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Impact of Spread of Diseases and Epidemics on Egyptian Economy Using Multiplier Model

Case Study: COVID-19 Crisis and Its Impact on Agricultural Sector

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أثر انتشار الأمراض والأوبئة على الاقتصاد المصري باستخدام نموذج المضاعف

دراسة حالة: أزمة فيروس كورونا وأثره على القطاع الزراعي

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Abstract

With the spread of the COVID-19 pandemic, a trade-off has emerged between the need to contain the virus and avoid economic and food security crises that further affect the poor. Therefore, the main purpose of this study is to describe the direct effects of the COVID-19 pandemic on the situation of households in Egypt. The study also analyses the current policy measures taken by the Egyptian government by evaluating programs to support the poor and their impact on food security in Egypt. Using a SAM multiplayer model, Social Accounting Matrix (2014/15 base year), the study adopts three scenarios. The first simulates the impact of the increase in the value of vegetable and fruit exports as a result of the increase in global demand motives; the second analyses the effects of the increase in the prices of local wheat as a result of the rise in global wheat prices, while the third deals with the evaluation of the Egyptian government's strategy to confront the COVID-19 crisis through social protection programs "Takaful & Karama". The three scenarios were formulated for the purpose of evaluating the Egyptian government's policies in confronting the COVID-19 pandemic in anticipation of occurrence of similar diseases or epidemics in the future. The most important results of the study came to clarify the following: The first scenario, increasing the value of exports, led to an increase in total production by 2.26%, and an increase in agricultural production by 1.54%. Raising the price of local wheat increased the income of rural household. In addition, the incomes of all rural households engaged in agriculture increased at rates ranging from 182% to 226% among the highest and lowest income rural households, respectively, indicating the success of this policy in generating additional income for households. Finally, the third scenario deals with the state's policy regarding Takaful & Karama Program, on which the state spent EGP 100 billion to improve the living conditions of the poor, as the income of all household groups increased by rates ranging from 110–230%. This is because the poor received direct support from the government, while other groups of the population had other productive activities which increased their incomes. The study recommends more support policies, social protection programs and measures commensurate with the economic situation, and avoiding lockdown policies in such critical matters.

Keywords: COVID-19, agricultural production**,** household income, SAM, multiplier model

مستخلص

مع انتشار جائحة COVID-19، ظهرت مفاضلة بين الحاجة إلى احتواء الفيروس وتجنب الأزمات الاقتصادية وأزمات الأمن الغذائي الكارثية، التي تؤثر بشكل أكبر على الفقراء. لذلك، فإن الغرض الرئيس من هذه الدراسة هو وصف الآثار المباشرة لوباء COVID-19 على وضع الأسر في مصر. كما تتطرق الدراسة إلى تحليل إجراءات السياسة الحالية التي تتخذها الحكومة المصرية من خلال تقييم برامج دعم الفقراء وتأثيرها على الأمن الغذائي في مصر، باستخدام نموذج مضاعف مصفوفة الحسابات الاجتماعية (SAM multiplayer) لمصر، ويستند إلى بيانات لسنة أساس 15/2014. تبنت الدراسة ثلاثة سيناريوهات على النحو التالي: السيناريو الأول يحاكي تأثير الزيادة في قيمة صادرات الخضار والفاكهة نتيجة لزيادة دوافع الطلب العالمي عليهما، بينما يتناول السيناريو الثاني تحليل وتتبع آثار الزيادة في أسعار المورد من القمح المحلي نتيجة لارتفاع الأسعار العالمية، في حين يتناول السيناريو الثالث تقييم استراتيجية الحكومة المصرية التي اتبعتها لمواجهة أزمة كورونا، من خلال برامج الحماية الاجتماعية "برنامج تكافل وكرامة". وتمت صياغة السيناريوهات الثلاث بغرض تقييم سياسات الحكومة المصرية لمواجهة وباء كورونا تحسبًا لحدوث أمراض أخرى أو أوبئة مشابهة في المستقبل. وجاءت أهم نتائج الدراسة لتوضح ما يلي: السيناريو الأول، أدت زيادة قيمة الصادرات إلى زيادة إجمالي الإنتاج بنسبة 2.26٪، وكذلك زيادة الإنتاج الزراعي بنسبة 1.54٪؛ السيناريو الثاني، أدى رفع أسعار التوريد للقمح المحلي إلى زيادة دخل الأسرة الريفية بنحو ثمانية أضعاف ما تم ضخه في هذه السياسة. علاوة علي زيادة دخل جميع الأسر الريفية التي تقوم بالزراعة بنسب تتراوح ما بين 182% الي 226% بين الاسر الريفية الأعلى دخلًا والأقل دخلًا، على التوالي؛ ما يشير إلى نجاح هذه السياسة في توليد دخل إضافي للمزارعين. وأخيرًا يتناول السيناريو الثالث سياسة الدولة من برنامج تكافل وكرامة؛ حيث أنفقت الدولة 100 مليار جنيه؛ لتحسين الأوضاع المعيشية للفقراء، وارتفع الدخل لكل الفئات الأسرية بنسب تتراوح من 110-230%، فقد حصلت فئة الفقراء على دعم مباشر من الدولة، بينما قامت الفئات الأخرى من السكان بأنشطة إنتاجية أخرى، أدت بالتالي لزيادة دخولهم. وتوصي الدراسة بمزيد من سياسات الدعم، وبرامج الحماية الاجتماعية، واتخاذ تدابير تتناسب مع الأوضاع الاقتصادية، وتجنب سياسات الإغلاق في مثل هذه الأمور الحرجة.

الكلمات الدالة: وباء كوفيد-19، الإنتاج الزراعي، دخل الأسر، مصفوفة الحسابات الاجتماعية، نموذج مضاعف

Introduction

The world has gone through various challenges, such as wars and revolutions that completely reshape societies, in addition to epidemics and contagious diseases, which are another type of challenge that the world is facing (Ceylan et al., 2020). Recently, COVID-19 is considered one of the most dangerous pandemics that seriously injured people around the world in the twenty-first century, due to its unprecedent mutations, rapid spread and high mortality rates worldwide (Omran et al., 2021). The COVID-19 pandemic has seriously affected all aspects of life around the world, causing unprecedented disruptions to the economy, sectors, trade, and labor markets (Kebede et al., 2020).

Indeed, as the COVID-19 pandemic unfolds, trade-offs have emerged between the need to contain the virus and avoid catastrophic economic and food security crises that disproportionately affect the world's poor and hungry. Although no major food shortages have emerged, so far, markets for agricultural and food products are experiencing disruptions as a result of labor shortages caused by restrictions on people's movements, shifts in food demand and income losses. Export restrictions imposed on some countries have disrupted trade flows of staple foods (Laborde et al., 2020).

