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Prioritizing public investment in agriculture for post-COVID-19 recovery: A sectoral ranking for Mexico

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ABSTRACT

Mexico's economy contracted unprecedentedly in 2020. Agriculture remains important for the economy and job creation, but it lacks strong productive dynamism and exhibits high informality. We show that investing in agriculture's infrastructure can contribute to economic recovery and welfare post-COVID-19. On the basis of a dynamic computable general equilibrium model, we allocate to agriculture sectors public investment in productive infrastructure equivalent to 0.25% of GDP during three immediate years and analyze effects up to 2030. We see improvement in GDP, agri-food output and private consumption with rural poverty reduction. Based on the impact on these variables, a ranking suggests that new investments should prioritize the sugar cane sector. Highly ranked are also cereals, mainly maize, and other export-oriented crops such as flowers and coffee. Not only should investments prioritize these sectors, but the government should also finance them with foreign borrowing to speed up recovery and avert the short-term macroeconomic trade-offs of domestic financing.

1. Introduction

COVID-19 has challenged decision-makers. Initially, they focused on addressing the health emergency, but nowadays economic recovery features more prominently in their agendas. In Mexico, as in many other countries, major economic activities were shut down as a result of the measures to contain the COVID-19 spread. In the second quarter of 2020, gross domestic product (GDP) recorded an unprecedented 18.7% negative growth rate. The 6.2% growth for 2021 that the International Monetary Fund (IMF) had forecasted for Mexico in October 2021 (IMF, 2020) is encouraging but raises questions: What could drive such a strong economic recovery under the current economic constraints? What are cost-effective ways to invest limited public resources to spur growth for the well-being of Mexicans? Low-income countries as well as middle-income ones like Mexico will have to exercise considerable fiscal responsibility and objectivity in reallocating their limited public resources to meet the most urgent needs arising from the pandemic while enabling economic recovery.

Economic stimulus measures should focus on key sectors not only for the economy, but also for job creation and the living conditions of millions of people. Mexico's agriculture accounts for a low percentage of GDP (3.3% and 4.2% in the last ten years and in the second quarter of 2020, respectively). However, the discussion on recovery in Mexico should not exclude agriculture for a number of reasons—based on information from INEGI (2019). Agriculture employs 12% of the workforce (6.5 million people) and the livelihoods of a large part of the rural population depend on it. Approximately 47% of farms sell what they grow, and this totals 87.4% of total production volume. Production for self-consumption is significant: specifically, 27.5%, 58.0% and 75.4% of farms use a part of their output to feed livestock (7.8%), as seed for planting (0.5%) and for family consumption (4.3%). A number of agricultural products are exported, mainly red fruits (especially blackberries), tomato, avocado, sugar cane, tequila, and malt beer (according to data from the Agrifood and Fisheries Information Service [SIAP] for 2017). The world trade treaty between the United States–Mexico–Canada Agreement (USMCA) has significant food trade implications not only for Mexico and its trade partners, but also for the rest of the world.

Mexico's agriculture sector has been resilience during the pandemic. Not only is it a sector with unrealized production potential, but it is also vital for reducing poverty. According to the official multidimensional poverty indicator, 55.3% of the rural population is poor, versus 37.6% in

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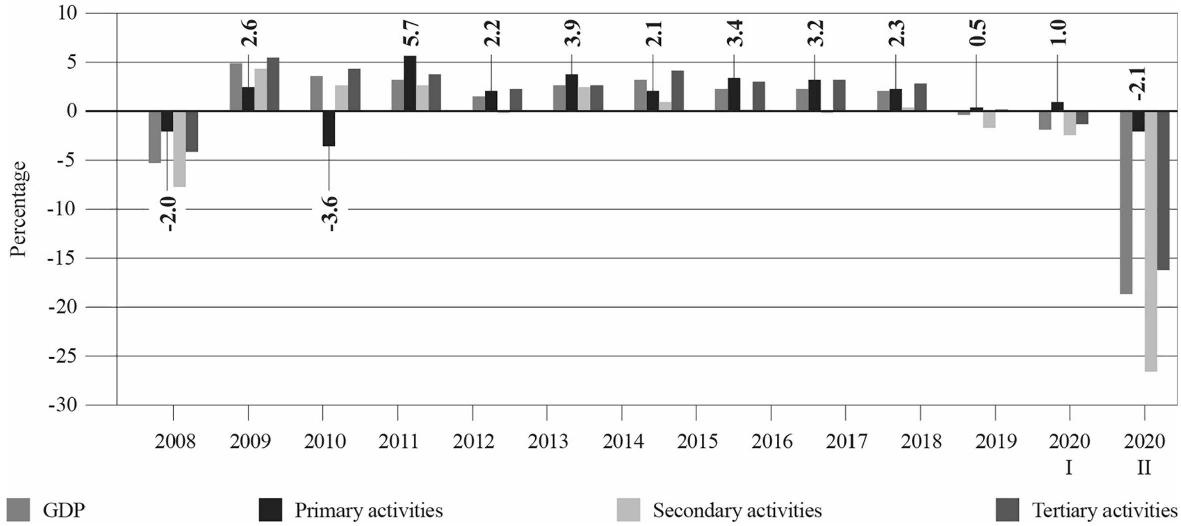

Fig. 1. Average annual growth of GDP and output in the three sectors of economic activity. *Note:* Percentages are presented only for primary activities. *Source:* Authors' own elaboration based on INEGI national account data.

Table 1
Value added by sector, 2010–2020 (average annual growth rates).

Items	2010–2019	2019	2020*	
			Quarter I	Quarter II
Primary sector (%)	**2.2**	**0.4**	**0.9**	**−0.5**
Crop agriculture	2.7	−0.5	0.4	−0.1
Livestock farming	1.3	3.3	2.8	1.8
Forestry	1.2	−2.0	−5.1	−35.6
Fishing, hunting and gathering	2.5	−4.9	−2.0	−0.4
Services related to agricultural and forestry activities	2.4	−31.2	8.7	−15.8
Secondary sector (%)	**0.9**	**−1.7**	**−2.6**	**−29.7**
Total food industry	2.1	1.6	3.2	−1.1
Animal feed production	2.1	1.5	7.1	6.1
Grinding of grains and seeds and production of oils and fats	2.5	2.3	2.9	0.7
Making of sugars, chocolates, sweets and the like	0.0	−8.8	−2.8	−25.3
Preservation of fruits, vegetables and prepared foods	2.7	2.6	0.6	−6.6
Dairy processing	1.4	1.0	2.5	−0.7
Butchering, packaging and processing meat from cattle, poultry and other edible animals	2.9	5.0	8.2	4.9
Preparation and packaging of seafood	1.0	−3.2	−7.5	−0.4
Preparation of bakery products and tortillas	1.5	0.5	2.0	−0.1
Other food industries	3.2	1.9	1.2	−5.9
Tertiary sector (%)	**3.0**	**0.2**	**−0.7**	**−17.7**

Note: *Constant prices of 2013, preliminary figures for 2020. *Source:* Authors' own elaboration using data from INEGI National Accounts System.

urban areas—based on the last official estimates for 2018 from the National Counsel for the Evaluation of Social Development Policy (CONEVAL, 2018). The government's agriculture and rural development sectoral program 2020–2024 aims to achieve food self-sufficiency by increasing agricultural, livestock and aquaculture production and productivity (Secretaría de Agricultura y Desarrollo Rural, 2020, p. 17).

Against this backdrop, this paper addresses two questions: Can public investment that promotes productivity in Mexico's agriculture drive growth in agri-food production with positive effects on the economy and rural poverty reduction? If it can, which agriculture sectors should be prioritized by the government? We answer these questions by analyzing scenarios of public investment using a recursive-dynamic, multisector computable general equilibrium (CGE) model for Mexico. We focus on public investment considering that in a crisis context—such as during the COVID-19 pandemic—private investors are more risk-averse and thus the government must intervene to create an environment more conducive for private investment.

We rank agriculture sectors according to the impacts that allocating the same public investment in productive infrastructure across them will generate on sectoral and national economic growth, household welfare and rural poverty. The impacts take into account the macroeconomic repercussions of using alternative sources to finance the public investment.

The rest of the paper is organized into five sections. Section 2 describes the recent context of the Mexican economy. It focuses on the evolution and contributions of agriculture in terms of production, employment and living conditions of the population, and also points to public investment and productive infrastructure gaps in the sector. Section 3 summarizes the modeling approach, presents the data used to apply it, and describes the scenarios that were developed. Section 4 then provides the analysis of the scenarios, including a ranking of sectors according to the socio-economic effects of investing in each of them. Section 5 presents policy implications, particularly with regard to what the results mean for national development planning and the importance of putting them in the right context and aligned with policy objectives. Finally, Section 6 presents the conclusions and highlights areas for future research. Four supplementary documents are provided for the reader to dive deep into the CGE model: i.e., mathematical statement, data set, key transmission mechanisms underlying the results, and sensitivity analyses.

2. Primary sector, productive infrastructure gaps and rural poverty

2.1. Primary sector resilience

COVID-19 hit Mexico hard. The economy was not growing impressively before the pandemic, but it decelerated more significantly as major economic activities were shut down. In the second quarter of 2020, GDP recorded an unprecedented 18.7% negative growth rate. While the secondary and tertiary sectors of the economy were affected the most, the primary sector has been more resilient (Fig. 1).

Mexico's economy has transitioned into a service economy, although not at the expense of the primary sector. The latter has stabilized in the last 12 years, representing around 3.4% of GDP. On the other hand, the secondary sector has reduced its share of GDP from 35.3% to 27.6%, and the tertiary sector has increased it from 61.3% to 68.3%—according to INEGI national account data. However, the GDP share of primary and secondary activities related to the agriculture and agribusiness sectors have exhibited significant fluctuations.

In the 2010–2019 period, primary activities, including crop production, livestock farming operations, forestry, fishing and hunting, report an average annual growth rate of 2.2% (Table 1). Of these activities, crop agriculture grew the most (2.7%), followed by the fisheries, hunting and gathering sector (2.5%) and by services related to agricultural and forestry activities (2.4%). However, the pattern from the previous decade had changed by 2019, when all primary sectors except livestock farming contracted. In the first half of 2020, during the unfolding of the pandemic, crop production sectors managed to recover insofar as they benefited from being designated as "priority sectors" for food, the food manufacturing industry and deliveries. Still, the food industry as a whole contracted 1.1% in the second quarter of 2020.

