domain. As cycles of informal Urfas surround the Istanbul-core, fragmented / dualistic activities form the basis of sources of cheap labor consisting mainly of the socially excluded ranks of migrants who are, in turn, pressed to offer their labor power in a race to the bottom. Turkey's experience is, by no means, unique. It is part of a larger picture of the international division of labor within the global economy where formal and informal structures co-habit side by side as part of a larger social formation"* (*ibid,* p.18).

We also argue that a fiscal expansion strategy driven by public investments towards intensifying the interlinkages between a green-agriculture-industry networks, to be complemented by green transitions in the power sector (as laid out in Kat, *et.al.* 2022), will constitute one solid strategy to break the ongoing impasse of low productivity, low employment capacity and increased inequality.

We also argue, as in our previous assessment in Orhangazi and Yeldan (2023), that "a paradigm shift in monetary policy must be an indispensable component of the new strategy". Acting as the most viable agents of monetary policy making towards green transitions, central banks will have to shift towards a more active policy stance that is more engaged with elimination of structural bottlenecks rather than market neutrality instrumentalization in their pursuit of price stability.

There is still a tremendous investment gap to be filled on the way to fulfilling 1.5°C scenario. The International Energy Agency (2021) in its Net Zero for 2050 Report, for instance, projects that the financial requirements of the energy transition are expected to add 1.5 to 2% more to the investment-GDP ratios in the developed countries. World Bank's (2017) Report of the High-Level Commission on Carbon Prices admits that "*it is unrealistic to expect market players to fill this gap on their own*". What's more, markets are already skewed to finance carbon-intense sectors. In World Bank's view "*this could be the result of lack of information, lack of guidance, or simply limited supply of green financial alternatives*". In the meantime, provision of credit by banks to socially undesirable activities are noted as "market failure" (Volz, 2017).

In fact, in the words of UNCTAD (2019), "*most of the current industrialization and governance problems originate from the excessive volatility of speculative finance flows characterizing the current realm of markets*". These observations taken together led Daniela Gabor (2020) to coin the term *Wall Street Consensus*, who along with her colleagues argued that "*the climate policy tools of the neoliberal agenda –carbon pricing via international climate markets and debt-driven climate infrastructure asset instruments"—will serve only for intensified financial vulnerability in the Global South and lead to little achievement, if any, towards hopes of a green development pathway*" (Dafermos, Gabor and Michell, 2021).

In a nutshell, then, we need a transition driven by the following principles at the minimum:

- Transforming the input requirements of the agricultural economy away from chemicals towards biological management.

- Increase in the energy and input efficiency and the expansion of sustainable practices such as the regenerative agriculture, reduced tillage, cover crops, crop rotation, organic agriculture and larger biodiversity zones.

- Addressing informalization and fragmentation of the domestic labor markets by sustaining a public investment-led green transition programme, allowing better living conditions for employees in the rural areas.

- Granting a more active role to the state in resource mobilization and resource allocation within principles of social evaluation, rather than myopic expectations of the oligopolistic financial markets, which would create better investment opportunities for the transformation of the rural areas and the expansion of the sustainable agriculture,

- Transition from fossil fuel-based production to sustainable and renewable forms of energy, with emphasis on strengthening the industry and agricultural interlinkages,

- Re-dressing the central banks with a more active role in combatting the risks of climate change along with principles of green finance and green central banking practices, re-regulate finance to sustain green transitions in agro-industries.

Green Agriculture is defined in various intelligent network technologies, intensive use of data gathered through multiple sources, and increased interconnectedness via new communication channels (Zambon et al. 2019; Trendov, Varas, and Zeng 2019; FAO 2017). Beyond the productivity gains it offers, potential (co)benefits of *green agriculture* include its contribution to more efficient use of natural resources and reduced impact of farming activities on the environment. New communication tools and applications also promise to reduce transactional costs by improving price transparency and enabling enhanced control and monitoring of supplies and logistics.

Yet the strategic move towards *green agriculture* comes with its challenges of structural transformation. While it may help bridge the gap between agriculture and industry in areas where economic institutions are conducive to the diffusion of new technologies, it will likely create/widen the duality within the agricultural sector. Addressing the structural bottlenecks and inefficiencies of a two-speed, dual economic structure may also result from an agricultural (sub)economy of rapid growth, resource efficiency, and market competitiveness against stagnation, resource degradation, or climate vulnerability.