On the one hand, COVID-19 has heightened global concerns about agriculture (Network, 2020; Ribeiro-Silva et al., 2020; Torero, 2020). Agriculture is one of the most important sectors in human development and is linked to food security (Abdelhedi & Zouari, 2020; Kogo et al., 2021; Lopez-Ridaura et al., 2019). The debate over food security centers on various factors that impact the availability, access, utilization, and stability of food (Abdelhedi & Zouari, 2020). Moreover, since the outbreak of the pandemic, panic buying of food items has occurred in many countries. Even worse, some countries have begun or are considering imposing export restrictions (Laborde et al., 2020). In the same boat, the Food and Agriculture Organization (FAO) (Q&A, 2020) reported that COVID-19 is affecting agriculture in two significant aspects: food supply and demand. These two aspects are directly related to food security, so food security has been also at risk.

On the other hand, workers in informal employment may be the most vulnerable to the effects of the pandemic on the labor market. At the same time, these workers are among the most difficult to reach through policy measures aimed at mitigating the negative effects on their livelihoods.

The economic impacts of the COVID-19 crisis are increasingly hitting low and middle-income countries and the poor (Breisinger et al., 2020). So, COVID-19 is most directly and severely impacting access to food (Barichello, 2020), even though impacts are also felt through disruptions to availability; shifts in consumer demand toward cheaper, less nutritious foods; and food price instability (Laborde et al., 2020). Egypt is not an exception. There are fears of massive consequences on health and livelihoods, and the government has imposed several restrictions to control the spread of COVID-19 within the country's borders. These restrictions comprise border closures, quarantines, partial lockdown, movement restrictions, social distancing, and staff reductions in non-essential services. Although these restrictions may have disrupted the supply of agro-food products to markets and consumers, the food supply has so far held up (Selim & Eltarabily, 2022). Given the precarious livelihoods of many Egyptians, agriculture, food security, and safety net policy and program responses are also urgently required (Barichello, 2020).

Some reports have highlighted the impact of COVID-19 on the food and agriculture sectors worldwide (e.g., UNESCO–IHE, Delft, OECD–Better Policies for Better Lives). Moreover, some government actions related to COVID-19 socioeconomic responsibilities, recovery plans, and mitigating scenarios (e.g., United Nations, Egypt) were highlighted, and non-governmental solutions were presented (e.g., Techno Serve – Business Solutions to Poverty). Nonetheless, a review of previous studies revealed that the multi-level impacts of the COVID-19 pandemic on agriculture, labour, and income have not been fully addressed.

Therefore, the main purpose of this study is to describe the direct effects of the COVID-19 pandemic on the work situation of vulnerable groups of workers in Egypt. It presents the current policy measures undertaken by the Government of Egypt (GoE) by evaluating the programs to support the poor and their impact on food security in Egypt. One must also consider the external effects transmitted through global markets—particularly increases in export demand. The SAM multiplier models are well suited for measuring the short-term direct and indirect impacts of unexpected, rapid-onset demand or supply-side economic shocks such as those caused by the COVID-19 pandemic.

Following the introduction, the methodology used to simulate the economic impacts of the COVID-19 pandemic, including the modelling approach and data sources, is presented, followed by scenarios and assumptions underlying the analysis, and then the study concludes with results and recommendations.

Methodology and Data Sources

In this section, the study discusses the modeling approach used and data sources. As previously mentioned, the pandemic is expected to have a widespread impact on the Egyptian economy. The assessment of the short-term COVID-19 impacts using the Social Accounting Matrix (SAM) and multiplier model is ideal for measuring the direct and indirect effects of unexpected events, such as those caused by the COVID-19 pandemic. The SAM -an economy-wide database that captures resource flows associated with all economic transactions that occur in the economy, typically over the course of a fiscal year- is at the heart of the multiplier model. Thus, the SAM represents the structure of the economy, displaying the relationships among actors such as productive activities, households, government, and the external sector in terms of how they interact and transact through commodity and factor markets. The SAM multiplier model provides a mechanism for estimating the effects of an external shock, usually an exogenous change in the final demand for goods and services, on sectoral and national production, income factors (wages and rents), and household incomes based on the SAM's production, employment, and consumption relationships. Other sectors are indirectly affected by changes in demand for intermediate inputs, in addition to the direct effect of production in the sector affected by a change in demand. Furthermore, changes in employment levels or structures may result in further changes in household consumption demand. The multiplier model's strength is that it fully captures the multiple rounds of these indirect effects (Sadoulet et al., 1996). The more accurate the analysis of the SAM multiplier in terms the direct and indirect impact pathways and distributional effects of the external shock, the more detailed the SAM is in terms of the activities, commodities, factors, and household accounts it includes. Since this is a short-run analysis period, it is assumed that technical input-output relationships, producers' input choices, and household consumption patterns do not (yet) change in response to the simulated shock. Such behavioral responses are captured in general equilibrium models, but the expected short-term nature of the COVID-19 shock and the likelihood that the economy will return to a "business-as-usual" state once the crisis dissipates over time makes the SAM multiplier framework a more appropriate tool for analyzing this shock. Consistent with the short-term nature of the analysis, we assume that net expenditures of households and governments, patterns of savings and investment, and international trade are exogenous to the model. That is, we do not consider second-round effects on these economic flows. The multiplier model of Egypt is based on a SAM that was jointly developed the Central Agency

for Public Mobilization and Statistics (CAPMAS) and the International Food Policy Research Institute (IFPRI). The SAM itself has 2015 as the base-year. For more details about the multiplier model on which the study is based, turn to the quantitative analysis of the development policy (Sadoulet et al., 1996), as well as the description and explanation of the system of equations in the appendix.

Policy Simulation

The COVID-19 crisis has caused significant disruptions to the strong economic progress to Egypt's strong economic progress over the past year. Economic shocks caused by COVID-19 are simulated through two main channels in the model:

- A shock stemming from external factors, e.g., the increase in demand for exports, as a result of exogenous increases in demand for agricultural commodities in Egypt. This led to an increase in the value of agricultural crops exported by Egypt, especially vegetables and fruits, by about 15.4%. In this scenario, the study will answer some questions through computing the input-output multipliers. These questions are as follows:

A) What is the impact of the increasing vegetable and fruit exports on production and on agricultural and other sectors, such as agro-food industries, and on aggregate production? Which sector has the highest multiplier on itself? The highest total multiplier? What is the sector's highest correlation with the rest of the economy? This represents the first scenario covered by the study.

B) The increase in global demand also led to a rise in international prices for some agricultural crops, especially wheat, which prompted the GoE to increase the prices of domestic wheat from EGP 680 to EGP 720 per ardeb, i.e., an increase of 6%. This is the second scenario covered by the study.

