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Abstract

Climate change is a reality in Egypt. Temperatures in Egypt have risen 0.34o C/Decade between 1961-2000. Climate change is likely to aggravate water scarcity problems, reduce agricultural yields and agricultural output as parts of the Nile Delta is threatened by inundation due to sea level rise. Reducing carbon emissions is thus essential. Utilizing an Intertemporal General Equilibrium Model, this paper investigates the effect of implementing a carbon tax on economic growth and consumer welfare. Alternative ways to recycle the tax revenue is also considered. The effect of the carbon tax on economic growth depends on the use of the additional tax revenue. If the revenue is used to fund additional government consumption or cash transfers to private households, the effect is mildly contractionary. If the revenue is used to reduce other tax rates in a way that stimulates additional investment, the carbon tax could have a positive impact on economic activity. The carbon tax has no discernible adverse effects on the distribution of household income.

Keywords: Climate Change, Egypt, Carbon Tax, Intertemporal General Equilibrium Models, Economic Growth, Equity
JEL Classification: O44, Q52, Q54, E16

ملخص

تغير المناخ حقيقة واقعة في مصر. ارتفعت درجات الحرارة في مصر بمقدار 0.34 درجة مئوية / عقد بين عامي 1961 و 2000. من المرجح أن يؤدي تغير المناخ إلى تفاقم مشاكل ندرة المياه، وتقليل المحاصيل الزراعية والإنتاج الزراعي حيث أن أجزاء من دلتا النيل مهددة بالفيضان بسبب ارتفاع مستوى سطح البحر. وبالتالي فإن الحد من انبعاثات الكربون أمر ضروري. باستخدام نموذج التوازن العام عبر الزمن، تبحث هذه الورقة في تأثير تطبيق ضريبة الكربون على النمو الاقتصادي ورفاهية المستهلك. يتم أيضًا النظر في الطرق البديلة لإعادة تدوير الإيرادات الضريبية. يعتمد تأثير ضريبة الكربون على النمو الاقتصادي على استخدام الإيرادات الضريبية الإضافية. إذا تم استخدام الإيرادات لتمويل استهلاك حكومي إضافي أو تحويلات نقدية لأسر خاصة، فإن التأثير يكون انكماشيا بشكل معتدل. إذا تم استخدام الإيرادات لخفض معدلات الضرائب الأخرى بطريقة تحفز الاستثمار الإضافي، فقد يكون لضريبة الكربون تأثير إيجابي على النشاط الاقتصادي. ليس لضريبة الكربون أي آثار سلبية ملحوظة على توزيع دخل الأسرة.

1. Problem

Climate Change is a reality in Egypt. According to the UNDP (Smith et al, 2013) temperatures in Egypt have risen 0.34º C/Decade between 1961-2000. Climate change poses many threats to the country. These threats include aggravating water scarcity problems, reducing energy generation from clean hydropower, and declining agricultural output as yields fall and as cultivated land decrease, since parts of the Nile delta is threatened by inundation due to rising sea level. Labour productivity is also susceptible to fall due to heat stress and deteriorating air quality.[2]

Egypt follows a command and control approach to control greenhouse gas emissions. By law, if emissions from a source exceed allowable limits set by the ministry of the environment, a fine is imposed. However, this fine which ranges from a minimum of EGP1,000 to a maximum of EGP 20,000 is very modest. As cited in the literature, if abatement cost of the firm is higher than the fine, firms will prefer to pay the fine rather than abate. Thus, this approach to controlling greenhouse gases is not very effective as evident from the continuous increase in Carbon dioxide emissions. In fact, between 1990 and 2018 Carbon dioxide emissions have increased by 183%. Moreover, unlike market-based incentives, this approach does not minimize the cost of controlling greenhouse gases in the economy, as it does not necessarily equalize marginal control costs across sources of emissions.

Nonetheless, the Egyptian government has taken several important steps over the past few years to reduce carbon dioxide emissions. By ratifying the Paris agreement, Egypt is committed to mitigate greenhouse gas emissions. However, as explained above this will be hard to achieve under the current command and control regime. Energy subsidies which have been in place for decades are being gradually phased out. It goes without saying that the complete removal of fossil fuel subsidies is imperative before it makes sense to implement any kind of market-based incentives to reduce fossil fuel use. A change in the energy mix towards renewables and nuclear energy and away from oil and gas which currently constitutes 98% of primary energy consumption is underway (Ministry of Planning and Economic Development, 2021), and the introduction of a carbon tax would be conducive to the achievement of the ambitious targets for the share of renewable energy sources in the power mix set out in Egypt's 2035 Integrated Sustainable Energy Strategy.

Meanwhile, the government is in dire need for resources to finance its ambitious development agenda and the revenues raised from the removal of energy subsidies and the implementation of a carbon tax would no doubt be helpful.

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[2] For a quantitative assessment of climate change impacts on Egypt's economic growth prospects up to 2050 see Elshennawy et al (2016).

Utilizing an intertemporal general equilibrium model, the main objective of this research is to assess the welfare and equity implications of implementing a carbon tax in the case of Egypt which is one of the most popular instruments that fall under market-based incentives. Given that the tax infrastructure is not optimal, we have opted for a carbon tax whose revenues can be recycled to help reduce the distortions arising due to existing taxes. Another option for recycling the tax revenue that will be considered is through providing affected households with cash transfers.

One of the advantages of implementing a carbon tax in the case of Egypt is that - unlike tradeable permits - it does not require the creation of a new administrative body that will be needed to administer and allocate tradable permits. Our contribution is two-fold: First: we are the first to address the distributional effects of a carbon tax within the framework of an intertemporal general equilibrium model. Static models by construction do not consider the effect of the tax on investment and are thus likely to underestimate such distributional effects. Second: this research represents the first attempt to explore the growth and equity implications of implementing a carbon tax in the case of Egypt. The results of this research project will help inform policy makers in Egypt regarding the effectiveness of a carbon tax in reducing energy consumption. Policy makers will be also informed about how the tax is likely to affect different segments of the population and different industries which will in turn shed light on the politically feasibility of implementing the tax.

The rest of this paper is structured as follows: section 2 presents the literature review, section 3 outlines the methodology. Section 4 presents data and section 5 reports simulation results, finally section 6 concludes.

2. Literature Review

Market based incentives like a carbon tax provide an alternative to the command and control approach to mitigating greenhouse gases cited in the literature. Using a longitudinal dataset for 142 countries, Best et al (2020) find that countries with carbon prices were able on average to lower annual carbon dioxide emission by 2%. This is quite significant if considered over period of decades. Sen and Vollebergh (2018) find that a carbon tax reduces energy consumption in OECD countries. A more recent study by Guglar et al (2021) provide empirical evidence showing that carbon pricing is more effective in abating emissions and more cost effective compared to subsidizing renewables.