There is significant growth variability within the primary sector. For example, within the legumes sector, chickpea production decreased by 57.5% in 2019, while peas increased by 4.4%. Growth variability is also seen over time. For example, within the maize sector, which is a priority product in the 2019–2024 National Development Plan (NDP) (Presidencia de la República de los Estados Unidos Mexicanos, 2019), the forage maize sector grew over the past decade at a rate of 8.4% per annum, but fell by 8.0% in 2019. Widely divergent growth rates across agriculture sectors reflect a number of factors ranging from markets to factors directly related to production and climate vulnerability.

There are also important production linkages between primary agriculture sectors and the food industry. As the number of cattle has risen, so has the production of milk. The food processing sector, within the secondary sector (32% of GDP), has fluctuated between 3.6% and 4.7% of GDP between 2010 and 2019, averaging 3.9% of GDP over the past 12 years. Within this sector, "butchering, packing and processing of meat from cattle, poultry and other edible animals" and "making of bakery products and tortillas" are the main sectors, each representing 1% of GDP, or a bit more.

2.2. Productive infrastructure gaps

Public investment has been decreasing since 2010, at an average of 6.1% in 2010–2019 and 9.9% in 2019. With the pandemic, public investment but also private investment dropped by more than 10% and 37%, respectively, in the second quarter of 2020 (see Table A1, Appendix A). This gives additional justification to step up public investment in support of economic recovery and to meet targets set in the 2019–2024 NDP.

Additional investment is particularly needed in agriculture. Past agricultural reforms did not bear the expected fruit. The first reform, which was completed in 1939 with the expropriation of mega-plantations and the creation of *ejidos* (areas of communal land used for agriculture), provided no financial support or training for farmers. The second, instituted in 1992, sought to privatize land without state intervention—that is, allowing *ejidal* land to be sold by its owner. These reforms did not result in significant investment in equipment, high-quality export agriculture, or any meaningful improvement of farmers' incomes (Cárcar Irujo, 2013).

In recent years, there has been little progress in agricultural reform. The Support Fund for Non-regularized Agricultural Nuclei (FANAR), established in 2007, helps farmers obtain land titles, which is essential to provide collateral guarantee when applying for production loans (RAN, 2015). Even so, credit remains a major constraint for productive investment in agriculture.[1] In fact, our analysis of data from the National Agricultural Survey (INEGI, 2019) suggests that, in 2019 for example, less than 11.0% of all farmers obtained credit. If one looks at the same survey for additional years (i.e., 2012, 2014, 2017 and 2019), the high costs of inputs and climate-related crop loss are two of the greatest problems farmers face over time. Moreover, purchasing inputs or raw materials and paying salaries or wages—rather than investing, continue to be the main uses of credit in agriculture. The National Agricultural Survey also shows that only 19.5% in 2017, and 20.5% in 2019, of farming units declared they had their own machinery, primarily tractors, followed by precision sowers. A study looking at approximately 43.0% of Mexico's rural population (25 million people) indicates agricultural households provide an average of 31 more employment days than non-agricultural households (Manning and Taylor, 2015). This reflects a lack of harvesting technology, which forces small farmers to spend most of their time harvesting. According to the same study, increased agricultural efficiency would raise the value of rural households' time, reducing their farm work and likely expanding their opportunities to sell their output on the market. Clearly, investment in productive infrastructure is greatly needed in Mexican agriculture in order to boost productivity.

Another reform was the amendment to the National Water Law. Currently, however, the regulation of irrigation water use—at the time of writing—is in conflict in the State of Chihuahua. Some northern Mexican states, such as Sonora, have been documented as pioneers in the use of water and cutting-edge technology in planting and harvesting. The issue of irrigation, however, does not appear to have been a priority in public policy since 1980, and has rather been addressed by the private sector through better water management, along with fertilizer use, crop diversification, and planting systems, among other measures (McCullough and Matson, 2016). In November 2012, the United States of America and Mexico signed a bilateral agreement, referred to as Minute 319 (Schlatter, Grabau and Waters, 2015), to allocate the Colorado River's environmental water flows in Mexico and expand restoration efforts to repair the water corridor. Under five-year agreements, both countries would provide 105,392 acre-feet of water to mimic natural flows to recover the Colorado River. These agreements—under review at the time of writing—are important to supply water to much of the country's Lagunera region. While water is a key resource to expand agricultural production, however, without new investment in irrigation water savings will not be possible.

2.3. Rural poverty

Given the lack of productive investments, labor market informality in agriculture and rural poverty are a concern. According to the National Agricultural Survey, in 2017 only 63.9% of agricultural workers were paid laborers (7.8% with a permanent contract, 12.6% as occasional hires, and 79.5%-day laborers), and this percentage decreased to 57.1% in 2019 (6.4% with a permanent contract, 10.3% occasional hires, and 83.3%-day laborers). Mexico's agriculture is a fairly unprotected sector in terms of social benefits and its informality has been rising. There are

[1] Credit to agriculture represents only 1.9% of total credit in Mexico, ranking among the lowest in Latin America and the Caribbean (ECLAC, FAO, IICA, 2019). Such low credit to agriculture signals a low support to the sector.

Table 2
Income poverty, 2008–2018.

Percentage of the population with income below:	2008	2010	2012	2014	2016	2018
The extreme income poverty line	**16.7**	**19.4**	**20.0**	**20.5**	**17.4**	**16.8**
rural areas	32.8	34.9	32.7	31.9	29.2	27.3
urban areas	11.9	14.7	16.2	17.1	13.9	13.4
The income poverty line	**49.0**	**52.0**	**51.6**	**53.2**	**50.5**	**48.8**
rural areas	63.1	65.9	62.8	62.4	59.7	56.7
urban areas	44.8	47.8	48.3	50.5	47.8	46.3

Source: Authors' own elaboration based on data from CONEVAL.

11.8 million jobs (contracts) for day laborers in the farms included in the survey, and the most widely used contract modality for workers is precisely as day laborers. Permanent jobs are fewer, regardless of the size of the cultivated area. Moreover, 95.9% of the labor force is hired by small and medium-sized farms, and 4.1% by large farms. Unsurprisingly, poverty remains a much bigger problem in rural areas compared with urban areas, even though the gap has been narrowing (Table 2). Because of the pandemic, the survey which provides biannual estimates of poverty and the population census were postponed; however, CONEVAL estimates for the second quarter of 2020 pointed to a significant increase in income poverty. The fact that rural poverty and overall poverty have been declining in unison while urban poverty has increased, points to the significant contribution that improved rural livelihoods that largely depend on agriculture can have on the welfare of millions of Mexicans.

3. Method and data

3.1. Recursive-dynamic CGE model

A public investment shock that boosts productivity in economic sectors will trigger a myriad of potential interrelationships among several economic agents and the direct and indirect effects they may generate. In agriculture sectors, the shock will have effects on their production directly, but also indirectly, for example through input–output relationships between them and other sectors of the economy, in particular the food industries. Some agriculture sectors also trade with the rest of the world. Farmers in sectors promoted by new investments will also increase their intermediate demand as well as also their final demand acting as consumers. For these reasons, our analysis of public investment in productive infrastructure in agriculture sectors relies on a recursive-dynamic CGE model for Mexico. The model had initially been developed as a generic model that can be applied in different contexts (Cicowiez and Lofgren, 2017), but we extended the treatment of the impact of investment in productive infrastructure on sectoral productivity and explicitly model government financing. In essence, this CGE model has some relatively standard characteristics (see, e.g., Lofgren, Lee Harris and Robinson, 2002; Robinson, 1989), as well as others that make it particularly useful for assessing the effects of a productivity shock triggered by public investment in agriculture sectors.

The remainder of this section highlights some of the key features of the modeling approach. The discussion of results in the next section also helps to understand how the model works. The complete mathematical statement of the CGE model is presented in Supplementary material A.

In our model, each year, agents (producers, households, enterprises, government and rest of the world) make decisions to pursue their objectives under their budget constraints. Income and expenditure of each agent are fully captured and balanced by design, as is the case in reality. More precisely, for producers and households, the aim is to maximize profits and utility, respectively. For example, households spend a share of their income on direct taxes and savings; another part is spent on their consumption basket, the composition of which they determine by maximizing their utility. As for the rest of the world, foreign exchange inflows and outflows are matched by an adjustment of the real exchange rate resulting from the model's solution. Wages, rents and prices play a crucial role in balancing the supply and demand in the markets for factors of production and products (goods and services). The world price is taken as given for those products that are traded internationally, be they exported or imported; thus, the implicit assumption is that Mexico is a "small" country. Domestically, however, the price for those products is also influenced by taxes, subsidies and the exchange rate.

Solutions for each year are linked to what occurred in previous years, never in subsequent years.[2] Over time, production is determined by the growth in both the use and the productivity of production factors (labor, capital, land and other natural resources). Capital stock growth is endogenous and depends on investment and depreciation. On the other hand, for labor and natural resources (land for crops and livestock, fish stock for fishing, and mineral stocks for mining), the projected supply levels for each period are exogenous. In the case of natural resources, those projected levels are linked to production forecasts. For labor, the projections reflect the evolution of the working-age population and labor participation rates. The labor unemployment rate is endogenous, which more realistically reflects the fact that the Mexican labor market clears mostly through quantities (i.e., unemployment and underemployment, the combined rate of which reached 20.9% in 2020) but also wages to certain extent—compared to the more extreme situations of unemployment with exogenous wages or full employment.[3] The growth of total factor productivity (TFP) depends on the volume of public investment.

Our model is dynamic not only to trace economic growth but also to properly include government investment as a key policy instrument. Government investment affects capital accumulation and productivity over time. Furthermore, our model includes government spending, not only recurrent spending—as is the case in most CGE models—but also capital spending in different sectors as well as alternative sources of financing it.

Specifically, our CGE model allows considering four alternative sources of financing when we simulate an increase in public investment: foreign borrowing, domestic borrowing, revenue from direct taxes and increased efficiency in public spending. The main transmission mechanisms of both increasing public investment itself and using each of these sources of financing it in the CGE model are described in detailed in Supplementary material B. Foreign borrowing will translate into an inflow of foreign exchange, which pushes the real exchange rate up, negatively affecting the tradable sectors of the economy. Domestic borrowing will crowd out private savings of households and enterprises available to finance their own investments. The model allows to trace public debt accumulation over time as a result of using these two borrowing options, which is also important to evaluate the feasibility of scenarios. Under the option of revenue from direct taxes, effective tax rates will increase for both households and enterprises, presumably as a result improved tax administration, in order to generate revenue to finance the new investment expenditure. Alternatively, increasing

[2] Producers and consumers are myopic and make decisions year-to-year, assuming the conditions of each year will hold for future years.