More specifically, three factors will shape the challenges and opportunities shaping the green agriculture transition and the agro-industrial development path in Türkiye. First, EU's Farm-to-Fork and Biodiversity strategies and policy actions, combined with the CBAM, will affect the world food prices, as well as the foods exports of Türkiye. In the realistic scenarios, EU's food imbalances will disrupt (positively or negatively) demand for the exported agricultural goods. Second, Türkiye's own path of decarbonization efforts in agriculture, however ambiguous it looks now, will create imbalances in the domestic supply of foodstuff and many challenges. Finally, rising temperatures, changing precipitation and rainfall patterns, and extreme weather events will significantly impact how much and what kind of food we can grow in different regions, affecting the availability of specific foodstuffs. Within such a challenging environment, the policy framework should be developed with the perspective of increasing resilience of the farming sector, adaptation capacity and reinforcing and reshaping the agriculture-industry linkages with a holistic approach. In the light of current challenges, the roadmap for a shift in the agricultural policies should focus on

- Landscape-Level Sustainability: Promote sustainable agricultural practices across large agricultural landscapes, encompassing both farming activities and related agro-industries. This holistic approach should consider the entire spatial unit.

- Strengthening Industry Linkages: Reinforce linkages between agriculture and industry to foster sustainability. This includes designing new financial instruments specifically tailored to support smallholder families.

- Arid and Semi-Arid Success Stories: Develop and showcase successful examples of agricultural transitions towards sustainability in arid and semi-arid regions. These models can serve as inspiration for other regions facing similar challenges.

- Digital Transformation: Develop digital monitoring and information tools to track the transformation of agricultural landscapes over time. This data will be crucial for evaluating the effectiveness of implemented strategies.

- Affordable Innovation: Promote research and development (R&D) efforts to create cost-effective techniques that enhance input efficiency in farming. These innovations should be readily available and affordable for small and medium-scale farmers.

- Results-Based Support: Redesign government financial support to encompass all sustainable agricultural practices. Prioritize a results-based approach that allows local solutions and empowers communities.

- Strengthening Farmer Resilience: Support the development of new organizational models, such as farmer organizations, cooperatives, and private initiatives. These structures can increase the resilience of the farming community by facilitating access to essential resources like information, technology, and communication tools.

- Rural Revitalization: Rethink approaches to rural life by promoting rural revitalization. This includes improving access to education, healthcare, and other social infrastructure to create a more attractive and sustainable way of life in rural areas.

5. Conclusion

The structural challenges outlined in this article can be generalized to many developing economies which have undergone substantial structural change in the second half of the twentieth century. These economies experienced industrialization to some degree, supported by the labor outflow from the rural sectors. At the same time, the rise in land productivity enabled them to keep food prices low and sustain the remaining rural population. On the other hand, increasing mechanization, expanded use of chemicals, and intensification have led to adverse environmental effects, such as land degradation, nutrient loss, water and soil contamination, and contributed to global carbon emissions by extensive energy use.

Today, on the one hand, the underlying structural problems in Turkish agriculture, such as the decline in land use and unfavorable demographic factors, compound the risk of food security. On the other hand, there are increasing attempts, while very limited in scope, to transform the farming systems towards sustainable production. Meanwhile, climate change's cumulative and geographically varied effects bring unprecedented challenges.

The historical data and macro simulations we present in this article show that although the challenges in the way of sustainable transformation of agriculture are complex and profound, there exist viable policy frameworks that can be combined in a way to stabilize the food supply, decarbonize the food production, and even increase the farm incomes. More specifically, we argue that a significant reduction in chemical use and a 10% carbon tax have non-negligible adverse macro effects. Yet, they can be reversed by decreasing the dependence on fossil fuels and increasing the efficiency of agriculture. Therefore, our findings are cautiously optimistic.

The policy options designed to promote a sustainable agricultural transition in Türkiye face a confluence of challenges. These include the ambitious goals outlined in the EU's Farm-to-Fork and Biodiversity strategies, Türkiye's existing structural issues within the agricultural sector (heavy reliance on fossil fuels, land degradation, inefficiencies, and an aging rural population), and the multifaceted complexities of climate change.

The magnitude of these challenges necessitates a significant overhaul of agricultural and agro-industrial policies. Crucially, the new framework should prioritize bolstering the resilience and adaptability of small and medium-scale family farms, recognizing the interconnectedness between and uniqueness of agricultural landscapes. This necessitates an approach encompassing technological and financial innovations, coupled with the creation of novel social organizations within rural areas. These social organizations, long neglected by public policy and mainstream economic thought, are vital for a successful agricultural transition.