- The combination of shocks induced by the country's own lockdown restrictions and related measures taken to contain viral transmission: (i) The partial lockdown of the economy combined with unfavorable external conditions reduced economic activity. This resulted in a large number of unskilled workers losing their jobs or at least halving the number of working hours, especially workers in the three main sectors in Egypt (services, industry, and agriculture); (ii) remittance inflows reductions from Egyptian immigrants working abroad, directly affected households' consumption; and (iii) to counter these adverse effects, the government has worked on supporting economic activities and households via accommodating fiscal and monetary policies. These

include allocating EGP 100 billion to combat some of the economic fallout from COVID-19. Hence, the third scenario is to mitigate the effects of the COVID-19 by the injection of additional income, estimated at EGP 100 billion, to compensate the neediest Egyptian families.

Results and Discussion

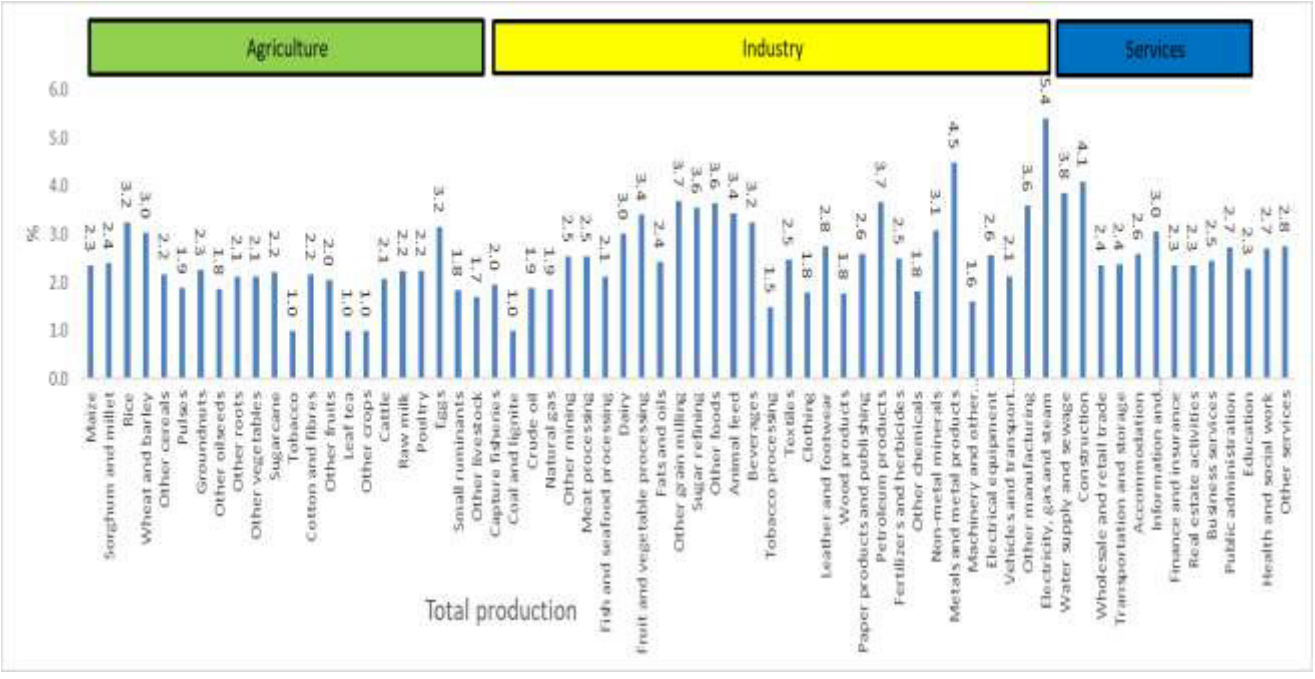
Multiplier analysis gives many results at the macro level (such as GDP, total production, and agricultural GDP), the micro level (such as production, consumption, exports and imports) and many other results, so the study will review only part of the results that show the purpose of the study.

Initially, the study will analyze the results through three main sectors: agriculture, industry and services. Then, the analysis will be broken down within each sector. The agricultural sector contains both plant production and livestock. While the industry sector includes all the sectors of mining, agro-processing, manufacturing, and other industries. The study addresses the third sector, which is the services sector, as it is.

In the beginning, this section will address the effect of the multiplier within all sectors before dealing with the impact of the three scenarios. In the agricultural sector, the sectors with the highest multiplier in plant production are rice, "wheat and barley", "sorghum and millet", and maize by 3.2%, 3%, 2.4%, and 2.3%, respectively. The sectors with the highest multiplier in livestock are eggs at 3.2%. and both poultry and raw milk at 2.2%. The industrial sector contains many sub-sectors, which makes it difficult to focus on all activities within this sector. Therefore, the study will analyze the highest activities in the output multiplier within each sub-sector. In more detail, the "electricity, gas and steam" activity is the highest ever within the Egyptian economy, with multiplier of 5.4%, followed by construction activity by about 4.1%. In the agro-processing sub-sector, the activity of "other grain milling" multiplies by about 3.7%, and the activity of sugar refining by about 3.6%. This was then followed by "other mining" activity, with about 2.5% from the mining sub-sector. The services sector contains the "information and communication" activity is the highest within the services sector, with multiplier reaching 3%, followed by "other services" activity by about 2.8%. Then, public administration and "health and social work" activities followed by about 2.7% (As shown in Figure 1).

Figure 1

Input-Output and Social Accounting Matrix Multipliers In Egypt: SAM Multipliers.