[3] The CGE model includes a wage curve (see equations PRD8 to PRD11 in Supplementary material A). We tested the sensitivity of our results with respect to our assumption for the labor market functioning. Specifically, we also considered two extreme assumptions: unemployment with exogenous wage, and full employment. As expected, under unemployment with exogenous wage, simulating for example an increase in government investment results in larger impacts in terms of the volume of indicators such as private consumption, GDP, and others, rather than in terms of their associated prices. The opposite is observed under the full employment assumption. Moreover, under the full employment assumption, the agricultural sectors that are less labor-intensive show the larger positive impacts from an increase in government investment. The results from this sensitivity analysis are available upon request to the authors.

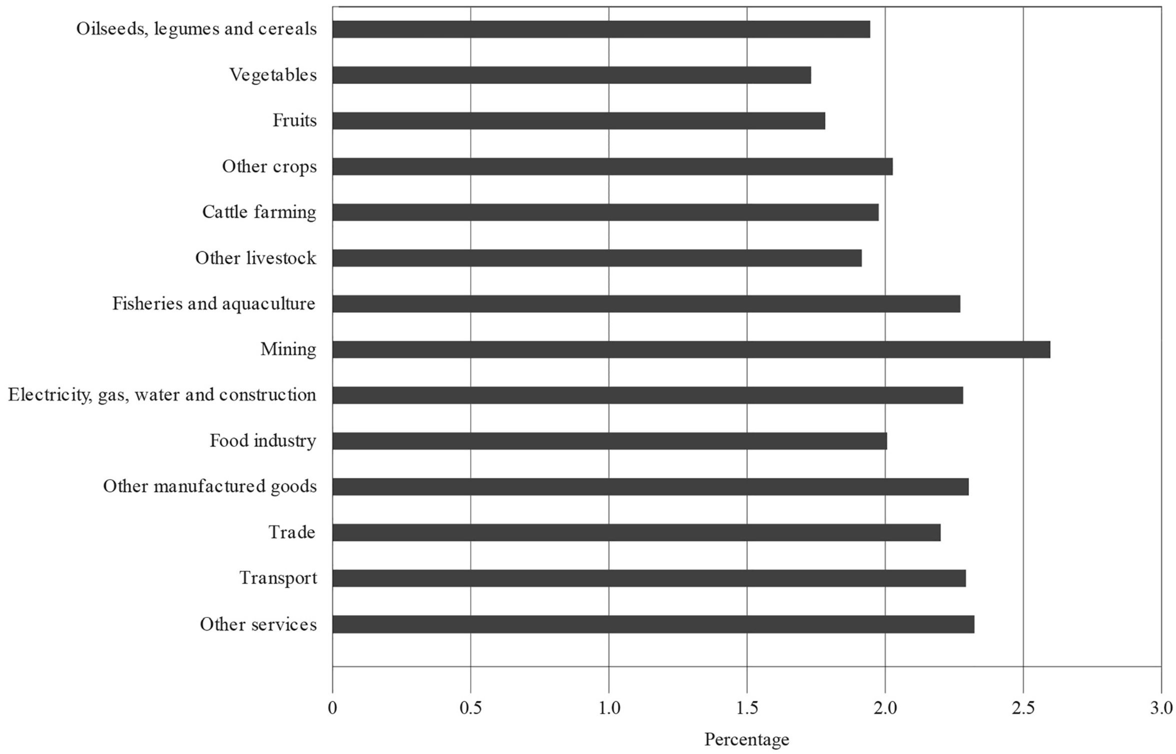

Fig. 2. Average annual growth rate (%) of sectoral production in the base scenario (2021–2030).

efficiency in public spending will imply that the public sector can provide the same volume of services (education, health and public administration) with fewer production factors (labor and capital). Thus, investment is financed by saving resources in other areas of government, without increasing public debt or tax collection.

In this way, this paper contributes to the body of CGE modeling literature that simulates public investment increases to achieve development goals and recognizes the different trade-offs that emerge from using alternatives ways of financing the public investment.[4] While this literature focuses on public investment in social sectors (education, health, and water and sanitation), in this paper we focus on public investments in agriculture.

3.2. Data for calibration

The main source of information for applying our CGE model is a social accounting matrix (SAM). We built a SAM for 2018, combining official national accounts. In general, when building the SAM, we made sure that production sectors that in one way or another appear as priorities in the 2019–2024 NDP were identified individually in the matrix, and we also took a separate account of those sectors of the food industry that use agricultural products as inputs. The SAM was also used to understand the structure of Mexico's economy which is key to interpret the results of public investment scenarios generated through the CGE model (see Supplementary material C).

In addition to the SAM, the CGE model uses several elasticities that define how producers and consumers respond to price and income changes. The value of these was selected on the basis of a review of the literature (see Supplementary material C). Moreover, given the uncertainty regarding their value, we carried out an analysis to determine the sensitivity of our scenario results to changes in elasticity values—and other key assumptions (see Supplementary material D).

3.3. Microsimulation model

The CGE model identifies 18 representative households based on their main income source (see Supplementary material C). A significant part of the distributional effects generated by changes in factor remuneration is thus captured within the CGE model. In particular, changes in income/consumption distribution among representative households are determined in the CGE model. However, income distribution within each representative household is assumed to be constant. In a second stage, we use a microsimulation model to distribute, among individual households identified in the National Survey of Household Income and Expenditure (ENIGH), the changes in income/consumption of each representative household. To do this, each individual household in the ENIGH is linked to one of the representative households in the CGE model (see Supplementary material A). For example, if the CGE model results show that income from unskilled labor increases, households earning part of their income from unskilled work will experience, all other things being equal, an increase in income/consumption. The microsimulation model helps us report standard indicators of monetary poverty.

3.4. Base scenario

We generated a base scenario against which we compare scenarios whereby new public investment in infrastructure boosts productivity in agriculture sectors. It starts from 2018—the year for which we built the SAM—and is projected by inputting the GDP growth rate for the 2019–2030 period into the model.[5] It reflects the growth observed in 2019–2020 and imposes a recovery according to IMF projections released in October 2020 for the period through 2025, assuming policy changes or external shocks are absent. Then, for the 2026–2030 period,

[4] See, for instance, several country applications in Sánchez and Cicowiez (2014), Sánchez and Vos (2013) and Sánchez et al. (2010).

[5] The growth rate is exogenous only to generate the base scenario, making TFP endogenous. Thus, the recession generated by the COVID-19 pandemic is interpreted as a negative TFP shock.

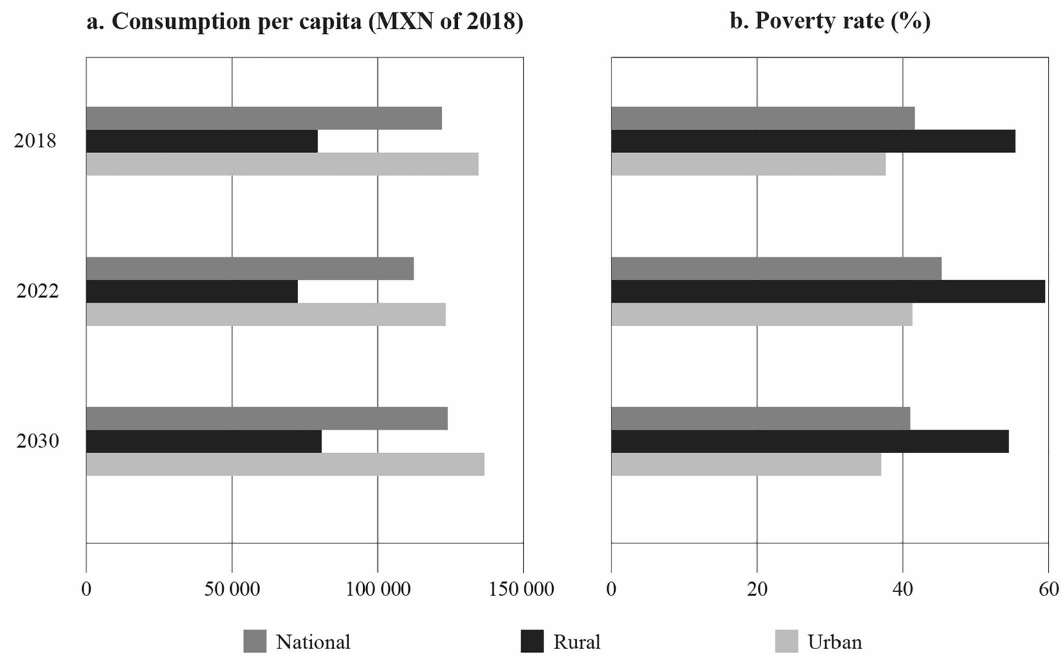

Fig. 3. Per capita consumption and poverty rates in base scenario.

Table 3
Definition of public investment scenarios in production infrastructure.

#	Name	Sectoral focus	Source of funding
1	crops-fbor	crops	foreign borrowing
2	crops-dbor	crops	***domestic borrowing***
3	crops-tdir	crops	***direct taxes***
4	crops-eff	crops	***efficiency public spending***
5	livestk	***livestock***	foreign borrowing
6	oilbrp	***oil-bearing plants***	foreign borrowing
7	bean	***beans***	foreign borrowing
8	othrlegum	***other legumes***	foreign borrowing
9	wheat	***wheat***	foreign borrowing
10	maize	***maize***	foreign borrowing
11	othrcereal	***other cereals***	foreign borrowing
12	veg	***vegetables***	foreign borrowing
13	coffee	***café***	foreign borrowing
14	othrfruts	***other fruits***	foreign borrowing
15	sugcane	***sugar cane***	foreign borrowing
16	othrcrops	***other crops***	foreign borrowing
17	flowers	***flowers***	foreign borrowing
18	bovine	***cattle***	foreign borrowing
19	pig	***pig***	foreign borrowing
20	poultry	***poultry***	foreign borrowing
21	fishing	***fisheries and aquaculture***	foreign borrowing

Notes: The element of the first scenario that is modified in scenarios 2–21 is highlighted in bold and italic letters. Scenarios 5 through 21 do not include the abbreviation "fbor" in their names because in all of them, by choice, the new public investment is financed exclusively by foreign borrowing. In these scenarios the other sources of funding (dbor, tdir and eff) are no longer used.

the 2025 growth rate is maintained unchanged. The projected fall in GDP for 2020 is 9.0%, but the recovery a year later is around 3.5% GDP growth. For the 2021–2030 period, an average annual growth rate of 2.3% is imposed, which essentially resembles the average annual growth rate of the past 20 years. The economically active population grows at the same rate as the working-age population. The supply of agricultural land remains constant. Extraction of natural fishery and mining resources grows at the same rate as GDP. Government revenues and spending are maintained constant as a share of GDP, so as to ensure policy stability in these major variables which grow at the same pace as GDP—at 2.3% during the 2021–2030 period.