There exists a vast body of literature investigating the economy-wide implications of carbon pricing particularly using general equilibrium models (CGE). (See Xu and Wei (2021) for a recent review of this literature). Examples include Devarajan et al (2009) in the case of South Africa, and Dissanayake et al (2018) in the case of Sri Lanka and Pakistan, both of which find a carbon tax to have favourable effects on welfare. Pradhan et al (2017) find that terms of trade effect lead to higher carbon prices in China compared to India. In the case of China, Xu and Wei (2021) and Zhang et al (2019) find that a carbon tax has an unfavourable effect on competitiveness.

Campagnolo and Davide (2019) examine the effect of Nationally Determined Contributions of several developed and developing countries – including Egypt - under the Paris Agreement on two Sustainable Development Goals: Poverty reduction and reduced inequality. With the aid of a Recursive Dynamic General Equilibrium Model (DCGE) they show that climate mitigation through a carbon tax leads to modest negative results in countries with non-stringent obligations to cut GHG like Egypt. Nonetheless, the model does not differentiate between households according to income quintiles or region of residence (urban/rural). The effect on sectoral employment and competitiveness of various industries was not examined.

Parry (1995) and Yamazaki, (2017) highlight that environmental taxes can discourage employment. With the exception of Bye (2000), Goulder (1995) and Pereira et al (2016), most of studies employing CGE models do not explore the effect of the carbon tax on investment and growth. Goulder (1995) accounted for how firms are likely to substitute cleaner or synthetic fuel for fossil fuel in response to the tax and how this may reduce the costs of the tax. Using an intertemporal general equilibrium model Pereira et al (2016) show that recycling carbon tax revenue to reduce taxes on physical and human capital can increase income and growth. However, none of these studies consider the distributional effects of the tax.

Examining the distributional effects of the carbon tax is important as these distributional effects strongly affect the political feasibility of implementing such taxes. In general, the literature addressing the distributional effect of climate policies is inconclusive. (Ohlendorf et al, 2021). Olale (2019) provided evidence that carbon tax hurt farmers in British Colombia. This is despite of the fact that agriculture was exempt from the tax. This is be explained by the fact that the carbon tax raises the prices for some of the inputs that farmers use such as fertilizers. Since the adverse effect of a carbon tax on the poor is one of the main challenges facing the implementation of this policy, Dorband et al (2019) investigate the distributional effect of carbon taxes on low- and high-income countries. A carbon tax was found to be progressive in low income countries.

In another vein, using a DCGE model, Pradhan and Ghosh (2019) compare the cost of climate change as manifested in declining agricultural productivity to the cost to the economy of climate mitigation policy. Simulation results show that the former cost is higher than the latter.

Although the literature reviewed above provides insights on the effects of carbon taxes, it is hard to generalize the conclusions of these studies. This stems from the fact that economies differ in structure. Under such circumstances, it is necessary to examine the effect of this policy on individual countries to be in a better position to evaluate its effectiveness.

3. Methodology

According to the intertemporal general equilibrium model employed in this research, consumers maximize an intertemporal utility function subject to an intertemporal budget constraint. Embedded in this dynamic structure is a within period static CGE model. There are six factors of production: capital, land, and four types of labour differentiated by level of educational attainment. These factors of production are combined into a CES value added aggregate. To capture intra-sectoral technology switches towards less energy-intensive modes of production as well as substitution effects between energy inputs in response to tax-induced changes in relative input prices, the model adopts a standard KLEM (Capital (**K**), **L**abour, **E**nergy, **M**aterials) technology specification.[3] Under this approach, the transition towards a higher share of renewables in the power mix induced by a rise in fossil fuel price is represented in a stylised form as a substitution of fossil fuel inputs by physical capital (Willenbockel et al, 2017). Moreover, the specification allows for substitution between petrol fuels and natural gas.

On the import side, the Armington specification is assumed whereby imports are combined with domestic output using a constant elasticity of substitution function to form a composite good. Domestic output and exports are combined according to a constant elasticity of transformation function. There are four institutions in the model, consumers, producers, government and the rest of the world. Households are disaggregated by income quintile and region of residence (urban/rural). Markets are assumed to perfectly competitive. A more detailed technical description of the core model as developed by Jean Mercenier can be found in Elshennawy (2014).

4. Data and Calibration

The model is calibrated using the 2014/2015 social accounting matrix for Egypt which differentiates between three household groups: rural farm, rural nonfarm and urban. Each household group is disaggregated into 5 income quintiles from poorest to richest. Manufacturing is disaggregated into 8 industries. Services are disaggregated into 5 sectors. There are three factors of production, labor , land and capital. The model differentiates between four types of labor: uneducated, primary, secondary and tertiary.[4]

The selection of values for the sectoral factor elasticities of substitution and the elasticities of substitution between imports and domestically produced output by commodity group elasticities of household demand is informed by available econometric evidence from secondary sources and uses estimates provided by the GTAP behavioural parameter database (Hertel and van der Mensbrugghe 2016). Based on the comprehensive meta analysis of empirical studies conducted

[3] See Pueyo et al (2015: Chapter 6) for a concise review of the use of the KLEM approach in energy-focused top-down CGE models.
[4] The GAMS code used in this paper is a modified version of GAMS code developed by Jean Mercenier. The GAMS code for the KLEM specification draws upon code developed for an earlier UNDP study (Willenbockel and Hoa, 2011).

by Havránek (2015), the intertemporal elasticity of substitution in household consumption is set to 0.25. The elasticity of substitution between agggregate energy and the capital-labour composite in the KLEM production function is set to 0.4[5] and the elasticity of substitution between petrol fuels and natural gas is set to 1.

5. Simulation Scenarios

5.1. Scenario Design

The scenario analysis considers the introduction of a carbon tax at a uniform final rate of USD 20 per ton of CO_2 emissions on refined petrol and natural gas. The carbon tax is gradually phased in over 5 years according to a pre-announced linear schedule - i.e, the carbon tax rate rises from USD 4.00/t CO_2 in year 1 to USD 20.00/t CO2 in year 5 and stays at this level thereafter.

Table 1. Specific Final Carbon Tax Rates Per Unit of Fossil Fuel

		CO_2 Emission Factor	Carbon Tax Rate		
	unit	t CO_2/unit	USD/ t CO_2	USD/unit	EGP/unit
Refined Petrol	ton	3.275	20	65.50	1023.47
Natural Gas	m3	0.0019	20	0.04	0.59

We consider three scenarios that differ in terms of the assumed allocation of the additional net tax revenue raised by the reform:

S1: No Recycling: Carbon tax revenue is used to finance additional goverment consumption;

S2: Re-Cycling: Lump-sum re-transfer of carbon tax revenue to household sector in proportion to households‘ baseline share in income tax payments;

S3 Indirect Tax Cut: Carbon tax revenue is used to finance a reduction in tax rates on domestic sales. (uniformly by 44 percent).

5.2. Macroeconomic Impacts

Table 2 provides a comparative summary perspective on the economy-wide impacts across the different carbon tax scenarios. The table reports the simulated long-run steady-state deviations of the main macroeconomic aggregates from the baseline in real terms. Figures 1 to 3 report the dynamic impacts on the time profile of real aggregate household consumption, aggregate real investment, real GDP and gross national income (GNP = GDP + net foreign asset income).