References

Acar, Sevil, Ebru Voyvoda and Erinç Yeldan (2018) *Macroeconomics of Climate Change in a Dualistic Economy: A Regional Computable General Equilibrium Analysis*. Elsevier.

Acar, Sevil and Yeldan Erinç (2016). "Environmental impacts of coal subsidies in Turkey: A general equilibrium analysis". *Energy Policy*, 90, 1-15.

Aghion, Philippe, Julian Boulanger and Elie Cohen (2011) "Rethinking Industrial Policy" *Bruegel Policy Brief*, No 4, June.

Andreoni, Antonio (2014) "Structural Learning: Embedding Discoveries and the Dynamics of Production" *Structural Change and Economic Dynamics*, Vol. 38. 941-951.

Andreoni, Antonio and Ha-Joon Chang (2019) "The Political Economy of Industrial Policy: Structural Interdependencies, Policy Alignement and Conflict management" *Structural Change and Economic Dynamics*, Vol. 48: 136-150.

Atkinson, Toy (2015) *Inequality: What Can Be Done?* Cambridge, MA: Harvard University Press.

Pınar Ceylan, Ulaş Karakoç, Derya Nizam (2022) "Sürdürülebilir tarım pratiklerinin yaygınlaştırılması için politika uygulama ve iletişim önerileri: WWF-Eti Burçak Sağlıklı Topraklar Hareketi Çiftçi Araştırma Raporu". DOI: 10.5281/zenodo.6464640.

Pınar Ceylan, Ulaş Karakoç, Esra Kutman (2023) "İyi Pamuk ve pamukta sürdürülebilir üretimin yaygınlaştırılması için öneriler", WWF-Türkiye Araştırma Raporu.

Ağır, Seven, Ulaş Karakoç ve Aylin Topal (2023) *Yeşil Dönüşüm ve Türkiye'de Gıda ve Tarım Sektörü*, Maliye Hesap Uzmanları Vakfı Yayınları.

Barreiro Hurle, Jesus, et al. Modelling environmental and climate ambition in the agricultural sector with the CAPRI model. No. JRC121368. Joint Research Centre (Seville site), 2021.

Beckman, J., vd. (2020). Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies, EB-30, U.S. Department of Agriculture, Economic Research Service.

Bolio, E., Remes, J., Lajous, T., Manyika, J., Rossé, M. and Ramirez, E. (2014). *A tale of two Mexicos: Growth and prosperity in a two-speed economy.* McKinsey Global Institute.

Bouzaher, Alex, Şebnem Şahin and Erinç Yeldan (2015) "How to go green? A general equilibrium investigation of environmental policies for sustained growth with an application to Turkey". *Letters in Spatial and Resource Sciences.* 8(1), 49-76.

Bohringer, C. and Loeschel A. (2006) "Computable general equilibrium models for sustainability impact assessment: Status quo and prospects", *Ecological Economics*, 60(1), 49-64.

Bremmer, Johann; Ana Gonzalez-Martinez; Roel Jongeneel; Hilfred Huiting; Rob Stokkers; Marc Ruijs; (2021) "Impact Assessment of EC 2030 Green Deal Targets for Sustainable Crop Production" Wageningen Economic Research Report no 150, December.

Dafermos, Yannis, Daniela Gabor & Jo Michell (2021) The Wall Street Consensus In Pandemic Times: What Does It Mean For Climate-Aligned Development?, *Canadian Journal of Development Studies / Revue canadienne d'études du développemen*t, 42:1-2, 238-251.

Diez F. and D. Leigh (2018) "The Rise of Corporate Giants" Vox EU.

Dikau, S., & Volz, U. (2021) “Central bank mandates, sustainability objectives and the promotion of green finance”, *Ecological Economics,* 184: 107022.

Eichengreen, B. (2021) “New-Model Central Banks”, Project Syndicate, February 9, 2021

https://www.project-syndicate.org/commentary/central-banks-have-tools-for-climate-change-and-inequality-by-barry-eichengreen-2021-02

Elshennawy, A., S. Robinson and D. Willenbockel (2016) “Climate change and economic growth: An intertemporal general equilibrium analysis for Egypt”, *Economic Modelling*, 52, 681-689.