In addition, to ensure the base scenario replicates the functioning of the economy that was observed in 2018–2020 and the economy subsequently converges to a stable growth rate, the following assumptions are made: tax rates remain unchanged; other government revenues (such as domestic and foreign borrowing) as well as all government spending evolve proportionally to the GDP; and, balance-of-payments components also evolve as an exogenous proportion of GDP, except for exports and imports. All macroeconomic aggregates grow in a balance manner, at the average annual growth rate of the economy (2.3%) for the 2021–2030 period. Agriculture sectors use agricultural land assumed to be in virtually constant supply, such that their growth rate is lower than that of other sectors, usually less than 2.0%, except, of course, for fishing, which is not land-intensive (Fig. 2).[6] The other productive sectors have average annual growth rates ranging from 1.7% to 2.6%. Interestingly, the oil sector has a relatively high growth rate, due to its significant export orientation.

The base scenario, on the basis of the microsimulation model, shows a significant increase in the poverty rate in 2020, the year of the COVID-19 crisis. Measured by consumption, rural and urban poverty rates—which are 55.3% and 37.6% in 2018 for rural and urban areas, respectively—are projected to increase, for example, to 60.0% and 41.8%, respectively, in 2022, maintaining the rural–urban gap. With the recovery of private consumption in the base scenario, poverty rates subsequently drop and are projected to be 54.3% and 36.7%, respectively, by 2030, in line with the projected per capita GDP growth (Fig. 3).

3.5. Public investment scenarios

We developed 21 scenarios where the shock in all of them is an

[6] In the other sectors, the growth rate is determined as a function of the amounts of capital and labor they employ. They are not restricted by the use of natural resources such as land or mining resources.

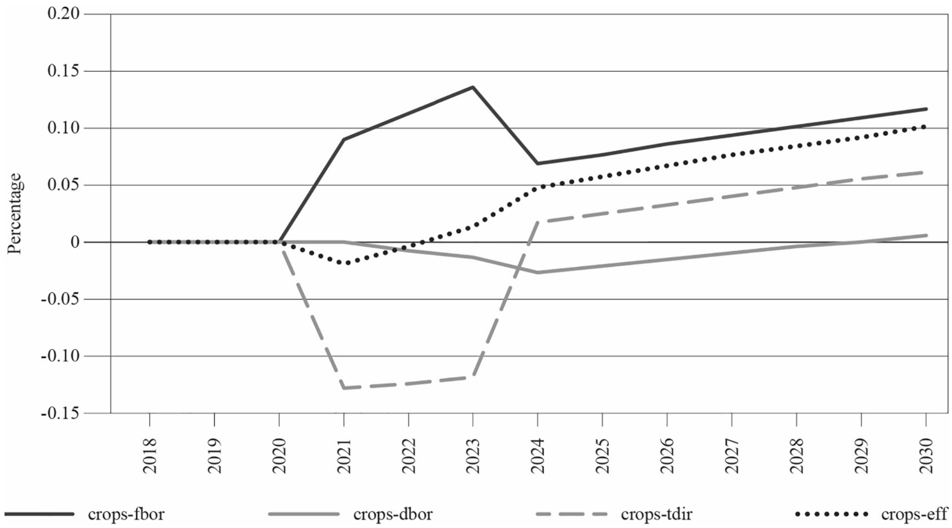

Fig. 4. Private consumption in four public investment scenarios with alternative financing sources (percentage deviation from the base scenario).

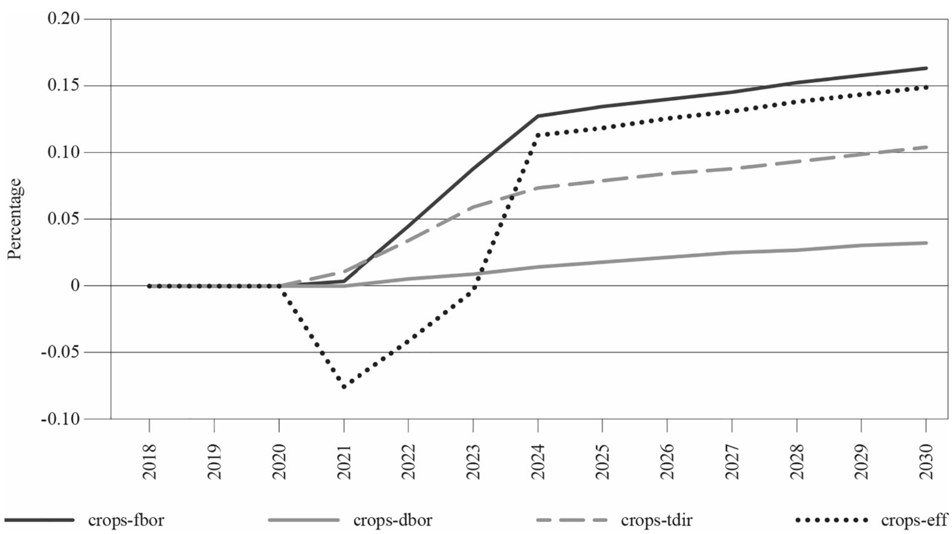

Fig. 5. GDP in four public investment scenarios with alternative financing sources (percentage deviation from the base scenario).

increase in public investment in productive infrastructure in agriculture sectors that represents 0.25% of GDP (around MXN 50 billion, in 2018) during the 2021–2023 period.[7] In these scenarios, factor productivity in the investment-receiving sector increases by the equivalent to 0.3 cents for each additional Mexican peso invested—which falls within the range of 0.15–0.60 that the literature estimates for a wide range of country categories (see, e.g., Lowe et al., 2019; Gupta et al., 2014; Dessus and Herrera, 2000).

The increase in public investment is initially captured in the model as an increase in the demand for goods and services, such as machinery and equipment and construction. In turn, it is reasonably assumed that the public investment is directed to the increase in sector-specific TFP. For instance, by improving the government capital that is used in upgrading rural roads, irrigation systems, storage infrastructure, etc. In our model, an increase in TFP will result in a higher output with the same level of utilization of production factors. Thus, the marginal product of public capital determines how much TFP increases with a given increase in public investment.[8]

While the shock is the same for all scenarios, there are two differences among them: the investment-receiving sector and the source that finances the investment. In Table 3, the name of each scenario contains an abbreviation for the agriculture sector whose productivity is boosted by public investment. In scenarios 1 through 4, for example, the new public investment is allocated to all crop sectors considered together. These scenarios also have an additional abbreviation denoting the source that finances the investment. Scenarios 1 through 4 respectively consider foreign borrowing (crops-fbor), domestic borrowing (crops-dbor), direct tax income (crops-tdir) and increased efficiency in public

[7] This assumption is realistic and was validated through previous discussions with the Secretariat of Agriculture and Rural Development (SADER).

[8] It is worth mentioning that the simulated increase in investment (i.e., 0.25% of GDP or around MXN 50 billion) is the same for each sector. Of course, the smaller the sector, the larger the simulated increase is relative to the sector's current income. However, all of the sectors were found to be capable to absorb the increase in investment (that is to say, we did not encounter unfeasible solutions when running the scenarios). Equation PRD-1 in Supplementary material A shows how the increase in government investment is transformed into an increase in TFP through the marginal product of public capital.

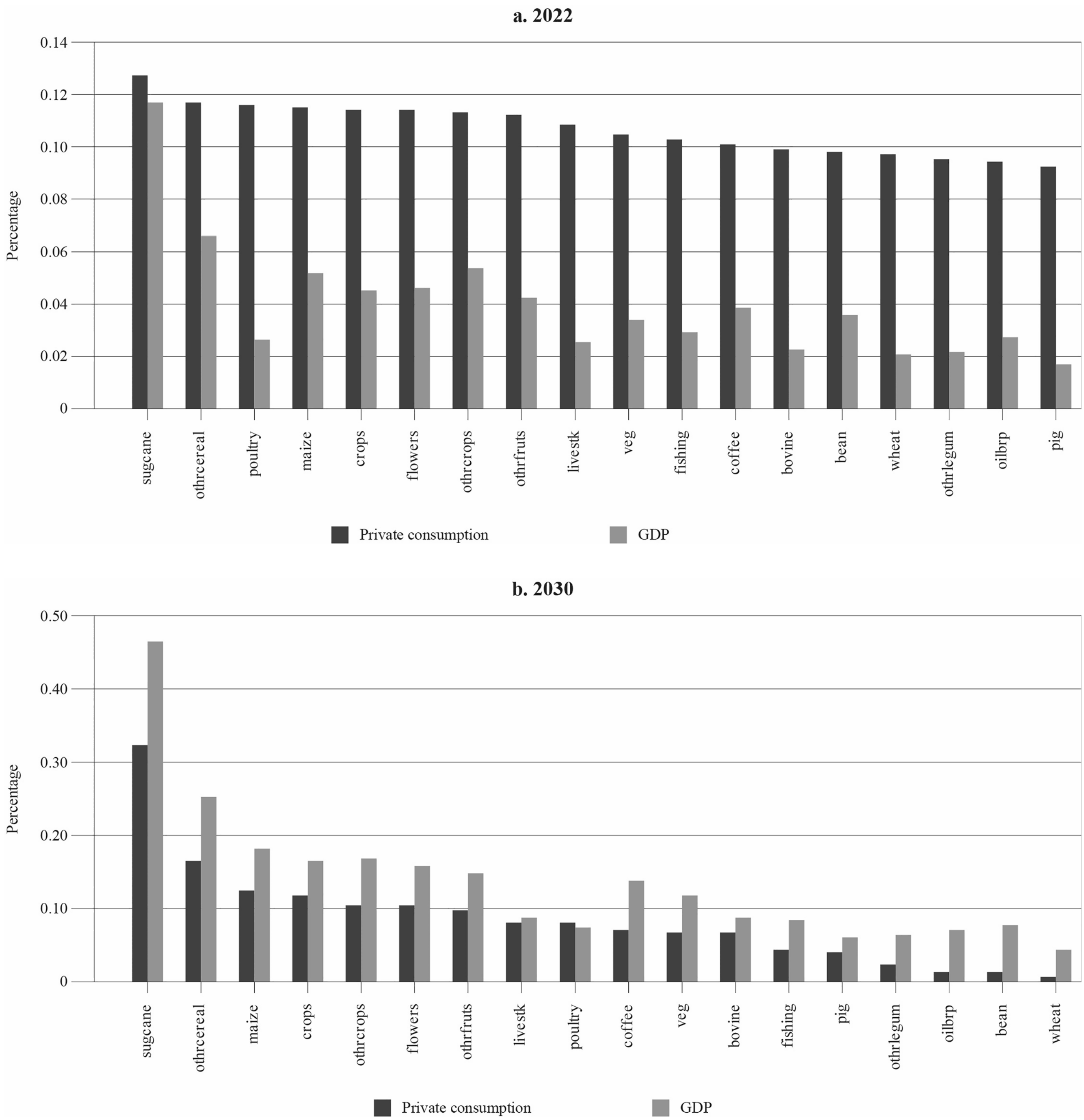

Fig. 6. Private consumption and GDP in selected public investment scenarios (percentage deviation from the base scenario). *Notes:* The horizontal axis represents the selected scenarios and omits the abbreviation “fbor” from the crop-fbor scenario (scenario 1, Table 3). Several of the following graphs use this horizontal-axis format.

spending (crops-eff). While public investment will have a positive effect on productivity, the final economy-wide and sectoral results will depend on the source of financing that is ultimately used, as explained in the previous section.