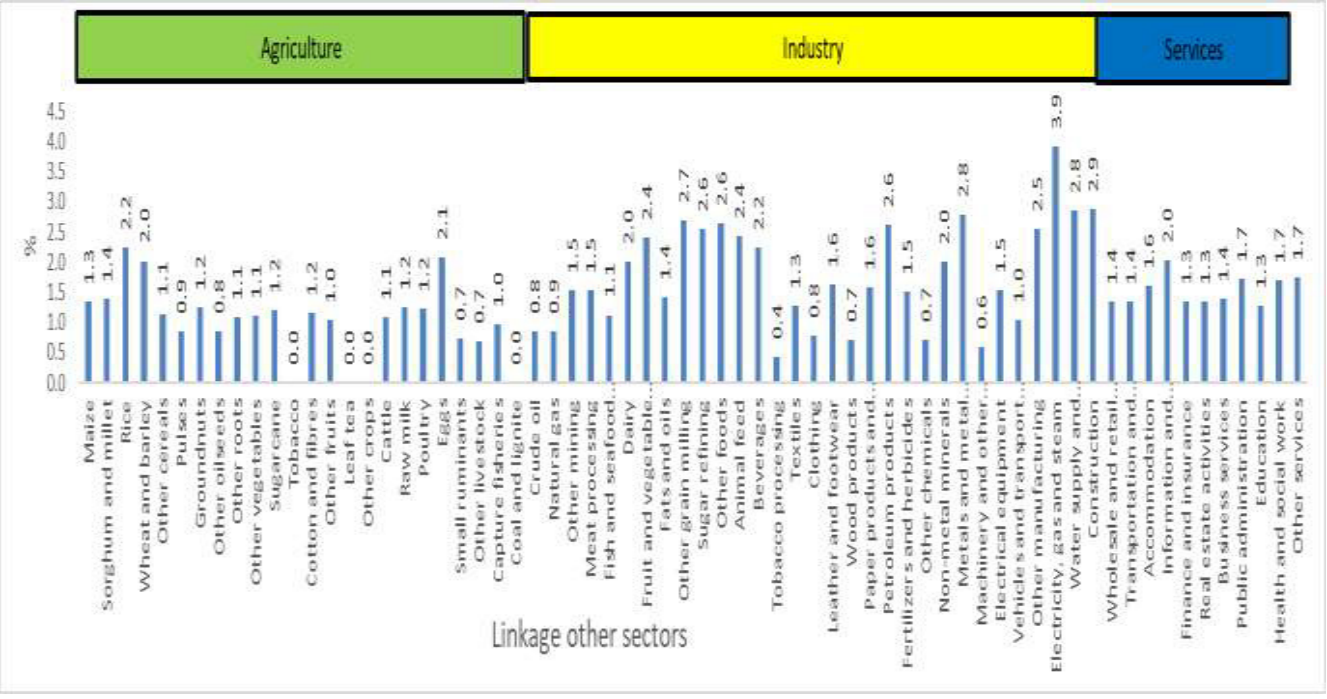
Source: Table 1 in the appendix.

Given the high value of the multiplier for these activities and sub-sectors, it is found that these activities have the highest correlations with the rest of the economy, as shown in Figure 2.

Then, the study deals in more detail with the above three scenarios. In the first scenario, we will review the impacts of increasing Egypt's exports of vegetables and fruits on the rest of the agricultural sector in Egypt on the one hand, and on other sectors on the other hand. This is done by reviewing the impact of increased exports on production and income

Figure 2

The Linkage Between Production Multipliers and Other Sectors



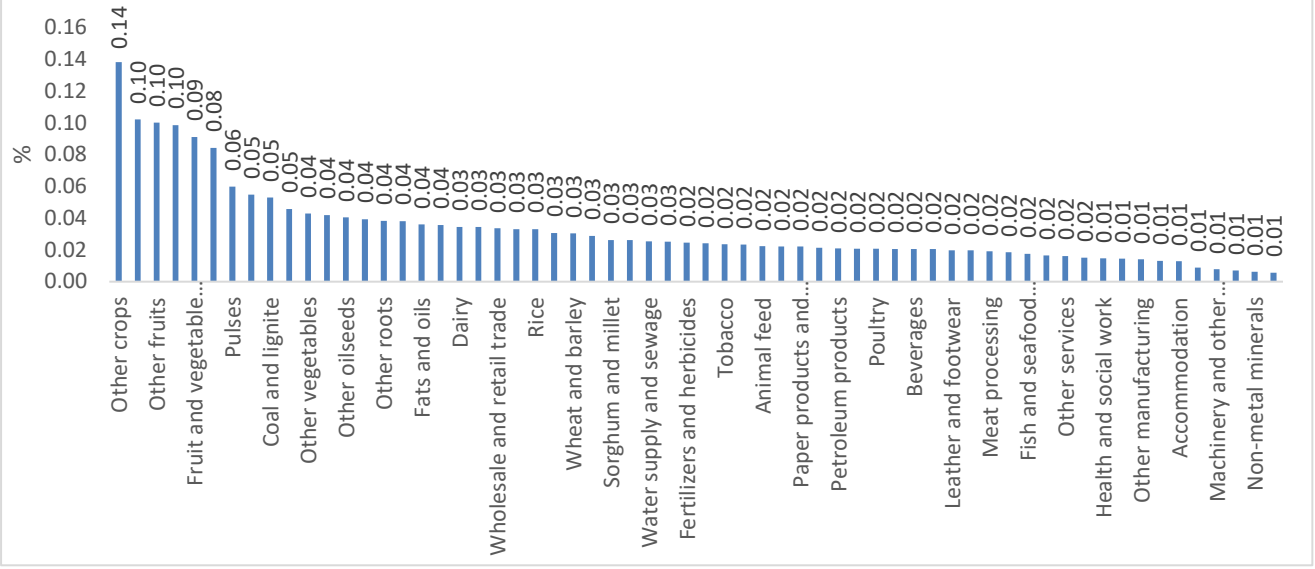
Source: Table 2 in the appendix.

This policy has a stronger effect on production but a less effect on income. This is because its first effect is the demand for commodities, which directly induces an increase in production. With the increase of agricultural production by 1.54%, the total production will also increase by 2.26%. Moreover, the effect will spill over to the rest of the production of goods as well as other sectors, as shown in Figure 3.

Other crops come at the forefront of the commodities whose production will increase by about 0.14% compared to the baseline, followed by each of textiles, other fruits, cotton, and fibers with an estimated increase of 0.1% in production. Fruit and vegetable processing, other cereals, pulses, clothing, coal, groundnuts, other vegetables, sugarcane, other oilseeds, crude oil, other roots, sugar refining, fats and oils, and other foods are all examples of products with a rate ranging from 0.09% to 0.03%. This indicates a potential of increased exports to create a catalyst for the agricultural sector to increase production, and then increase the production of the rest of the sectors related thereto with forward and backward links.

