THE WELFARE AND SPILLOVER EFFECTS OF INDUSTRIAL SUBSIDIES IN GENERAL EQUILIBRIUM

COUNTERFACTUAL EXPERIMENTS WITH A STANDARD QUANTITATIVE TRADE MODEL

ABSTRACT

In a partial equilibrium setting without externalities industrial subsidies promote manufacturing output in the subsidizing region but harm welfare, whereas spillover effects to welfare in other regions are positive. We employ a standard quantitative trade model with perfect competition to analyse the welfare and spillover effects of counterfactually raising industrial subsidies in a general equilibrium setting with multiple sectors and intermediate linkages. The analysis generates six main findings: (1) welfare falls in most regions raising industrial subsidies with variation in the effects depend on the size of the subsidy, the initial size of manufacturing in the economy and the global market share of the subsidized sector; (2) spillover effects of subsidies to other regions are positive for most regions and variation in the spillover effects can be explained by the strength of four effects, a competition effect, a downstream effect, an upstream demand effect, and an upstream competition effect; (3) Revenue neutrality of the subsidy, capital mobility, and the type of tax used to finance the subsidy have a large and intuitive impact on the welfare effects of subsidies. (4) Introducing subsidies in all regions together has a positive impact on most regions with the economic costs paid by a small set of regions (China, EU, Japan, Korea, India and SEA) who tend to have the highest initial share of output in manufacturing; (5) industrial subsidies by BRICS countries compared to OECD countries have a more positive impact on low-income regions because of larger demand for intermediate inputs. (6) More generally, in many countries the positive spillover effects are driven by upstream demand effects raising demand for natural resources. The analysis verifies that in the long run this might not be a welfare increasing strategy if there are positive externalities from specializing in sophisticated sectors.

1 INTRODUCTION

Industrial subsidies are back on the agenda of many governments. Such subsidies come with cross-border spillover effects, a reason for potential trade tensions. Traditionally, economists argue that subsidies harm the country imposing them by introducing distortions to the allocation of resources and driving down the price of its exports thus generating terms of trade losses and benefits other countries through lower costs for consumers and firms purchasing intermediate inputs. Subsidies are argued to boost domestic firms` sales in the subsidized sector and reduce sales in other countries. Furthermore, it also results in gains for consumers and downstream firms in other countries which typically surpass the loss of producers, resulting in a net gain in welfare of other countries.

However, in a general equilibrium setting with real-world data the impact of subsidies might not follow theory. The objective of this paper is to provide economic context and explore the welfare and spillover effects of subsidies employing counterfactual policy experiments in a standard general equilibrium setting, considering the various mechanisms through which subsidies affect other countries through trade spillovers.

For the time being, quantitative work on the economic effects of industrial subsidies is hampered by the lack of systematic data on such subsidies. However, quantitative work based on stylized scenarios can still provide many valuable insights about the mechanisms driving both the welfare effects for the subsidy-providing region and the spillover effects to foreign consumers, producers, and industrial structure.

We employ the WTO Global Trade Model, a standard computable general equilibrium model very similar to standard new quantitative trade models. The analysis confirms the hypothesis that subsidies adversely affect welfare in most subsidy-providing regions and promotes welfare in most other regions. However, the effects are heterogeneous and depend on model settings and the

strength of various channels. Also, in a standard model with perfect competition subsidies do not always adversely affect subsidizing regions and promote welfare in other non-subsidizing regions.

More into detail the analysis with the standard CGE model generates six main findings.