The second set includes scenarios 5 through 21, which vary only in terms of which sector benefits from the new public investment and allows for a more disaggregated sectoral detail. Moreover, only foreign borrowing is used in these scenarios because this turned out to be the most feasible financing option to allow for short-term economic recovery, as explained in the next section. The sectoral detail of this set of scenarios helps us rank agriculture sectors according to the cost-effectiveness of the new public investment that boosts their productivity.

4. Analysis of scenario results

In this section, we focus on those variables in the CGE model whose changes—with respect to the base scenario—are key to answering this paper’s questions. Moreover, the changes discussed are robust to changing the elasticity values of Mexico’s CGE model (see first part of Supplementary material D).

4.1. Macroeconomic results

Figs. 4 and 5 show private consumption (a proxy of household welfare) and GDP, respectively, in terms of how their annual value deviates from the base scenario when the investment goes to all crop sectors seen

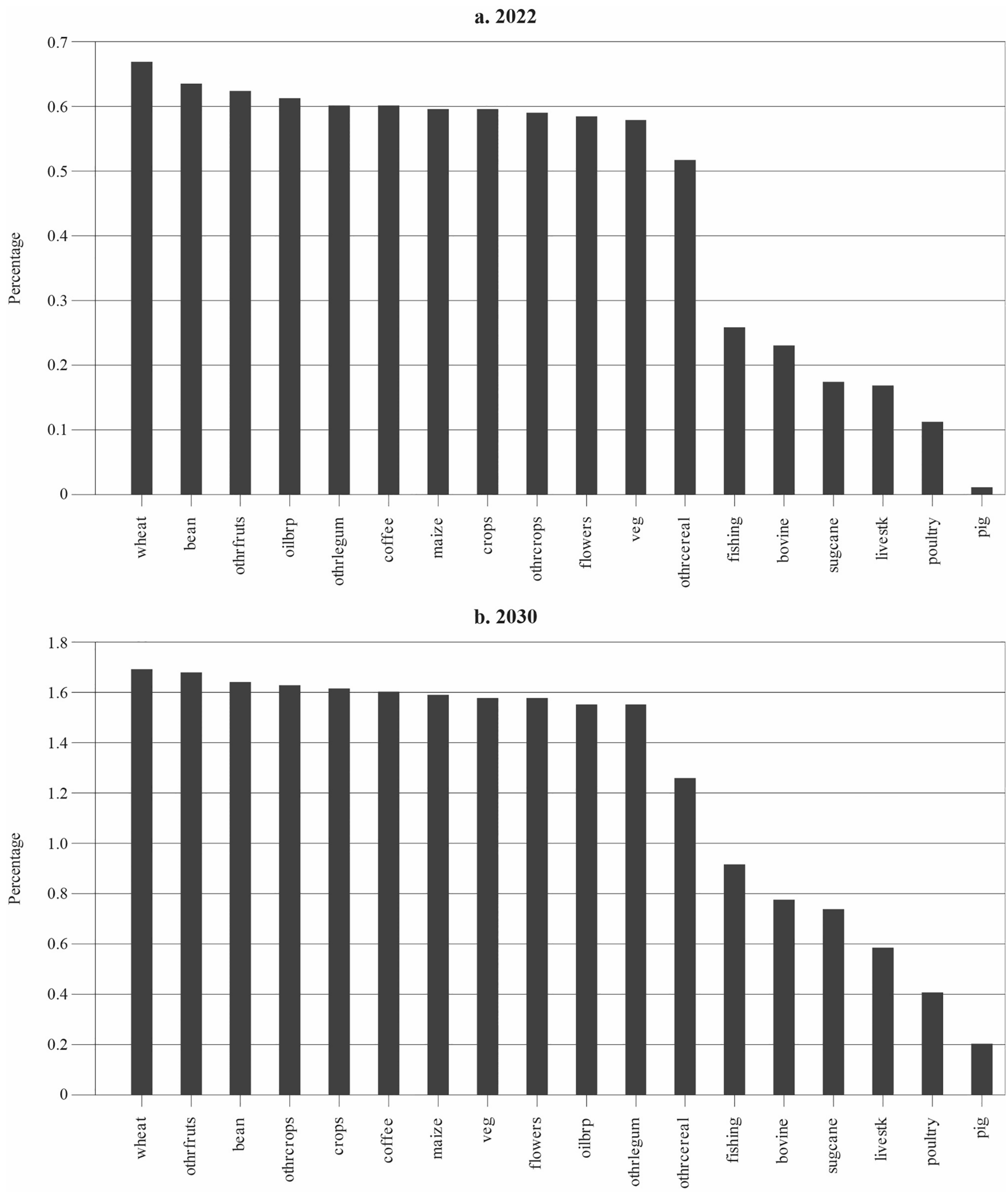

Fig. 7. Agri-food GDP in selected public investment scenarios (percentage deviation from the base scenario).

as a single group, using alternative funding sources in the first four investment scenarios. In all cases, the investment made in 2021 has positive effects on TFP starting in 2022. However, the results vary substantially across these first four investment scenarios because of the source of financing.

Financing the investment through foreign borrowing does not hurt private consumption and is considered preferable for this reason, specifically for how this reflects in short-term output growth, and also because, as a result of the increased production over time, public debt (not shown here) does not climb up by more than 0.55 percentage points of GDP in 2030—compared to the base scenario. Financing through domestic borrowing, in turn, crowds out private investment, which naturally has a negative impact on private capital stock and GDP growth in the short term. Interestingly, resorting to direct-tax revenues to fund the increased public investment cuts disposable income and adversely impacts private consumption in the short term. However, while GDP increases, it does so at a lower rate than when the investment is financed through foreign borrowing. Finally, in the public-sector efficiency gains scenario, there is an initial decline in private consumption as household incomes suffered from a cut in employment in the public sector that can presumably produce more with less factors. However, in the medium to long term, the positive effect of the public investment though increased productivity in crop production predominates. In fact, the level of total employment grows over time in all four scenarios. The evolution of GDP (economic recovery) in Fig. 5 is qualitatively similar to that recorded in Fig. 4 for private consumption (household welfare); in quantitative

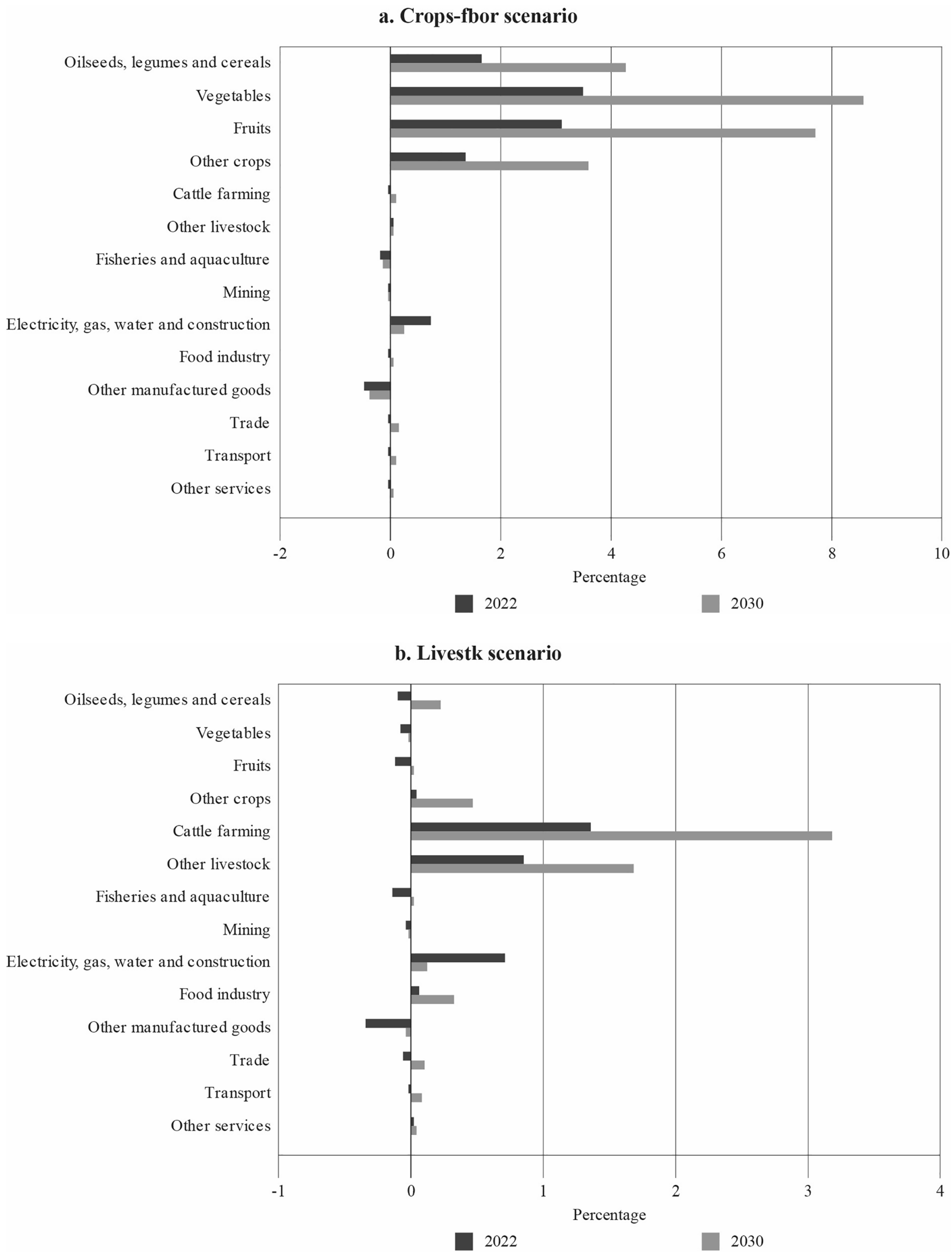

Fig. 8. Production of productive sectors in selected public investment scenarios (percentage deviation from the base scenario). *Note:* The horizontal axis represents the productive sectors of the Mexican economy.

terms, however, the effects on GDP are somewhat more significant.