In relation to GDP, the carbon tax revenue rises gradually from 0.4 percent in the first year to about 2.1 percent in the long-run equilibrium. Under the no-recycling scenario, the new tax thus shifts a significant amount of purchasing power from the private to the public sector. Correspondingly, long-run private consumption drops noticeably while government consumption

[5] This value is significantly lower than typically assumed in respective studies for advanced economies. For further reference to empirical studies of energy substitution elasticities see Pueyo et al (2015: 56).

rises by 13 percent relative to the baseline. As the carbon tax raises the price of investment goods (see section 5.3) , the cost of capital rises and aggregate real investment and GDP drop.

Under the recycling scenario, the carbon tax revenue is re-transfered to the household sector in the form of lump-sum cash transfers, and therefore the long-run reduction in private consumption is far less pronounced than in the no-recycling scenario. Interestingly, as shown in Figure 2, the anticipation of rising prices of consumer prices due to the carbon tax entails a moderate initial *rise* in aggregate consumption during the phasing-in period, as it is rational for intertemporally optimizing household to shift planned purchases of (durable) consumption goods forward to the present to some extent, given that prices of such goods are expected to rise in the future.[6] Correspondingly a stronger drop in initial savings and domestic investment than in the long-run. The long-run effect on aggregate real investment is similar to the first scenario. Government consumption drops in real terms in this case as the negative effect on GDP reduces income tax revenue and indirect tax revenue.

Under the indirect tax cut scenario, the carbon tax revenue allows a revenue-neutral uniform[7] reduction in other indirect taxes on products by a sizeable 44 percent by the end of the phasing-in period (and by around 9 percent in the first year). This means that for a product taxed at a baseline rate of, say, 10 percent, the tax rate drops by 4.4 percentage points to 5.6 percent by the end of the phase-in period. As shown in Table 2 and Figure 3, this alternative use of the carbon tax revenue entails notably different macroeconomic effects in comparison to the other scenarios. The simulation results suggest a positive double-dividend effect on aggregate income due to the carbon-tax-financed reduction in distortionary taxes.

Key to the expansionary impact under this scenario is the net effect of the tax rate changes on the effective user prices of investment goods. While the steady-state price index of investment goods rises by 2.7 to 3.3 percent in the other scenarios due to the carbon tax, it declines by 2.1 percent in the indirect tax cut scenario – i.e. in aggregate terms the price reduction effect of the tax cuts dominates the opposite price effect of the carbon tax with respect to capital goods. The downward pressure on the cost of capital stimulates real investment after the initial drop at the start of the phasing-in period and GDP rises.

[6] In the no-recycling scenario, this intertemporal substitution effect is also present but is dominated by the stronger negative income effect on consumption.
[7] Fossil fuel sales are exempted from this tax cut.

Table 2. Steady-State Impacts on Macroeconomic Variables
(Percentage deviations)

	No Recycling	Recycling	Indirect Tax Cut
Real Private Consumption	-2.3	-0.5	0.7
Real Investment	-4.0	-4.0	1.9
Real Government Consumption	13.0	-4.0	2.5
Real Exports	-16.2	-14.4	9.7
Real Imports	-2.6	-2.3	1.9
Real Gross Domestic Product	-2.6	-2.9	2.1
Real National Income	-1.1	-1.5	1.2
CPI/Import Price Index	4.2	3.8	-1.8