1. In a standard general equilibrium setting welfare effects of raising industrial subsidies are negative for most regions. Variation in the welfare effects depend on the size of the subsidy with effects more likely to be negative for larger subsidies due to rising distortions, the initial size of manufacturing in an economy with the fiscal costs of industrial subsidies rising of the size of the manufacturing sector is bigger, as well as the global market share of the subsidized sector which affects a region`s impact on its terms of trade with a larger market share making it more likely that subsidies drive export prices down and thus deteriorate a country's terms of trade.
2. In l our model with a perfectly competitive market, spillover effects of subsidies to other regions are mostly positive. The simulations show that variation in the spillover effects can largely be explained by the strength of four effects, a competition effect, a downstream effect, an upstream demand effect, and an upstream competition effect. The competition effect tends to be negative depends on the degree to which a region exports similar goods to the subsidizing region and thus suffers from enhanced competition from the subsidizing region. The downstream effect is positive and reflects the price reducing effect of sectors and final consumers buying subsidized goods. The upstream demand effect is positive and reflects the increased demand for intermediates from the subsidized sector and the upstream competition effect is negative reflecting the increased competition for intermediates also demanded by the subsidizing sector.
3. Revenue neutrality of the subsidy, capital mobility, and the type of tax used to finance the subsidy have a large and intuitive impact on the welfare effects of subsidies. As expected, without revenue neutrality and with less distortionary taxes employed to finance the industrial subsidies, subsidizing and other regions are more likely to gain from the subsidies. However, revenue neutrality is necessary to build a proper counterfactual experiment considering all GE effects of industrial subsidies. Including capital mobility makes it more likely that the impact is positive with subsidizing regions attracting more inward investment and thus expanding the production capacity. Hence, effects are more likely to be positive in the long run due to (partial) factor mobility between regions, a finding in line with the work by Ossa et al. (2023) on subsidies competition between American states.
4. Introducing subsidies in all regions together has a positive impact on most regions with the economic costs paid by a small set of regions (China, EU, Japan, Korea, India and SEA) who tend to have the highest initial share of output in manufacturing and where the costs of a same percentage subsidy is thus much higher compared to other regions with a relatively smaller manufacturing sector. Nevertheless, some regions (in particular India) would lose more if they would not introduce industrial subsidies together with the other regions. This suggests that also the regions losing with global subsidies have an interest to continue subsidizing and sets the stage for a discussion on when a subsidy war becomes unavoidable later.
5. Introducing subsidies in a subset of regions or at different moments in time has unexpected effects: industrial subsidies by BRICS countries compared to OECD countries have a more positive impact on low-income regions because of larger demand for intermediate inputs.
6. In many countries seeing their welfare increase with the global introduction of subsidies, the welfare increases are driven by upstream demand effects generating more demand for natural resources. In the long run this might not be a welfare increasing strategy if there are positive externalities from specializing in sophisticated sectors. Hausman et al. (2007) argue that specialization of exports in sophisticated sectors by high-income countries is what helps them remain rich and prevents low-income countries from catching up. Global industrial subsidies might raise the dependence on exports of raw materials by some low-income countries and thus harm long-run growth perspectives. In line with these arguments considering positive externalities of specializing in sophisticated sectors in the simulations, the gains for natural resource dependent regions become smaller and turn into losses for some regionsOpening up trade can push countries to specialize in their respective sophisticated sectors, if it is one where foreign competition is minimum. However, empirically, the complex sectors have high foreign competition, leading to trade becoming a zero-sum game and making subsidies costlier for regions that are unable to develop this comparative advantage (Atkin et.al. 2021).

This paper makes a contribution to the literature on the economic effects of industrial subsidies. Standard economic reasoning indicates that introducing subsidies harms the welfare of the subsidizing region by driving a wedge between consumer and producer prices which leads to deadweight losses and by adversely affecting a country's terms of trade since subsidies raise a country's exports supply and thus drives down its price. At the same time, the subsidy tends to promote welfare in other countries since they benefit from terms of trade increases. . However, this traditional conclusion holds for perfectly competitive market with no information asymmetry or externalities like learning by doing or increasing returns to scale. Theoretically, in markets with imperfect competition government can select sectors with scale effects and other positive externalities such that subsidies can offset market imperfections and raise economic welfare, keeping in mind that the scope for such interventions or the ability of governments to select such "winners" might be limited (Ford and Suyker, 1990; Agarwal 2023).

Furthermore, subsidies or interventionist industrial policies can be linked to political motives (Blais, 1986). However, in this paper we restrict our focus on the economic arguments for and against subsidies.

Turning from domestic industrial subsidies to export subsidies, there is an extensive trade literature, arguing that trade policy intervention can raise welfare in specific situations. Arguments for and against this theory range from interventions focused on capturing monopoly profits in imperfectly competitive world markets to capturing production externalities by providing a boost to sophisticated high growth sectors, or sectors with high learning rates. But all such arguments also come with counterarguments and a lack of clarity when it comes to their impact on welfare, making it difficult to draw a single conclusion (Baldwin, 1991; Krugman, 1987).