The conclusion that foreign borrowing is the financing alternative that best allows to recover short-term economic activity is robust to changes in investment-receiving sectors. Moreover, seen in context, there are additional reasons to support this financing option (see Table A2 in Appendix A). With public investments not increasing recently, as noted above, Mexico's public sector debt has remained at a relatively low level; for example, at 45.5% of GDP in 2019—according to additional data from Secretariat of Finance and Public Credit (SHCP). Thus, Mexico's government possesses space for additional borrowing. On the revenue side, the Federal Government's foremost source of income, oil revenues, have dropped owing to falling oil prices. Fiscal surveillance has been increased to access non-oil resources through the tax system. Still, the tax load is relatively low and non-oil tax revenue represented approximately 13.1% of GDP in 2019, which theoretically means there is room for increasing taxes to generate revenues for financing public investment. However, it would not be economically (as our scenario analysis shows) and politically feasible to raise taxes if the intention is to stimulate the economy. Neither would additional public sector reforms to cut public jobs to generate government savings be politically feasible amid the COVID-19 crisis. The budget deficit has been financed mostly with domestic borrowing, but the economic downturn has left the government with less room to continue this policy and foreign borrowing has predominated over domestic borrowing in the first two quarters of 2020. This is also indication that the government has access to international financial markets.

Against this backdrop and considering in particular that public debt is relatively low, fiscal leeway can be created through foreign borrowing to stimulate the economy through public investment. Therefore, all the other scenarios discussed next assume that the increase in productive public investment is financed exclusively through foreign borrowing.

The favorable macroeconomic effects of the investment discussed up until now are also confirmed by the scenarios with more sectoral detail (scenarios 5 through 21 in Table 3). For these scenarios, the results are presented only for 2022 (short-term effects) and 2030 (longer-term effects) (Fig. 6). Two important comparisons stand out, though.

First, when all crops (scenario crops-fbor) or all livestock (scenario livestk) are promoted, the short- and long-term effects are similarly positive, although the magnitudes change. Crops are more integrated with international markets (see Supplementary material C) such that promoting their production generates somewhat more favorable effects than promoting all livestock: it increases exports over time while also replacing (reducing) imports more than when promoting livestock. This happens “over time” because, in the short term, foreign borrowing results in a real exchange rate appreciation that immediately leads to falling exports and increased imports, while the effects of increased productivity are not yet so significant. Such findings also apply when investment is intended to promote sectors within both the crop and the livestock aggregated sectors.

Second, looking at the scenarios at a more sectoral disaggregated level, a ranking shows that the largest impacts on private consumption and GDP are achieved when new public investment is intended to promote productivity in the sugar cane sector (sugcane scenario). Private consumption and GDP are approximately as much as 0.3% and 0.5% higher, respectively, than in the base scenario in 2030. In the first year of the simulation period, 2018, the value added of the sugar cane sector represents 0.2% of GDP. Therefore, the increase of 0.5% in GDP in 2030 is by no means negligible—the cumulative increase in GDP in 2030 is equivalent to 3.5% of GDP in that first year of the simulation period. Private investment (not shown graphically here) is also stepped up in the medium and long term. Naturally, higher private investment translates into a larger private capital stock, which in turn has a positive second-round effect on macroeconomic indicators. Sugar cane shows the lowest value-added per worker of all agriculture sectors considered in the analysis. Therefore, the very increase in its productivity allows more workers to be reallocated to other production activities. Thus, the sector is particularly benefited by the increased productivity generated as public investment was scaled up. In addition, it is a sector with strong forward production linkages as all of its production goes to intermediate consumption by other production activities.

Overall, the effects on major macroeconomic aggregates tend to be more favorable when the promoted sectors are directly or indirectly export-oriented, or import-oriented due to increased import substitution. Domestic price decreases are, *ceteris paribus*, less important when there is an increase in domestic supply for an export-oriented or import-oriented product, as further explained below. The sectors that generate the highest increases in exports are sugar cane, flowers, other cereals and coffee. Sugar cane is not exported directly; however, for a group of products for which sugar cane is an important input (sugar, chocolate, sweets and the like, and beverages), around 20% of their production is exported. Promoting cereals through productive investment does not increase exports, but does reduce imports significantly. In general, a significant share of cereal consumption is covered by imports (see Supplementary material C). For example, in the scenario that promotes productivity in the wheat sector, the ratio between imports and wheat consumption in 2030 is reduced to 56.1%, from 74.1% in the base scenario.

4.2. Sectoral production and linkages

Two additional effects on, respectively, production linkages and sectoral production, also stand out. Regarding the former, sectors are ranked according to their impact on agri-food GDP when they are promoted individually (Fig. 7). Agri-food GDP is defined as the sum of the value added generated in agriculture and the food industry and captures the production linkages between agriculture and the food industry. The three sectors that generally show the greatest effects on agri-food GDP are wheat, other fruits and beans—with livestock sectors at the opposite end of the ranking. Again, crops have a more significant export and import orientation than livestock. Therefore, the negative effects on domestic prices generated by increases in their production are mitigated by increased exports and/or reduced imports. As a result, agri-food GDP increases further when promoting sectors that, directly or indirectly, are more export- or import-oriented.

Interestingly, while the scenario whereby the productivity shock from the new investment occurs in the sugar cane sector ranks first, given the highest impact on GDP (Fig. 6), it ranks 15th in terms of its impact on agri-food GDP (Fig. 7). The sugar cane sector is linked only to sectors of the food industry that are relatively intensive in the use of capital (sugars, chocolates, sweets and the like, and beverages). As a result, public investment targeting the sugar cane sector promotes private investment, capital accumulation and GDP growth more than in the other scenarios.

The second important effect is about how the promotion of one agriculture sector affects not only its own production, but also that of other economic sectors. Take as an example the two scenarios where the investment promotes all crops (crops-fbor) or all livestock (livestk) (Fig. 8). The results for all livestock show that there are direct effects on the “cattle and other animals sector”, with backward linkages with crops and transport, and forward linkages with the food industry, trade and transport.[9] Production linkages with the food industry are relatively less important when investment flows to crops considered altogether. This was expected because many agricultural products, such as vegetables and fruits, are consumed directly without processing. However, linkages with sectors associated with trade, transport and public services are more important.

The greatest sectoral effects in other industries and services are seen when the new productive investment is exclusively channeled to the sectors producing maize, other cereals, sugar cane and other crops. These four sectors also have a higher level of integration with the food industry. By contrast, the sector that produces vegetables allocates most of its production to private consumption (48.7%) and exports (43.1%) (see Supplementary material C), such that promoting its production drives relatively less the production in other sectors. Consequently, the scenario where vegetable production is promoted is not at the top of the ranking (Fig. 7).

Overall, these results underscore the importance of making public investments that: a) promote sectors currently integrated into value

[9] Backward linkages measure a sector’s ability to pull other sectors along with them, by purchasing intermediate inputs from them. Forward linkages measure a sector’s capacity to push other sectors by producing intermediate inputs for them.

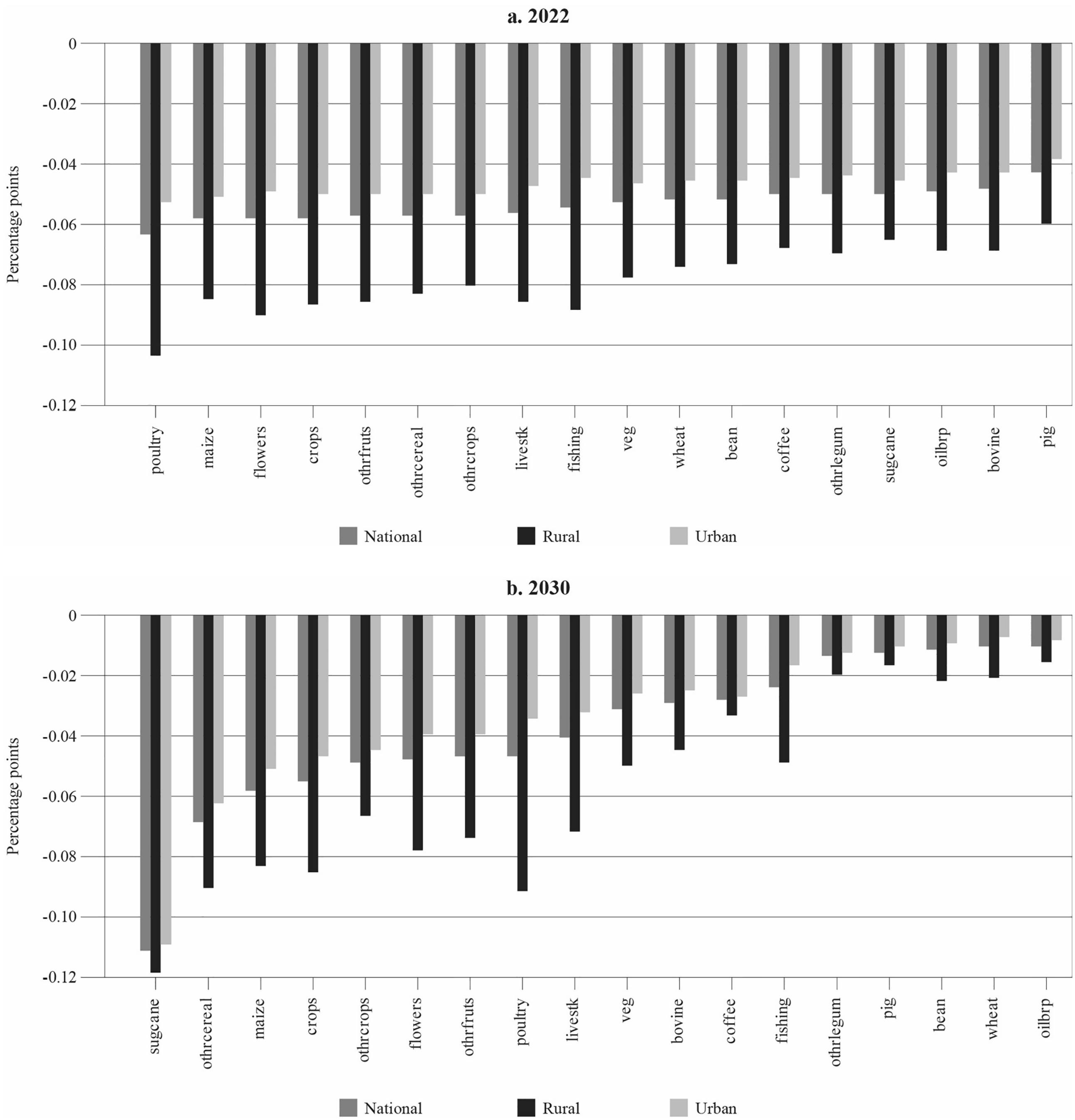

Fig. 9. Poverty rates in selected public investment scenarios (deviation by percentage points from the base scenario).

chains, or b) promote the entire value chain rather than just the primary stage for sectors that are not currently integrated into value chains. Moreover, sectors with greater international integration can increase their production and their exports without being limited by the size of the domestic market.