Figure 1. Macroeconomic Impacts – No-Recycling Scenario

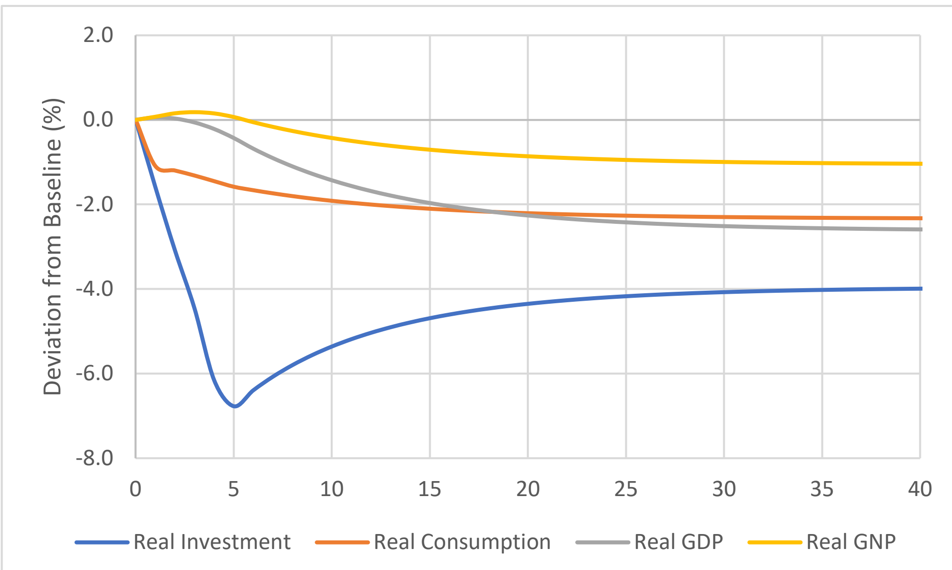


Figure 2. Macroeconomic Impacts – Recycling Scenario

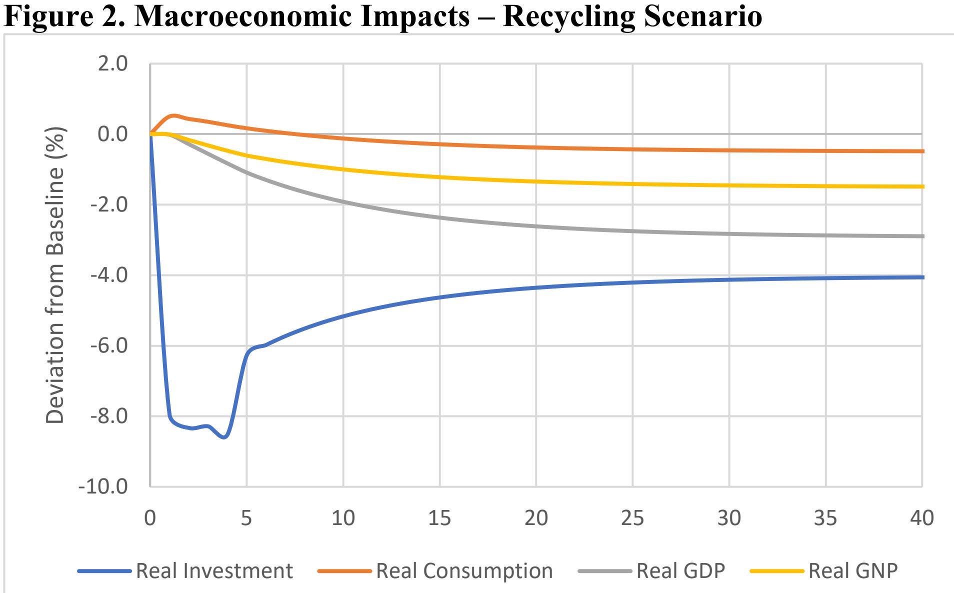
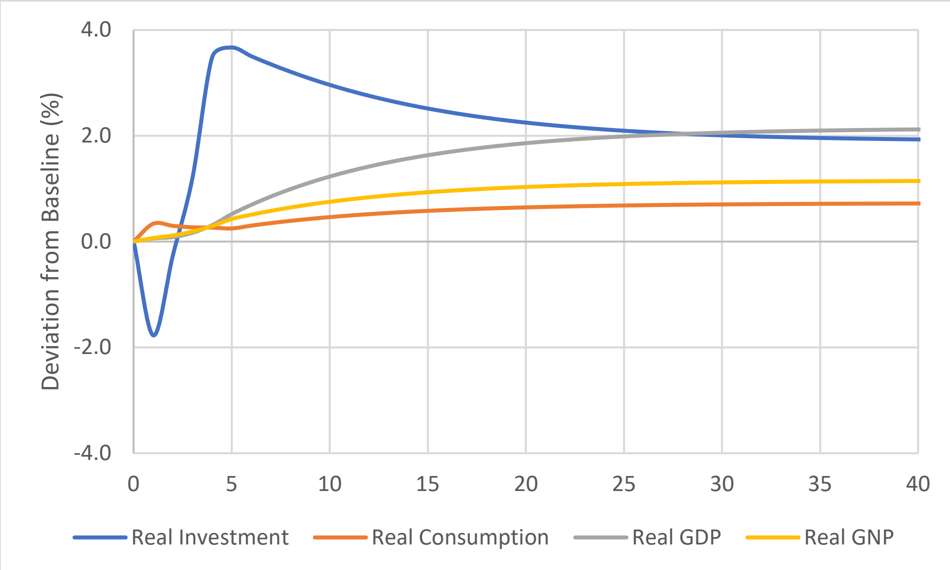


Figure 3. Macroeconomic Impacts – Indirect Tax Cut Scenario

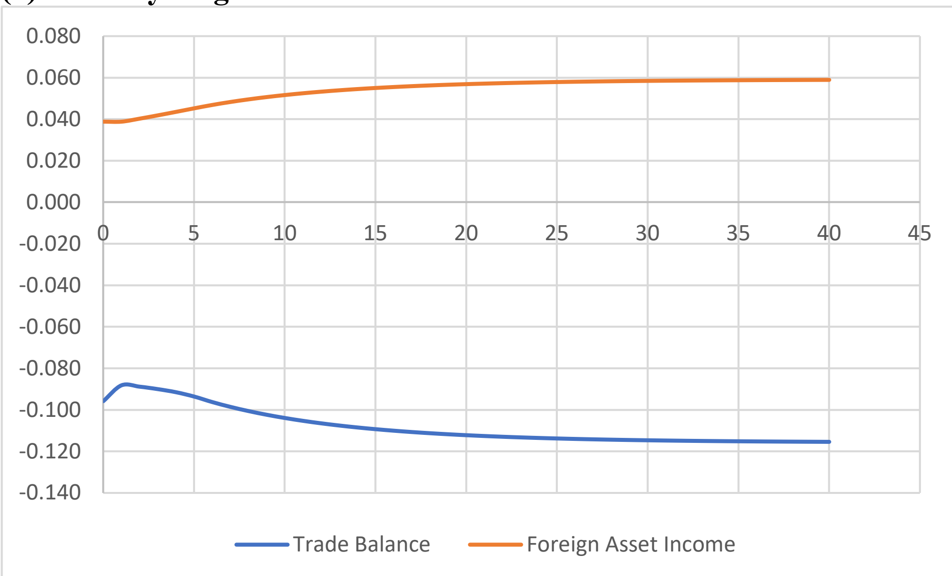


To explain the long-run steady-state effects on exports, imports and the trade balance under the different scenarios, we have to look at the implications of the carbon tax on the allocation of domestic savings. Since under the first two scenarios the carbon tax exerts downward pressure on returns to domestic capital, domestic savings shift in tendency from investment in domestic real capital to investment in foreign assets. As a result, domestic residents' net foreign asset income is higher in the new steady-state, and this entails via the external balance-of payments constraint a higher trade balance deficit in the new long-run equilibrium than in the initial steady state (Figure 4(a) and (b)). Correspondingly, the gross national product (= GDP + net foreign asset income) drops less than GDP in these scenarios

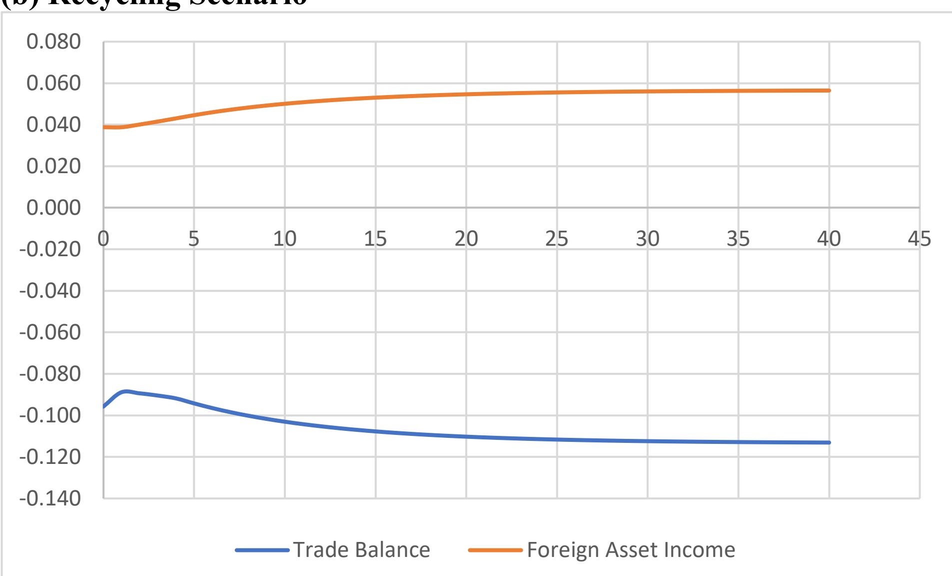
In contrast, in the indirect tax cut scenario, domestic households shift in tendency from investment into foreign assets to investment in domestic firms. Thus, foreign asset income drops relative to the baseline and the steady-state trade balance deficit must drop to maintain the long-run balance-of payment equilibrium (Figure 4(c)).