Figure 3

The Effect of Increasing Egypt's Exports Of Vegetables And Fruits (The First Scenario %)

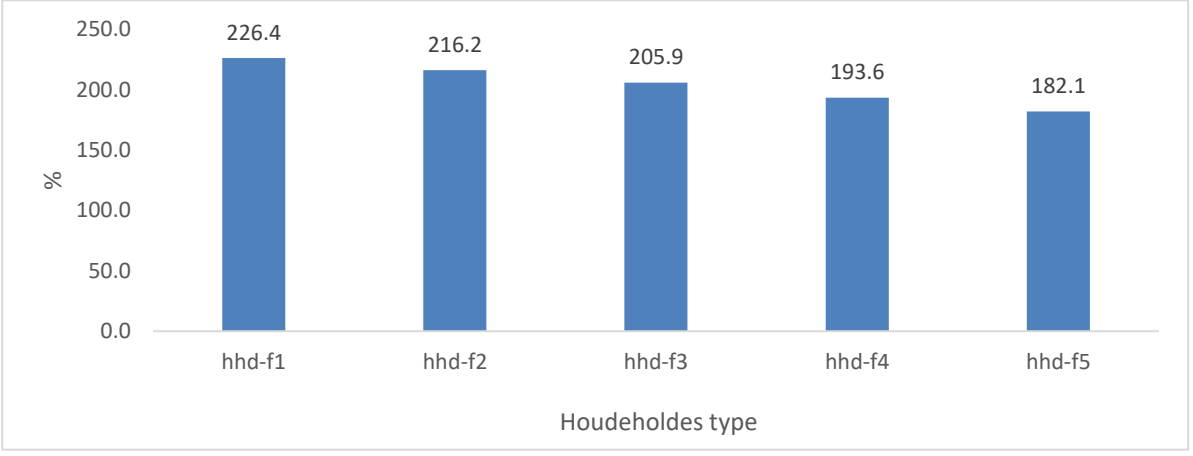


Source: model results.

In the second scenario, we will simulate the effect of increasing wheat supply prices in the local market by about 6%. The results are shown in Figure 4. In this SAM context, the experiment simulates the income effect of a price support, with its consequences on demand and its multiplier effect. The transfer of income to rural households induces increased demand in proportion to their consumption structure. The overall impact on production and households' income increases. All rural households farming are the ones who reap the profits from this policy, and the first three rural families are considered the highest income from the impact of this policy (because they own agricultural land, even if the possession is fragmented, they are also the ones who reap most of the benefits from this policy). On the other hand, high-income rural households benefit less from the multiplier effect of this policy because the extent of their ownership of agricultural land is lower compared to the poor.

Figure 4

The Effect of Higher Wheat Supply Prices on The Income of Rural Households (% Second Scenario)



Source: model results.

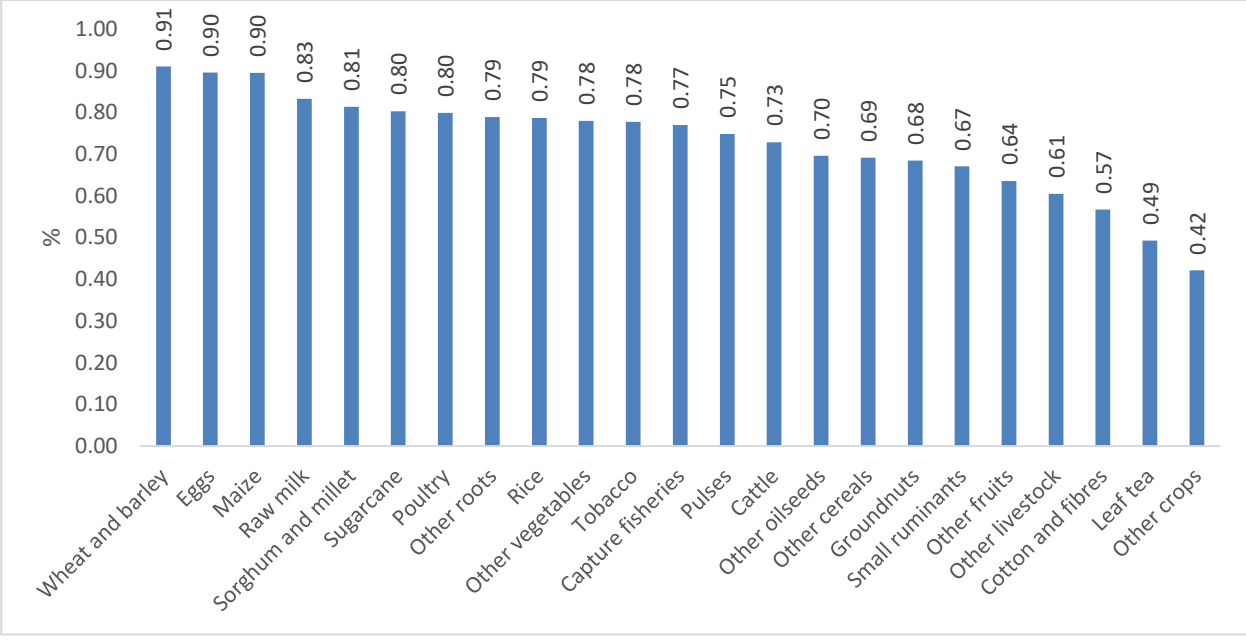
Figure 5 indicates the effect of increasing local wheat prices on encouraging farmers to produce wheat, as wheat production is expected to increase by 0.91%, which indicates the effectiveness of this policy on wheat producers. Moreover, the agricultural sector will be positively affected, which indicates the effectiveness of the forward and backward links, as well as the ability of this policy to revitalize the agricultural sector clearly, even if the percentages are simple.

In the third scenario, the government acted to support economic activity and households via accommodating fiscal and monetary policies. Hence, the third scenario is the injection of additional income, estimated at EGP 100, to compensate the most unprivileged Egyptian families, to mitigate the effects of the COVID-19, and combat some of the economic fallout of the pandemic.

This simulation shows that with no external injection, redistribution of income alone can generate some growth in production and income (123% and 141% of the amount of the redistribution, respectively).

Figure 5

The Effect of Higher Wheat Supply Prices on Production (The Second Scenario %)

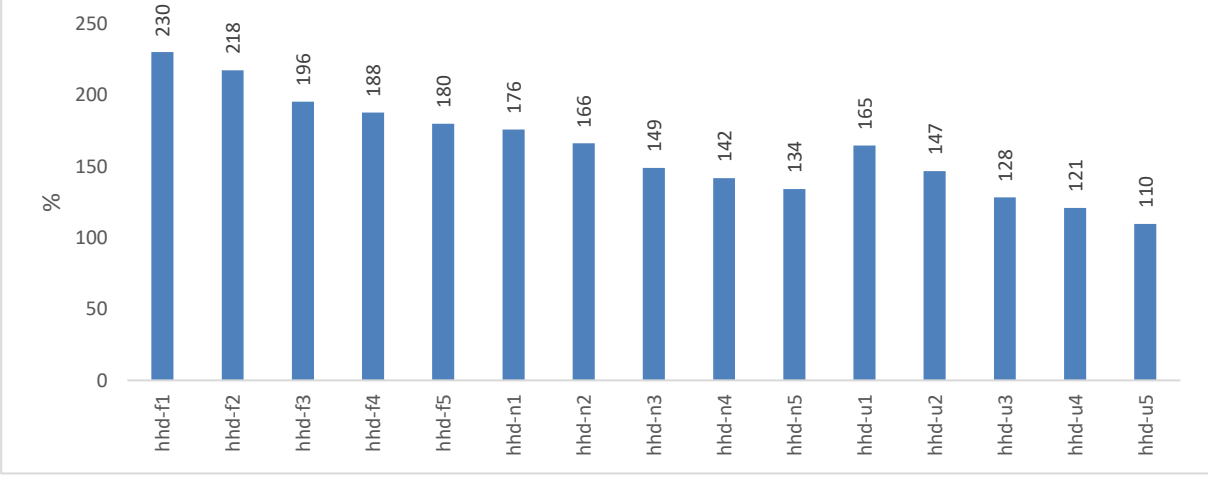


Source: model results.