European Commission, Joint Research Centre (JRC) (2021) *Modelling environmental and climate ambition in the agricultural sector with the CAPRI model.* Bruxells.

International Energy Agency (2021) *Net Zero By 2050*, https://www.iea.org/reports/net-zero-by-2050.

(FAO) Food and Agriculture Organization of the United Nations (2017). *The future of food and agriculture: Trends and challenges*. Rome.

Johnston, Bruce F., and Mellor, John W. (1961) “The Role of Agriculture in Economic Development”, *The American Economic Review*, Vol. 51, No. 4, pp. 556-593.

Kat, Bora, Ümit Şahin, Osman Bülent Tör, Saeed Teimourzadeh, Ebru Voyvoda, Erinç Yeldan (2022) “Coal Phase-out in the Turkish Power Sector towards net-zero emission targets: An Integrated Assessment of Energy-Economy-Environment Modeling” Sabancı University, Istanbul Policy Center Research Paper.

Lewis, W. Arthur (1954) “Economic Development with Unlimited Supplies of Labour”, *The Manchester School*, Vol. 22, No. 2, pp. 139–191.

Lipton, M. (1977) *Why poor people stay poor: Urban bias in world development*, Cambridge, MA: Harvard University Press.

Milanovic, Branko (2023) *Visions of Inequality from the French revolution to the End of Cold war*, Cambridge, MA & London, England: The Belknap Press of Harvard University.

Orhangazi, Özgür & A. Erinç Yeldan (2023) “Turkey: Challenges and Strategies Towards Sustainable Development”, Country Report prepared for the Project, *Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development*, UNCTAD, Geneva.

Palma, Gabriel (2011) “Why has productivity growth stagnated in most Latin American countriessince the neo-liberal reforms?” Cambridge Working Papers in Economics (CWPE) No 1030.

Piketty, Thomas (2014) *Capital in the 21st Century* Harvard University Press.

Rada, Codrina and Rüdiger, von Arnim (2012) “India’s Structural Transformation and Role in the World Economy” University Utah, Department of Economics Working paper No 2012-05.

(ÇŞB) T.C. Çevre ve Şehircilik ve İklim Değişikliği Bakanlığı (2024) *İklim Değişikliği Azaltım Stratejisi ve Eylem Planı 2024-2030.*

Telli, Çağatay, Ebru Voyvoda and Yeldan Erinç (2008) “Economics of environmental policy in Turkey: A general equilibrium investigation of the economic evaluation of sectoral emission reduction policies for climate change”, *Journal of Policy Modeling*. 30(2): 321-340.

Timmer, Peter C. (1998) ‘The Agricultural Transformation,’ in Eicher, Carl and J. Staatz (eds.), *International Agricultural Development*, Baltimore; London: The John Hopkins University Press.

(TOB) TC Tarım ve Orman Bakanlığı Tarım Reformu Genel Müdürlüğü (2021). *İklim Değişikliği Değerlendirme Raporu.* Ankara.

TÜSİAD (2020), *Sürdürülebilir Büyüme Bağlamında Tarım ve Gıda Sektörünün Analizi: İklim Değişikliği Etkisi Altında Tarımsal Ürün Arzının Sürdürülebilirliği*.

Trendov, N.M., Varas, S., Zeng, M. (2019) “Digital Technologies in Agriculture and Rural Areas: Briefing Paper”, Report by the Food and Agriculture Organization of the United Nations (FAO), Rome.

(UNCTAD) United Nations Conference on Trade and Development (2019) *Trade and Development Report: Financing a Global Green New Deal,* Geneva.

(UNCTAD) United Nations Conference on Trade and Development (2016) *Trade and Development Report: Structural transformation for inclusiveand sustained growth*, Geneva.

Villeroy de Galhau, F. (2021). “How to revisit central banking and financial stability”. *Peterson Institute for International Economics.*

Volz, U. (2017). On the role of central banks in enhancing green finance. *The UN Inquiry Working Paper,* No: 17/01.

Voyvoda, E. and Erinç Yeldan (2015) Greening Turkish Economy: A General Equilibrium Investigation of Environmental Policies for A Low Carbon Growth Path. Report prepared for the Istanbul Policies Center and World Wild Foundation (WWF-Turkey).

Zambon, I., Cecchini, M., Egidi, G., Saporito, M.G., Colantoni, A. (2019) “Revolution 4.0: Industry vs. Agriculture in a Future Development for SMEs”, *Processes,* 7. https://doi.org/10.3390/pr7010036