Figure 4. Impact on Trade Balance and Foreign Asset Income

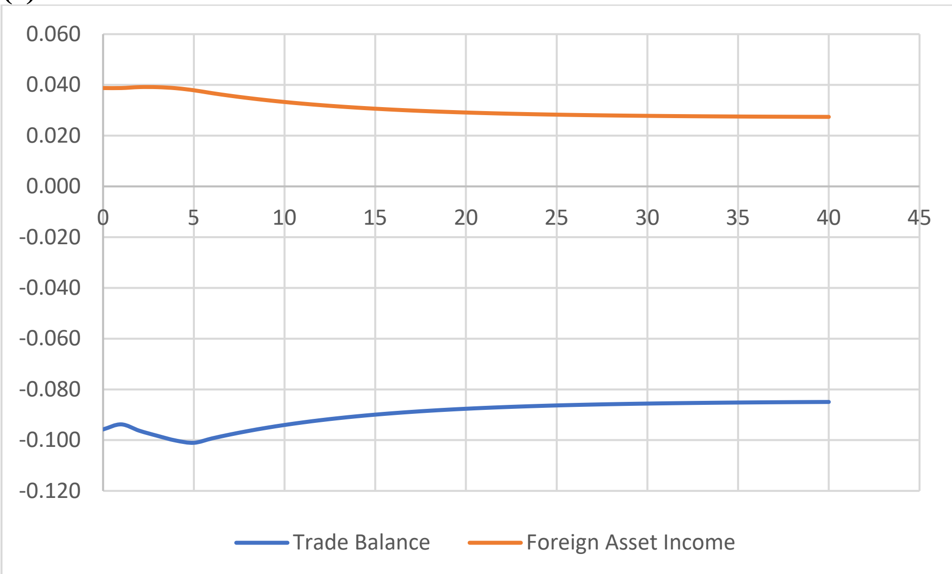
(a) No-Recycling Scenario



(b) Recycling Scenario



(c) Indirect Tax Cut Scenario



5.3. Sectoral Impacts

Turning to sectoral impacts, Figure 5 shows that in scenarios S1 and S2 domestic purchaser prices increase in the new steady state for all commodities due to the carbon tax with prices of energy-intensive commodities the most affected. In response to higher prices and lower income, in S1 domestic demand for all commodity groups except Other Services - which includes public services demanded by the government - fall in the new steady state as shown in Figure 6. Domestic demand for petrol products drops by more than 10 percent and demand for natural gas by over 9 percent in this scenario. Correspondingly GHG emissions from the combustion of fossil fuels drop by about 10 percent relative to the baseline. The drop in in electricity demand partly reflects shifts to more energy-efficient modes of production and consumption. Electric power use drops by less than fossil fuel use, reflecting a shift towards a higher share of renewable energy sources in the power mix in response to the carbon tax.

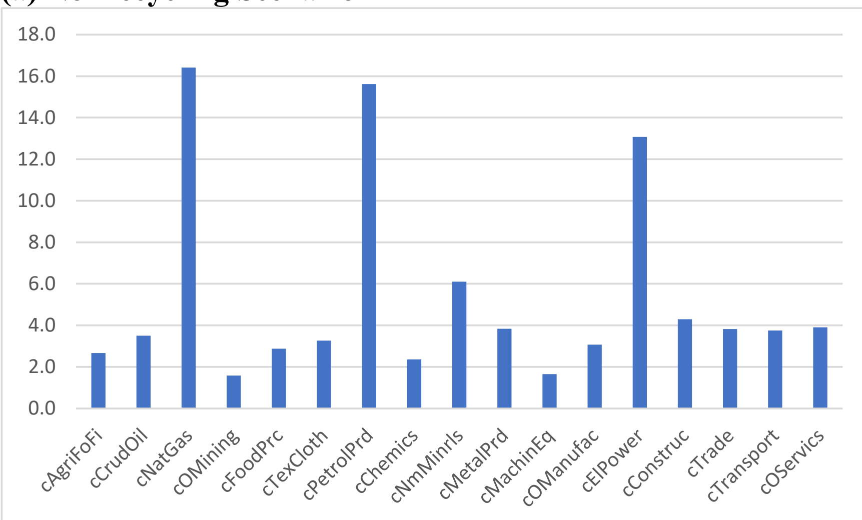
These effects are slightly less pronounced in the recycling scenario (S2), where domestic fossil fuel demand and related GHG emissions drop by around 9 percent (Figure 7).

The price and demand impacts are markedly different under the S3 scenario, in which the user price effect of the cut in indirect product taxes turns out to dominate the price effect of the carbon tax except for fossil fuels and electricity (Figures 5(c) and 8). As noted earlier, the net reductions in the purchaser price of investment goods such as Machinery and Equipment and Construction Services shown in Figure 5(c) triggers the positive investment effect and resulting double-dividend effect on income in this scenario. Due to the positive effect on overall economic activity, the GHG emission reduction effect is significant lower under S3 compared to S1 and S2.

The resulting steady-state impacts on domestic production by sector are displayed in Figures 9 to 11.

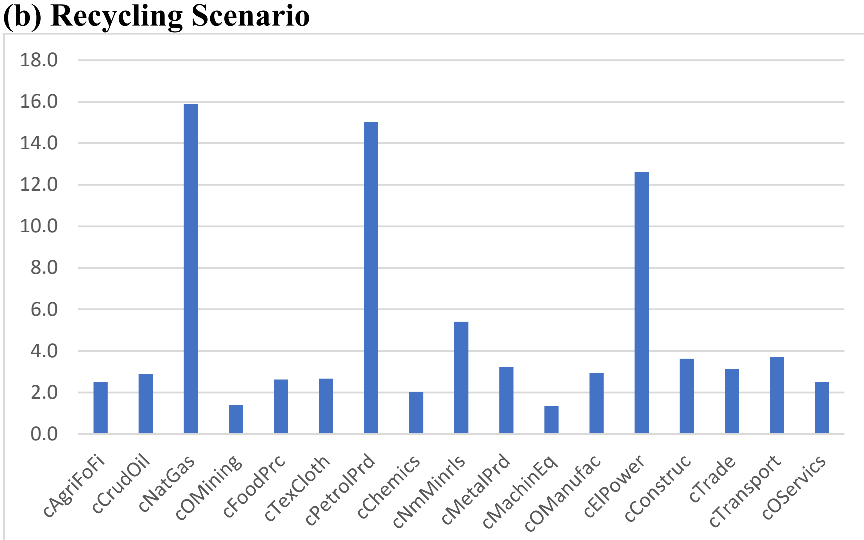
Figure 5. Impact on Steady-State Domestic Purchaser Prices by Commodity
(Percentage deviation from Baseline)