As for household income, the first three categories in each family group (F: rural farming, N: rural not farming, and U: urban) are the ones who get the greatest number of benefits compared to the rest of the members of the same group. As shown in Figure 6, rural households are the ones who benefit most from this policy compared to urban households.

Figure 6

The Effect of An Additional Income Distribution on Household Groups (The Third Scenario %)



Source: model results.

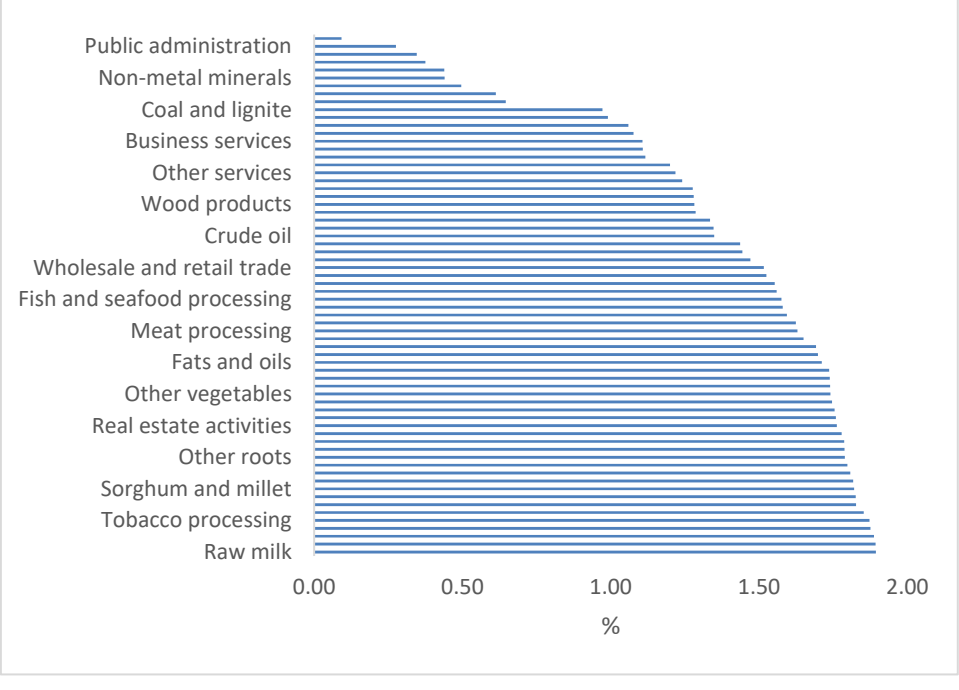
With the presence of additional income (which led to compensating the housing groups, even if partially for what they lost in income), consumers will tend to modify their consumption behavior, as they will tend to consume more agricultural commodities and medical services at the expense of reducing consumption of manufactured and petroleum commodities, as well as other services such as education.

From the results presented in Figure 7, it is clear that the demand for agricultural commodities, in general, has increased at a high rate compared to other commodities. The demand for both raw milk, eggs, and tobacco, poultry, tobacco processing, animal feed, wheat and barley, capture fisheries, sorghum and millet, maize, sugar refining, water supply and sewage, other roots, other grain milling, rice, and sugarcane has increased by about 1.89–1.76%.

This indicates the urgent needs of consumers for basic commodities. Therefore, we can be certain of the success of the policies of the protection programs pursued by the GoE "Takaful & Karama" to partially correct the path and eliminate the impact of COVID-19 pandemic, especially at the level of consumption, so that the Egyptian economy does not enter a state of economic recession.

Figure 7

The effect of an additional income distribution on Demand (the third scenario %)



Source: model results.

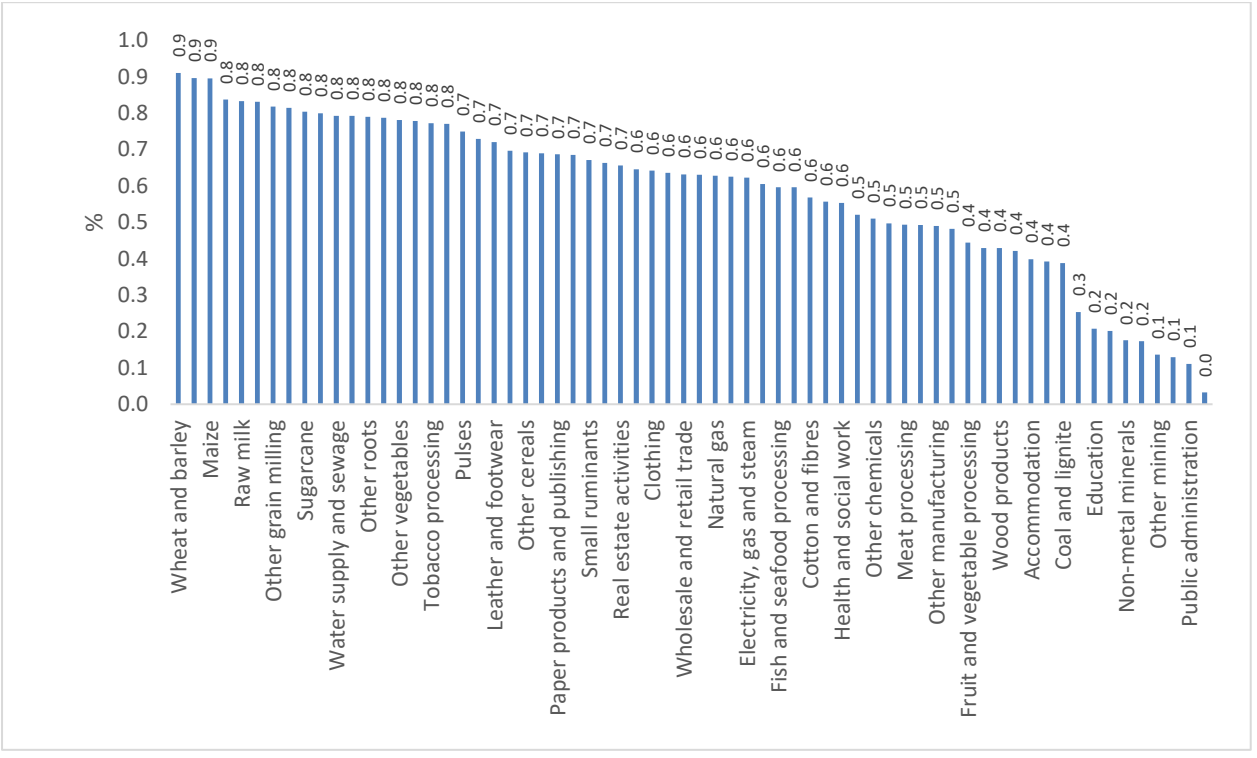
On the other hand, there are some obstacles that may result from this policy, given the inability of local production to cover the excess demand referred to in Figure 7, which requires more imports. Figure 8 indicates a slight increase in imports of basic commodities, which does not exceed 0.9%.