4.3. Employment and poverty

We see employment creation in all scenarios, but those for cereals, sugar cane and pigs. In these cases, the drop in employment resulting from the initially increased productivity of the sector is not offset by employment creation elsewhere in the economy. However, the aggregated results are positive in terms of private consumption, which is extremely important when analyzing the economy as a whole. The results underscore the importance of considering the demand side when promoting certain agriculture sectors. For example, increased oilseed production has a particularly positive effect on the employment of unskilled workers because it helps to replace imports of oilseeds—which cover more than 95% of total oilseed consumption. As a result, the income and consumption of households that mostly rely on the use of unskilled labor rise and, therefore, their poverty rate is reduced.

The effects on poverty—which are generated using the microsimulation model—are consistent with those on private consumption, as the poverty rate depends on changes in income and prices. The promotion of agriculture sectors reduces, in all cases, the average price of food. This reduction is not trivial, as food represents a relatively large proportion of the consumption basket of Mexico's poorest households. In general, the scenarios show reductions in total poverty rates by 2030 ranging from 0.01 to 0.11 percentage points, depending on the scenario and whether the poverty rate is national, urban or rural (see Fig. 9).

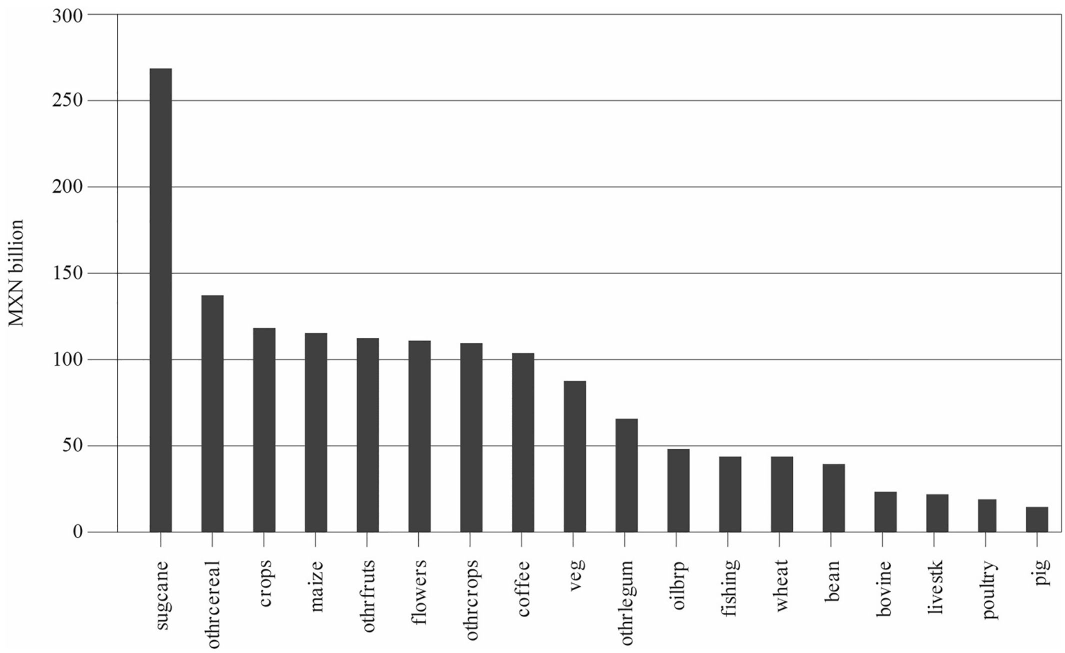

Fig. 10. Net present value of public investments in selected scenarios.

The greatest poverty reductions are seen for rural areas because increased productivity in agriculture has a positive impact on the labor income of rural households, and lower agri-food products prices cheapen the main component of the consumption basket for lower-income households.

4.4. Net present value of public investment

We examine the net present value (NPV) of the simulated public investments. The NPV is calculated from the equivalent variation, which measures the change in welfare experienced by Mexican households (Banerjee, Cicowiez and Moreda, 2019). It indicates how much income would have to be transferred to Mexican households to achieve the same change in welfare as is generated by the simulated public investment.[10] We find that the NPV ranges from 0.1% to 1.3% of GDP when comparing the results obtained in the different public investment scenarios. Scenarios for sugar cane, other cereals, maize and all crops are located at the top of the NPV ranking. In these sectors in particular, the simulated public investments result in a discounted household welfare gain (in MXN billion) that is above the cost of the public investments (i.e., around MXN 50 billion during the 2021–2023 period) (Fig. 10). The ranking of sectors is similar to that presented earlier for private consumption (Fig. 6).

4.5. A sectoral ranking to prioritize public investment in agriculture

Lastly, to summarize, Table 4 shows a ranking of the top ten sectors which are ordered in terms of the impact (from highest to lowest) that the same public investment in their productive infrastructure would have on total GDP, agri-food GDP, private consumption (welfare) and rural poverty. Clearly, the sugar cane sector is first in three of the four variables. Cereals, primarily maize, but also rice, sorghum, oats, barley and other cereals (excluding wheat, which is at the bottom of the ranking), are sectors whose promotion would also have positive effects on private consumption, GDP and rural poverty reduction. Export-oriented crops, such as flowers and coffee, are also relatively high in the ranking. Under no circumstances are livestock sectors among the top five positions in the ranking.

5. Policy implications

The ranking of the top ten sectors provides important information about the priorities in existing development plans, as well as new priorities that might be considered for enabling economic recovery with increased welfare post-COVID-19. It validates the importance of having included sugar cane and cereals, primarily maize, but also others such as rice (which falls within the "other cereals" group in our analysis), and coffee, as priority sectors of the 2019–2024 NDP, given these sectors' potential to generate production growth with rural poverty reduction. On the other hand, other sectors that are prioritized in the NDP, such as those involving livestock, do not appear to be the most cost-effective in terms of the variables analyzed in this paper. The flowers sector appears among the highest positions in our ranking, but it is not considered as a priority in Mexico's NDP. Although this sector has no direct influence on food security, investments that promote its productivity would have a significant impact on production, and, indirectly, on household's welfare. A similar scenario-based validation of key recipient sectors for investment that have or have not been prioritized in national development plans can be useful to inform policy decisions in other countries.

In practice, of course, results from such scenario-based analysis need to be put in the right context and aligned with other potential policy objectives. Consider in particular the sugar cane sector, which came up at the top of our ranking. This is a relatively labor-intensive sector, and all of its production goes to intermediate consumption for export-oriented activities. On the other hand, the agro-industrial sectors that use sugar cane for producing sugar and beverages are capital-intensive. Therefore, we found that the profits of enterprises in those agro-

[10] The following equation was used to estimate the NPV: $NPV = \sum_{t=2021}^{t=2030} \frac{\sum_{h \in H} EV_{h.t}}{(1+intrat)^{2021-t}} EV_{h.t}$ is the equivalent variation or measurement of welfare of households and *intrat* is the interest rate that, following official practice in Mexico, is assumed to be 8%. In the equation above, the welfare of each of the 18 households identified in Mexico's CGE model is weighted in the same way. That is, a utilitarian social welfare function is used implicitly. The results of the scenarios indicate that the increase in overall welfare would be higher if a welfare function that gives a higher weighting to households with the lower-consumption per capita were used.

Table 4
A top ten of sectors according to the socio-economic effects of public investment.

#	Private consumption	GDP	Agri-food GDP	Rural poverty
1	Sugar cane	Sugar cane	Wheat	Sugar cane
2	Other cereals	Other cereals	Other fruits	Other cereals
3	Maize	Maize	Beans	Maize
4	Other crops	Other crops	Other crops	Other crops
5	Flowers	Flowers	Coffee	Flowers
6	Other fruits	Other fruits	Maize	Other fruits
7	Poultry	Coffee	Vegetables	Poultry
8	Coffee	Vegetables	Flowers	Vegetables
9	Vegetables	Cattle	Oilseeds	Cattle
10	Cattle	Fishing	Other legumes	Coffee

Note: The agriculture sectors that are considered in the scenarios, but that ranked lower than 10th, are not presented here.

industrial sectors benefit from a reduction in their production costs, as sugar cane prices decrease when public investment boosts productivity in the sugar cane sector. Subsequently, enterprises that receive a relatively large share of capital income tend to have a relatively high savings rate and, therefore, more significant impacts are generated for the economy as a whole, for example in private investment, capital stock, GDP and other factor income.

Certainly, it is Mexican policy makers' choice and decision to invest or not resources in the sugar cane sector, given the economic and welfare gains this seems to generate. However, should they decide to do so, they may also like to consider other policy objectives and trade-offs, which are not well captured in our modeling analysis. For example, if improved consumption patterns and better nutrition (and a reduced economic and health burden of non-communicable diseases) were among the key policy objectives (which should be the case, considering the high rates of overweight and obesity in Mexico)[11], Mexican policy makers will then have to keep in mind that the sugar cane sector is strongly linked to sectors of the food industry such as sugars, chocolates, sweets and the like, and beverages, the consumption of which is associated with non-communicable diseases.[12] It is important to understand, though, that the highest calorie intake of the average Mexican diet comes from high consumption of foods with high energy density not only with high amounts of sugars but also of fats and refined flours (Rippe & Angelopoulos, 2016).

Nonetheless, promoting the sugar cane sector to generate the estimated economic and social gains may not necessarily be at the cost of jeopardizing efforts to fight overweight and obesity in Mexico if three necessary—albeit not sufficient conditions—are met.