(a) No-Recycling Scenario

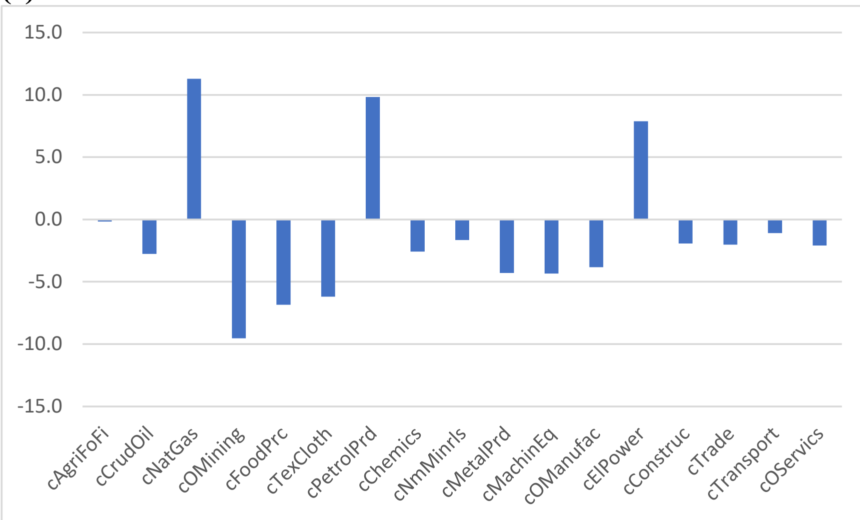


AgriFoFi: Agriculture, Forestry, Fishing; CrudOil: Crude Oil Extraction; OMining: Other Mining; TexCloth; Textiles, Clothing, Leather and Footwear; PetrolPrd: Refined Petrol Products; Chemics: Chemicals, Plastic and Rubber Products; NmMinrls: Non-metallic Mineral Products; MachinEq: Machinery and Equipment; OManufac: Other Manufacturing; ElPower: Electricity; Construc: Construction; Trade: Whole- and Retail Trade Services and Storage; Transport: Transport Services; OServics: Other Services.

(b) Recycling Scenario



(c) Indirect Tax Cut Scenario



Note: The model numeraire is the baseline basket of import goods – i.e. reported price changes are measured relative to the import price index.

Figure 6. Impact on Steady-State Domestic Demand by Commodity Group - No Recycling Scenario

(Percentage deviation from Baseline)

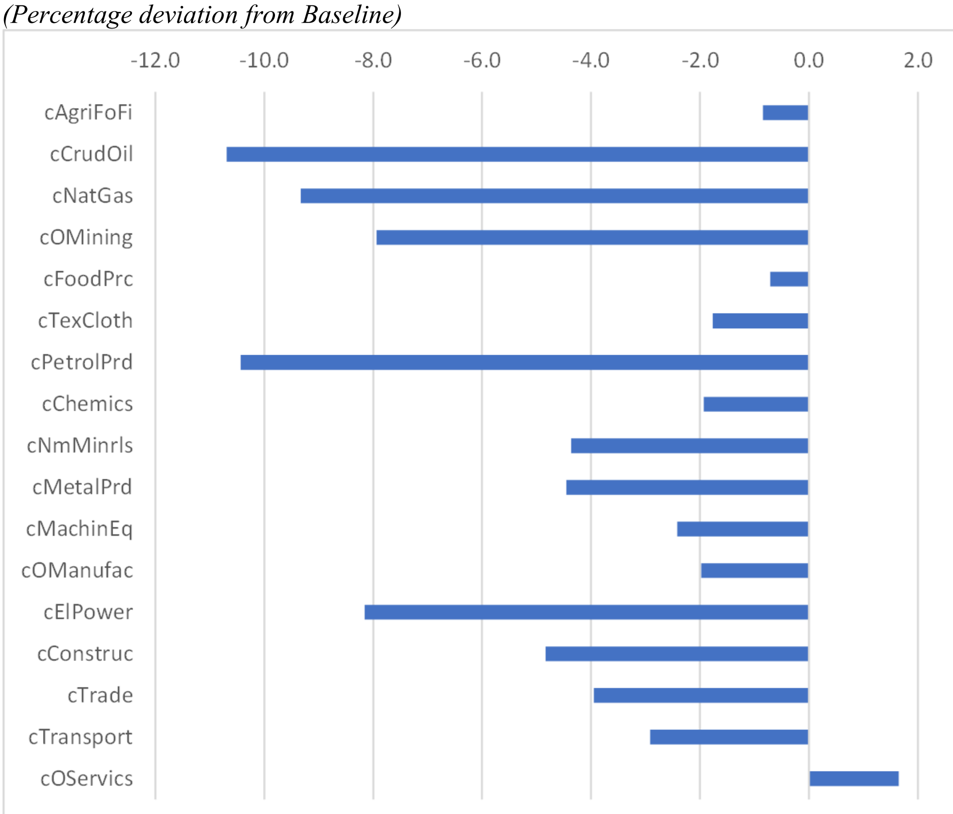


Figure 7. Impact on Steady-State Domestic Demand by Commodity Group – Recycling Scenario

(Percentage deviation from Baseline)

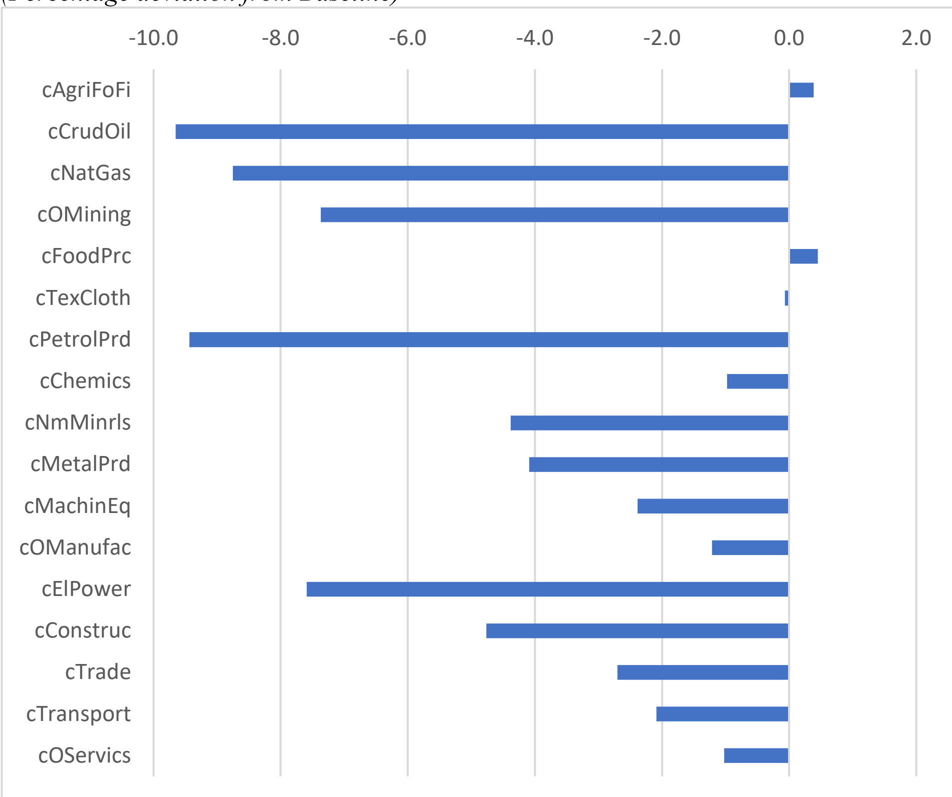


Figure 8. Impact on Steady-State Domestic Demand by Commodity Group – Indirect Tax Cut Scenario

(Percentage deviation from Baseline)