At the forefront are the main agricultural commodities such as wheat and barley, eggs, maize, animal feed, raw milk, sugar refining, other grain milling, sorghum and millet, sugarcane, poultry, water supply and sewage, fats and oils, other roots, rice, other vegetables, and tobacco by about 0.9% -0.8%.

It is worth noting that the rates of increase in demand ranged between 1.89–1.76% compared to the rates of increase in imports that did not exceed 0.9% for the same commodities. This indicates the ability of the Egyptian agricultural sector to produce more than half of the increase in demand due to the application of the third scenario.

Figure 8.

The Effect of An Additional Income Distribution on Imports (The Third Scenario %)



Source: model results.

Ultimately, despite the good results of the third scenario, the level of social protection required to fully offset the income losses of poor households is likely to be prohibitive, especially given the decline in revenues from economic activity. Moreover, social protection programs will remain the best option given the spread of similar pandemics compared to the lockdown option.

Therefore, the study recommends the necessity of increasing the value of exports (through export support programs) for the benefits to the economy (as the first scenario shows). In addition to the need for direct price support to wheat farmers, which encourages them to grow wheat, we recommend adopting social protection programs, as these programs have proven beneficial for all sectors of the economy (as discussed in the third scenario).

Conclusion and Recommendations

Many difficult situations have occurred throughout history. Sometimes, these challenges were wars or revolutions that completely reshaped society. As the COVID-19 pandemic unfolds, trade-offs have emerged between the need to contain the virus and to avoid catastrophic economic and food security crises that disproportionately affect the world's poor and hungry. Thus, the purpose of the study is to describe the immediate effects of the COVID-19 pandemic on the work situation for vulnerable groups of workers in Egypt. It presents the current policy measures undertaken by the Government of Egypt through evaluating the programs supporting the poor and their impact on food security in Egypt.

Using a multiplayer model, Egypt based on the Social Accounting Matrix, SAM (2014/15 base year), the study adopts three scenarios. The first scenario simulates the impact of the increase in the value of vegetable and fruit exports as a result of the increase in global demand motives. The second scenario analyses the effects of the increase in the domestic wheat prices as a result of the rise in global wheat prices, while the third scenario deals with evaluation of the GoE's strategy to confront the COVID-19 crisis through social protection programs "Takaful & Karama".

The most important results of the study clarify the following: The first scenario, increasing the value of exports led to an increase in total production by 2.26%, as well as an increase in agricultural production by 1.54%. Raising the price of domestic wheat resulted in an increase in rural household income. In addition, the incomes of all rural households that engage in agriculture have increased by rates ranging from 226% to 182% among the lowest-income and highest-income rural households, respectively, which indicates the success of this policy in generating additional income for households. Finally, the third scenario deals with the State’s policy from the Takaful

& Karama Program, in which the State spent EGP 100 billion to improve the living conditions of the poor, as the income of all household groups increased by rates ranging from 110–230%. This is because the poor received direct support from the government, while other groups of the population had other productive activities, which led to an increase in their incomes.

Ultimately, despite the good results of the third scenario, the level of social protection required to fully offset the income losses for poor households is likely to be prohibitive, especially given the decline in revenues from economic activity. Moreover, social protection programs will remain the best option, given the spread of similar pandemics compared to the lockdown option. Therefore, the study recommends the necessity to increase the value of exports (through export support programs) due to its benefits to the economy (as the first scenario shows). In addition to the need for direct price support to wheat farmers, which encourages them to grow wheat, we recommend adopting social protection programs, as they have proven beneficial for all sectors of the economy (as discussed in the third scenario).

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Appendix

Table 1

Input-Output and Social Accounting Matrix Multipliers in Egypt: SAM Multipliers

Total production			
Maize	2.3	Sugar refining	3.6
Sorghum and millet	2.4	Other foods	3.6
Rice	3.2	Animal feed	3.4
Wheat and barley	3.0	Beverages	3.2
Other cereals	2.2	Tobacco processing	1.5
Pulses	1.9	Textiles	2.5
Groundnuts	2.3	Clothing	1.8
Other oilseeds	1.8	Leather and footwear	2.8
Other roots	2.1	Wood products	1.8
Other vegetables	2.1	Paper products and publishing	2.6
Sugarcane	2.2	Petroleum products	3.7
Tobacco	1.0	Fertilizers and herbicides	2.5
Cotton and fibers	2.2	Other chemicals	1.8
Other fruits	2.0	Non-metal minerals	3.1
Leaf tea	1.0	Metals and metal products	4.5
Other crops	1.0	Machinery and other equipment	1.6
Cattle	2.1	Electrical equipment	2.6
Raw milk	2.2	Vehicles and transport equipment	2.1
Poultry	2.2	Other manufacturing	3.6
Eggs	3.2	Electricity, gas and steam	5.4
Small ruminants	1.8	Water supply and sewage	3.8
Other livestock	1.7	Construction	4.1
Capture fisheries	2.0	Wholesale and retail trade	2.4
Coal and lignite	1.0	Transportation and storage	2.4
Crude oil	1.9	Accommodation	2.6
Natural gas	1.9	Information and communication	3.0
Other mining	2.5	Finance and insurance	2.3
Meat processing	2.5	Real estate activities	2.3
Fish and seafood processing	2.1	Business services	2.5
Dairy	3.0	Public administration	2.7
Fruit and vegetable processing	3.4	Education	2.3
Fats and oils	2.4	Health and social work	2.7
Other grain milling	3.7	Other services	2.8

Source: Model results.