First, the government of Mexico may also have to consider environmental sustainability elements of the entire sugar cane value chain, which are not taken into account in our analysis, and new investments may be needed to modernize and increase the sustainability and diversification of the sector's production processes. In this regard, Aguilar-Rivera (2017) argues that Mexico's sugar cane has significant potential as a major feedstock for biofuel, which presents the most viable opportunity for the diversification of the country's sugar cane zones and for increasing the value of their production. Not only can biofuel production contribute to renewable energy to substitute fossil fuels particularly in transport, but if highly profitable, it will also make the use of sugar cane for sugar production less attractive. In addition, sugar cane also has potential to become a key input to produce livestock feed, chemicals and organic fertilizers. Currently, Mexico imports biofuels particularly from the United States of America. Of course, important reforms to norms and renewed financing, marketing, organization and administration schemes will be needed to tap into this potential.

Second, it is necessary that the government continues curbing consumption of unhealthy products, including through taxes on sugar-sweetened beverages (see, e.g., Pan American Health Organization, 2015) that seem to be making Mexicans less likely to consume soft drinks (see, e.g., Sánchez-Romero et al., 2020). At the same time, though, given the sugar cane sector's potential, but considering also the present and accelerating consumer-driven trend toward healthier, sustainably produced, and more natural foods and ingredients, it is also true that the sugar cane industry more generally is increasingly implementing sustainable practices to supply natural cane sugars (Eggleston, Aita and Triplett, 2021). To tap into its sugar cane potential, Mexico may also promote natural sugar production which is less processed and contain a greater range and higher quantity of nutrients, including antioxidants, minerals, and vitamins.

Third, sugar cane is not traded with the rest of the world directly, but, as noted earlier, around 20% of sugar cane by-products, such as sugars, chocolates and sweets, are exported. However, there is also export potential to tap into—provided that Mexico becomes competitive. According to INEGI's data, Mexico only imports and does not export at all lactose, glucose and fructose, as well as sugar extract or refined molasses and, with regard to sugar more generally, imports were still equivalent to 4.4% of exports in 2021.[13] The third condition would then be that increased production of these products both substitutes imports and also translates into more exports, rather than more domestic consumption. Of course, a potential scenario could be that, over time, the present and accelerating consumer-driven trend toward healthier diets results in less demand for sugar, which would be reflected in a reduced world price for sugar. Projections available at OECD/FAO (2020), which are based on futures contracts, nonetheless, suggest that by 2029 world sugar prices in real terms will actually have increased somewhat compared to 2019. To add perspective, our own additional sensitivity analysis shows that a reduction in the world price of sugar cane and sugar of 20% relative to the base scenario during 2021–2030 would imply that the gains in private consumption due to the increase in government investment are slightly reduced (see second part of Supplementary Material D).[14] Even so, sugar cane remains in the highest positions in the sectoral ranking for indicators such as private consumption, GDP, and rural poverty. It should also be noticed that, as an importer of sugar products, Mexico would also benefit somewhat from a decrease in the world price of sugar.

[11] In 2020, 6.3% of Mexican children under five years of age were overweight (compared to 5.7% in the world) and, in 2016 (the most recent year for which data are available), 24% of Mexican adults (eighteen years and older) were considered obese (compared to 13.1% in the world) (FAO, IFAD, UNICEF, WFP and WHO, 2021, p. 163).

[12] For example, there is compelling evidence pointing to an alarming association between soda consumption and the incidence of diabetes, particularly among Mexican women (Balcazar and Perez Lizaur, 2019).

[13] Based on data from INEGI's Economic Information Bank, specifically the summary of Mexico's commodity trade balance. https://www.inegi.org.mx/sistemas/bie/ (accessed 5 January 2022).

[14] For context, the world price of raw sugar decreased by 19.3% from 2010 to 2011 and 20.1% from 2013 to 2014.

One final consideration is that promoting the sugar cane sector may also not be so harmful under the current recessionary conditions. This is because the value added of the sectors producing sugars, chocolates, sweets and the like have actually shown negative growth rates since 2019 (see Table 1).

6. Conclusions

Even in a middle-income country such as Mexico could reactivating agriculture still be one of the drivers of economic recovery with welfare gains after the COVID-19 pandemic. Agriculture provides employment and supports rural livelihoods for millions of Mexicans. It provides Mexican households with food, not only directly but also indirectly by supplying inputs to food industries. In addition, Mexico's agriculture is linked to international trade. In fact, because many of the agricultural products consumed by Mexican households are imported, promoting their domestic production as a way to recover from the crisis could generate longer-term benefits in terms of food security, which is a priority objective of the government, without necessarily discouraging trade. Most of the poorest Mexican households live in rural areas, where agriculture is key for economic activity. At the same time, Mexican agriculture requires a productivity boost should it be among the drivers of socio-economic recovery.

Our prospective scenarios have showed that, under existing fiscal constraints, a modest increase of public investment in productive infrastructure channeled to agriculture sectors, amounting to 0.25% of GDP (around MXN 50 billion) during the 2021–2023 period, will contribute to economic recovery, productive linkages and more welfare through 2030. A key recommendation is to finance new public investment in agriculture using foreign borrowing, the only financing alternative that facilitates a recovery in short-term economic activity, with gains in household welfare (measured by private consumption). Alternative sources of domestic financing considered (i.e., domestic borrowing, tax revenues, or efficiency gains in the public sector) have short-term macroeconomic trade-offs that would prevent a swift economic recovery.

Our findings show that the effects on major macroeconomic aggregates such as household consumption and GDP are favorable in all scenarios with foreign borrowing, and relatively more so when the sectors promoted are export-oriented or import-oriented—which is generally seen with crop sectors, particularly those that were placed at the top of a ranking, including sugar cane and cereals, primarily maize, but also others such as rice, among others. However, other sectors such as in livestock have greater potential to push food sectors by supplying intermediate inputs to them thus resulting in more significant impacts on agri-food GDP. Results for peoples' well-being, as measured by private consumption and rural poverty reduction, are also favorable in all scenarios. Furthermore, according to the net present value of public investment, the discounted gain, in terms of Mexican households' welfare, is above the investment cost in all the scenarios.

One might imagine these findings are of relevance for other countries, particularly lower income countries where agriculture is a larger sector in the economy, compared to Mexico. In such countries, well prioritized investments in agriculture, whose financing has carefully considered trade-offs of using different resource sources, can contribute significantly to socio-economic recovery. Similar studies to this are welcome to inform government investment decisions in food and agriculture in many other countries.

The ranking of sectors presented is an excellent tool for prioritizing investments in agriculture for recovery post-COVID-19 while, at the same time, it can also be the starting point for more focused research on the sectors that appear at the top, which is certainly the case also in the Mexican context. More precisely, new research is needed to identify the specific investments that are required along the value chains linked to the priority sectors. In this respect, it is necessary to identify the component of primary production that should be promoted in these sectors (what to invest in) and the amount of resources needed to that end (how much to invest) so as to justify the budgets. An additional decision-making criterion which should be considered, is the identification of those territories where such sector-specific investments could have the greatest socio-economic impact in an environmentally friendly and nutrition-sensitive manner, due to the high production and poverty reduction potential they offer (where to invest). Addressing these questions will of course require extensions to an economy-wide modeling framework such as that used in this paper and perhaps also the use of more georeferenced analysis of agroecological zones.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Additional statistics

See Tables A1 and A2.

Table A1
Gross domestic product by expenditure component (growth rate and structure).

Items	2010–2019	2019	2020*		2010–2019	2019	2020*	
			Quarter I	Quarter II			Quarter I	Quarter II
	Growth rate (%)				Percentage structure of GDP			
Gross domestic product (GDP)	2.66	–0.30	–2.13	–18.68	2.3	–0.3	–2.1	–18.6
Government consumption	1.96	–1.35	3.3	2.4	11.9	11.8	12.3	14.7
Private consumption	2.68	0.4	–1.2	–2.6	66.1	67.9	67.7	65.9
Public investment	–6.11	–9.68	–7.2	–10.2	3.9	2.5	2.5	2.9
Private investment	2.97	–4.35	–9.8	–37.4	16.9	16.20	16.0	12.8
Exports of goods and services	4.86	1.45	1.8	–31.1	32.8	36.4	38.0	31.8
Imports of goods and services	4.12	–0.85	–5.0	–29.7	33.5	36.2	36.0	31.9

Note: *Constant prices of 2013. *Source:* INEGI National Accounts System.

Table A2
Public sector financial situation, 2010–2020.

Items	2010–2019	2019	2020		2010–2019	2019	2020	
			I	II			I	II
	Growth rate*(%)				Percentage of GDP (%)			
1. Budget revenue	**2.7**	**14.3**	**19.2**	**−3.8**	**22.6**	**22.0**	**6.2**	**13.2**
Oil revenue	6.7	25.9	−48.3	−8.8	6.1	3.9	0.6	1.3
Non-oil income	5.7	11.3	32.7	−2.8	16.6	18.1	5.6	12.0
Federal Government non-oil revenue	5.3	15.1	38.2	−3.2	12.9	14.6	4.8	9.9
Non-oil tax revenue	8.0	−0.1	34.3	−7.0	11.2	13.1	4.3	8.9
Non-tax non-oil income	104.4	399.2	84.7	88.8	1.7	1.5	0.5	1.0
Revenue from agencies and companies other than Pemex	19.7	−1.6	6.7	−1.6	3.6	3.5	0.9	2.1
2. Net public expenditure paid	**2.6**	**13.7**	**21.2**	**−4.6**	**25.0**	**23.7**	**6.3**	**14.8**
Programmable budget expenditure paid	2.3	20.0	25.5	0.9	19.3	17.3	4.6	10.5
Current budget expenditure	2.6	30.3	26.3	−6.0	14.8	14.3	3.7	8.5
Budget capital expenditure	9.7	−16.2	21.6	43.5	4.6	3.0	0.8	2.0
Non-programmable budget expenditure	6.1	2.6	8.4	−12.1	5.7	6.4	1.7	4.3
3. Budget balance (1–2)	**26.6**	**12.0**	**198.2**	**−6.8**	**−2.4**	**−1.7**	**−0.1**	**−1.6**
4. Financial balance of entities under indirect budgetary control	**−1.8**	**133.7**	**281.9**	**−323.0**	**0.0**	**0.1**	**0.2**	**0.1**
5. Public balance sheet (3 + 4) = (6 + 7)	**23.3**	**22.1**	**417.5**	**−4.7**	**−2.4**	**−1.6**	**0.1**	**−1.5**
6. External financing	**142.0**	**2 075.4**	**576.2**	**−83.6**	**0.9**	**0.2**	**0.6**	**1.6**
7. Domestic financing	**−477.5**	**46.4**	**474.2**	**−0.8**	**1.5**	**1.4**	**−0.7**	**−0.1**

Note: *Constant prices of 2018. *Source:* Secretariat of Finance and Public Credit (SHCP).

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2022.102251.

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