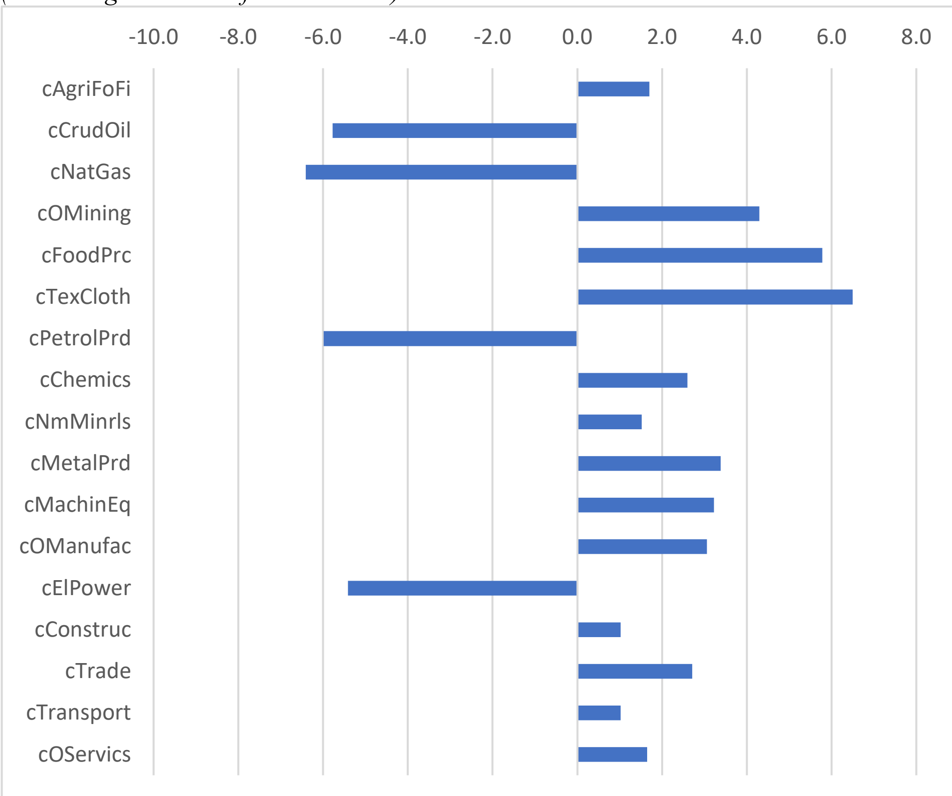


Figure 9. Impact on Steady-State Domestic Production by Sector – No-Recycling Scenario

(Percentage deviation from Baseline)

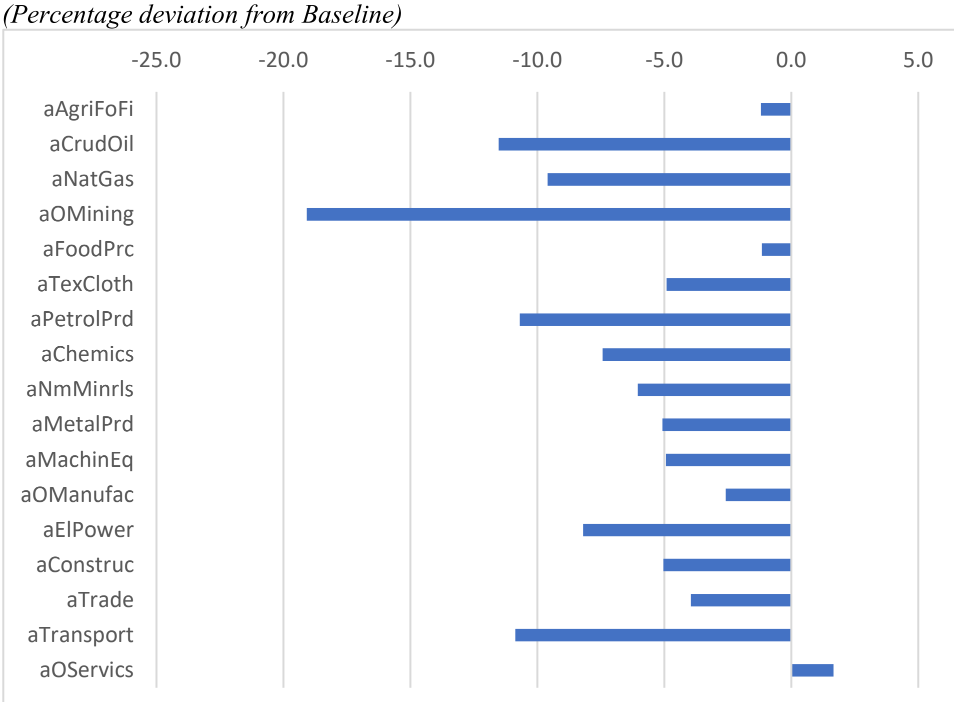


Figure 10. Impact on Steady-State Domestic Production by Sector – Recycling Scenario
(Percentage deviation from Baseline)

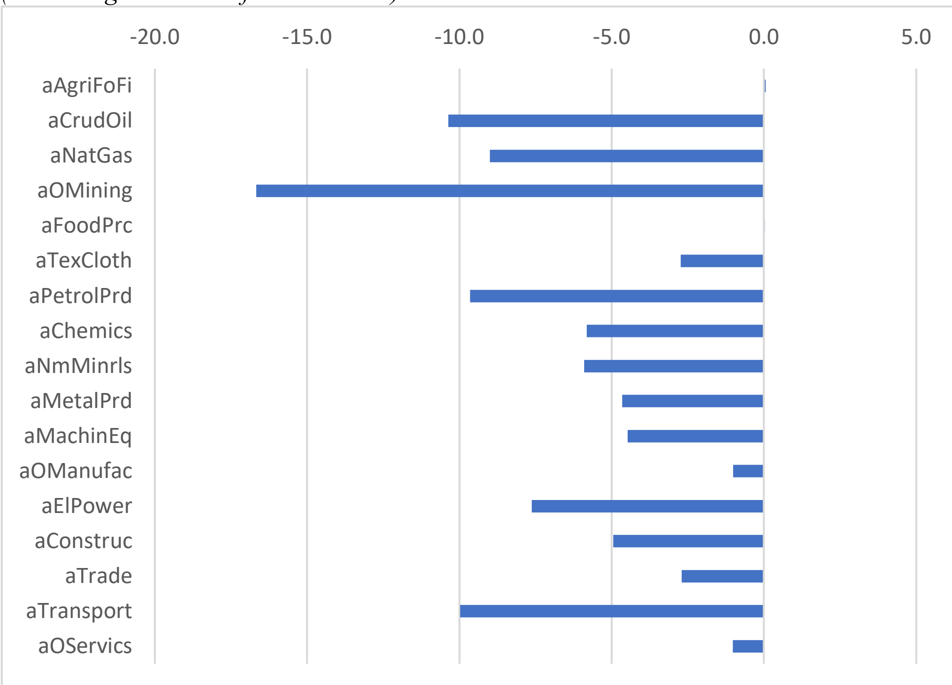
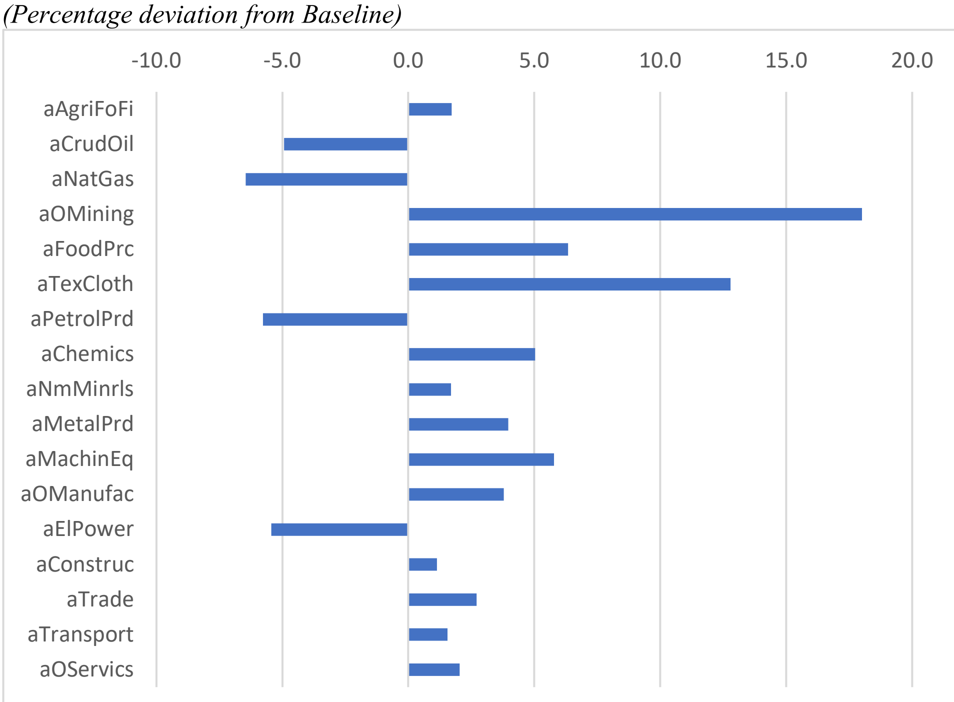