Table 2

The Linkage Between Production Multipliers and Other Sectors

Linkage other sectors			
Maize	1.3	Sugar refining	2.6
Sorghum and millet	1.4	Other foods	2.6
Rice	2.2	Animal feed	2.4
Wheat and barley	2.0	Beverages	2.2
Other cereals	1.1	Tobacco processing	0.4
Pulses	0.9	Textiles	1.3
Groundnuts	1.2	Clothing	0.8
Other oilseeds	0.8	Leather and footwear	1.6
Other roots	1.1	Wood products	0.7
Other vegetables	1.1	Paper products and publishing	1.6
Sugarcane	1.2	Petroleum products	2.6
Tobacco	0.0	Fertilizers and herbicides	1.5
Cotton and fibers	1.2	Other chemicals	0.7
Other fruits	1.0	Non-metal minerals	2.0
Leaf tea	0.0	Metals and metal products	2.8
Other crops	0.0	Machinery and other equipment	0.6
Cattle	1.1	Electrical equipment	1.5
Raw milk	1.2	Vehicles and transport equipment	1.0
Poultry	1.2	Other manufacturing	2.5
Eggs	2.1	Electricity, gas and steam	3.9
Small ruminants	0.7	Water supply and sewage	2.8
Other livestock	0.7	Construction	2.9
Capture fisheries	1.0	Wholesale and retail trade	1.4
Coal and lignite	0.0	Transportation and storage	1.4
Crude oil	0.8	Accommodation	1.6
Natural gas	0.9	Information and communication	2.0
Other mining	1.5	Finance and insurance	1.3
Meat processing	1.5	Real estate activities	1.3
Fish and seafood processing	1.1	Business services	1.4
Dairy	2.0	Public administration	1.7
Fruit and vegetable processing	2.4	Education	1.3
Fats and oils	1.4	Health and social work	1.7
Other grain milling	2.7	Other services	1.7

Source: Model results.

SAM Multilayer System of Equations

In SAM, we substitute the following symbols for actual numbers.

	Activities		Commodities		Factors	House-holds	Exogenous demand	Total
	A1	A2	C1	C2	F	H	E	
A1			X_1					X_1
A2				X_2				X_2
C1	Z_{11}	Z_{12}				C_1	E_1	Z_1
C2	Z_{21}	Z_{22}				C_2	E_2	Z_2
F	V_1	V_2						V
H					$V_1 + V_2$			Y
E			L_1	L_2		S		E
Total	X_1	X_2	Z_1	Z_2	V	Y	E	

To generate the coefficients matrix, divide the columns by their total (M-matrix). It should be noted that the M-matrix does not include the exogenous components of demand.

	Activities		Commodities		Factors	House-holds	Exogenous demand	Total
	A1	A2	C1	C2	F	H	E	
A1			$b_1= X_1/Z_1$					X_1
A2				$b_2= X_2/Z_2$				X_2
C1	$a_{11}=Z_{11}/X_1$	$a_{12}=Z_{12}/X_2$				$c_1 = C_1/Y$	E_1	Z_1
C2	$a_{21}=Z_{21}/X_1$	$a_{22}=Z_{22}/X_2$				$c_2 = C_2/Y$	E_2	Z_2
F	$v_1=V_1/X_1$	$v_2=V_2/X_2$						V
H					1			Y
E			$l_1 = L_1/Z_1$	$l_2 = L_2/Z_2$		s = S/Y		E
Total	1	1	1	1	1	1	E	

Where values

X refers to gross output of each activity, Z refers to total demand for each commodity, V refers to total factor income, Y refers to total household income, E refers to exogenous components of demand

Where shares

a refers to technical coefficients, b refers to share of domestic output in total demand, v refers to share of value-added, l refers to share of the value of total demand from imports or commodity taxes, c refers to Household consumption expenditure shares, and s refers to household savings rate.

As a result, we can now derive equations that represent the relationships in the SAM. We begin with simple demand equations.

$$Z_1 = a_{11}X_1 + a_{12}X_2 + c_1Y + E_1$$
$$Z_2 = a_{21}X_1 + a_{22}X_2 + c_2Y + E_2 \quad \text{(A1)}$$

Total demand = intermediate demand + household demand + exogenous demand

According to the SAM, domestic production X accounts for only a portion of total demand Z.

$$X_1 = b_1Z_1 \qquad \text{and} \qquad X_2 = b_2Z_2$$

We know that household income Y is affected by how much each factor earns in each sector.

$$Y = v_1X_1 + v_2X_2 \qquad \text{or} \qquad Y = v_1b_1Z_1 + v_2b_2Z_2$$

Now we replace Xs and Vs in Equation A1.

$$Z_1 = a_{11}b_1Z_1 + a_{12}b_2Z_2 + c_1(v_1b_1Z_1 + v_2b_2Z_2) + E_1$$
$$Z_2 = a_{21}b_1Z_1 + a_{22}b_2Z_2 + c_2(v_1b_1Z_1 + v_2b_2Z_2) + E_2$$

Everything except E is moved to the left side.

$$Z_1 - a_{11}b_1Z_1 - c_1v_1b_1Z_1 - a_{12}b_2Z_2 - c_1v_2b_2Z_2 = E_1$$
$$-a_{21}b_1Z_1 - c_2v_1b_1Z_1 + Z_2 - a_{22}b_2Z_2 - c_2v_2b_2Z_2 = E_2$$

group Zs together.

$$(1 - a_{11}b_1 - c_1v_1b_1)Z_1 + (-a_{12}b_2 - c_1v_2b_2)Z_2 = E_1$$
$$(-a_{21}b_1 - c_2v_1b_1)Z_1 + (1 - a_{22}b_2 - c_2v_2b_2)Z_2 = E_2 \quad \text{(A2)}$$

We express Equation A2 in matrix format.

$$\begin{pmatrix} 1 - a_{11}b_1 - c_1v_1b_1 & -a_{12}b_2 - c_1v_2b_2 \\ -a_{21}b_1 - c_2v_1b_1 & 1 - a_{22}b_2 - c_2v_2b_2 \end{pmatrix}\begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix} = \begin{pmatrix} E_1 \\ E_2 \end{pmatrix} \quad \text{(A3)}$$

The identity matrix (I) minus the coefficient matrix is the first term in Equation A3 (M).

$$\begin{pmatrix} 1 - a_{11}b_1 - c_1v_1b_1 & -a_{12}b_2 - c_1v_2b_2 \\ -a_{21}b_1 - c_2v_1b_1 & 1 - a_{22}b_2 - c_2v_2b_2 \end{pmatrix} = I - M$$

If we rename the other two vectors Z and E then we can simply Equation A3.

$$(I - M)Z = E \quad \text{(A4)}$$

Rearranging, we get the final multiplier equation.

$$Z = (I - M)^{-1}E \quad \text{(A5)}$$

Total demand = multiplier matrix × exogenous demand

This tells us that when exogenous demand € increases, then after you have taken all the direct and indirect multiplier effects into account ($(I-M)^{-1}$), you will end up with a final increase in total demand equal to Z (Breisinger et al., 2010).