Figure 11. Impact on Steady-State Domestic Production by Sector – Tax Cut Scenario
(Percentage deviation from Baseline)



5.4 Distributional Impacts

The differential effects of the carbon tax on income by household type in real purchasing power terms depend (i) on the impact of the carbon tax on factor price relations, given that households in the lower income quintiles receive income primarily from low-skilled employment while the top income quintiles receive most of their income from high-skilled employment and capital, (ii) on the commodity composition of consumer demand by household type, and (iii) the allocation of the additional tax revenue.

Table 3 reports the long-run steady-state impacts of the carbon tax on the household-specific consumer price indices and the resulting impact on real income (i.e., nominal income after direct taxes and transfers deflated by the household-specific CPI). Under scenarios S1 and S2, urban households in the top income quintile (HUQ5) experience the strongest increase in their consumer price index, which indicates that these households have on balance a higher share of energy-intensive goods /services subject to strong price increases according to Figure 5(a) and (b) in their total consumption basket than all other household groups. However, the differences in the CPI effects across household groups are quite moderate. Within each group of households, the tax tends to be mildly progressive under S1 as real income of the richest quintile falls by slightly more than real income of the poorest quintile. Under S2 real income of all households falls by less compared to S1 as expected while under S3 real income increases for all households.

With the administratively simple lump-sum cash transfer mechanism for the recycling of the carbon tax revenue under S2 the differences in real income effects across income quintiles are moderate to insignificant and do not exhibit a clear-cut systematic regressive or progressive pattern. However, alternative tax revenue recycling mechanims that would generate distinctly progressive distributional outcomes are of course conceivable. For example, the entire carbon tax revenue could be reserved for a full compensation of the lower income quintiles via lump-sum transfers (so that the net real income effect becomes zero for the poorest households) while high-income households would receive no compensatory transfers.

Under scenario S3 the distributional impacts are again slightly progressive as the lowest quintile in each household group enjoys a higher percentage gain in real income than the top quintile. Due to the positive impacts on real investment in this scenario, the equilibrium returns to unskilled labour rise relative to the returns to capital, and low-income households also appear to benefit disproportionately from the net reduction in consumer prices due to indirect tax rate cuts on consumer goods, as indicated by the stronger CPI reductions for the bottom quintiles in Table 3.

Table 3. Impacts on Real Steady-State Income by Household Group

(Percentage deviation from Baseline percent)

	No-Recycling Scenario		Recycling Scenario		Indirect Tax Cut Scenario	
Household Class	**CPI by HH Class**	**Real Income**	**CPI by HH Class**	**Real Income**	**CPI by HH Class**	**Real Income**
Rural Farm						
HRFQ1	4.44	-2.16	3.89	-1.48	-1.76	1.31
HRFQ2	4.46	-2.20	3.88	-1.46	-1.78	1.34
HRFQ3	4.44	-2.13	3.84	-1.40	-1.80	1.23
HRFQ4	4.48	-2.17	3.86	-1.44	-1.72	1.18
HRFQ5	4.57	-2.17	3.89	-1.39	-1.64	1.07
Rural Non-Farm						
HRNFQ1	4.55	-2.84	3.95	-1.53	-1.86	0.88
HRNFQ2	4.42	-2.79	3.80	-1.34	-1.94	0.92
HRNFQ3	4.39	-2.81	3.76	-1.28	-1.95	0.94
HRNFQ4	4.41	-3.07	3.75	-1.49	-1.92	1.05
HRNFQ5	4.64	-3.35	3.94	-1.78	-1.60	0.86
Urban						
HUQ1	4.37	-2.76	3.76	-1.33	-2.00	1.00
HUQ2	4.33	-2.80	3.70	-1.24	-2.09	1.04
HUQ3	4.23	-2.71	3.59	-1.08	-2.17	1.08
HUQ4	4.26	-2.81	3.60	-1.10	-2.12	1.06
HUQ5	4.73	-3.12	3.98	-1.23	-1.56	0.54

Q1: Bottom income quintile, Q5: Top income quintile.

6. Conclusion

An appropriately designed carbon tax at a uniform rate per ton of CO_2 emissions that is aligned to the marginal external costs of these emissions internalizes the external costs into the market prices faced by producers and consumers, and thus generates incentives to shift towards less emission-intensive modes of production and consumption. The relative price changes induced by a carbon tax would in particular incentivize shifts in the power generation mix towards a lower share of fossil fuels and a higher share of renewables, the adoption of more energy-efficient technologies in industry and households, and shifts to more fuel-efficient modes of transportation.

Our simulation results suggest that a carbon tax at a rate of USD 20 / ton CO_2 could reduce Egypt's fossil-fuel-related GHG emissions by around 6 to 10% relative to the baseline path.

The effects on economic growth and household welfare depend crucially on the use of the carbon tax revenue. Our results indicate in particular the possibilty of a positive double-dividend effect – reduced emissions and a positive impact on economic growth – if the carbon tax revenue is used to finance a cut in distortionary product taxes.

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