This paper makes three main contributions to the literature. First, we validate the traditional hypotheses on the welfare and spillover effects of subsidies in general equilibrium with multiple sectors and perfect competition.. We show that even with perfectly competitive markets, subsidies may lead to welfare increases in the subsidizing region. Second, we provide a deep dive into the mode of operation of subsidies in a general equilibrium environment identifying the various channels through which they impact the subsidizing as well as the non-subsidizing regions. These insights will aid policymakers in making more informed decisions and help in identifying a framework to measure spillover effects. Third, we identify a set of model assumptions with a decisive impact on the welfare and spillover effects of subsidies, more specifically assumptions on the trade balance, capital mobility, and revenue neutrality.

We were unable to find literature with such an in-depth discussion of how subsidies impact real income or economic welfare of a region in a general equilibrium setting. In this manner, our paper is novel in presenting such results and adds insight to the ongoing debate in the literature regarding the verity of the traditional argument against industrial subsidies and the new found support in its favour.

The paper is organised as follows. Section 2 introduces the methodology by describing the economic model and the way industrial subsidies are introduced in the analysis. Section 3 focuses on unilateral subsidies, Section 4 on multilateral subsidies, and Section 5 on the role of closures. Section 6 concludes.

2 METHODOLOGY

2.1 Economic model

We employ the WTO Global Trade Model (GTM), a recursive dynamic computable general equilibrium (CGE) model featuring perfect competition and trade handled through Armington preferences (Aguiar et al, 2019). The model is calibrated to the GTAP Data Base, Version 10 (2014).

The GTM features multiple sectors and factors of production (skilled labor, unskilled labor, capital, land, and natural resources), intermediate linkages, a representative agent demanding three types of goods (savings, private household demand, and government demand). This structure implies four types of demand in the model (private household demand, government demand, investment demand, and intermediate demand by firms). Furthermore, the model incorporates non-homothetic preferences for private households, and a global transport sector. Factor income and tax revenues are collected by a representative agent that in turn distributes total income into three spending categories, namely: private consumption, government consumption, and savings. In each region,

perfectly competitive firms choose the optimal mix of factor inputs and intermediate inputs by maximizing profits.

The GTM assumes perfect mobility of labour, which means that arbitrage equalizes the cost of labour across all sectors. Hence, when output rises in some sectors, but falls in others in a particular region, it is expected that labour from the latter would move to the former. If more sectors face a fall in output (e.g., due to higher import competition than a rise due to export opportunities), in a particular region, then factor demand would fall and lead to a fall in wages.

The GTM features recursive dynamics, with the capital stock in the current period being a function of net investment and the capital stock in the previous period. National investment is determined by global savings with the latter derived as the sum of all national savings. National savings are a fixed share of household income and are collected by a global trust which then allocates global savings to investment in each of the regions in the model with investment flowing to regions with rising rates of return. The model allows for isoelastic factor supply of land and natural resources.

The trade structure is standard with Armington preferences. In equilibrium all markets clear: goods market, factor market, transport services market, and global savings market. We calibrate the model to the GTAP Data Base, Version 11, with 2017 as reference year. Except when otherwise indicated comparative static results for the reference year are reported. We aggregate the data into 24 sectors and 24 regions and five factors of production. In case recursive dynamic results are reported, first a baseline is constructed targeting real income, GDP, population, and labour force growth rates and changes in savings rates based on the IMF World Economic Outlook and the OECD Shared Socioeconomic Pathways (SSPs).

2.2 Set-up of counterfactual experiments

In the counterfactual experiments a 10 percent ad valorem output subsidy is introduced in all manufacturing sectors. To make the introduction of the subsidy tax revenue neutral, thus taking into account the fiscal costs of subsidies, the ratio of net tax revenues (taxes minus subsidies) to GDP is kept unchanged by raising taxes levied on the employment of primary factors in all sectors of the economy. Labour supply is characterized by an upward sloping supply curve to account for the distortions related to raising tax revenues. Except when otherwise indicated the trade balance to income ratio is assumed to be fixed.

Three sets of simulations are conducted. First, a unilateral industrial subsidy is introduced in one of the economies, analysing the production, welfare, and spillover effects. Second, an industrial subsidy is introduced in a group of countries, at different moments in time, and of different sizes. Third, the impact of model setting choices such as closures and parameters is explored.

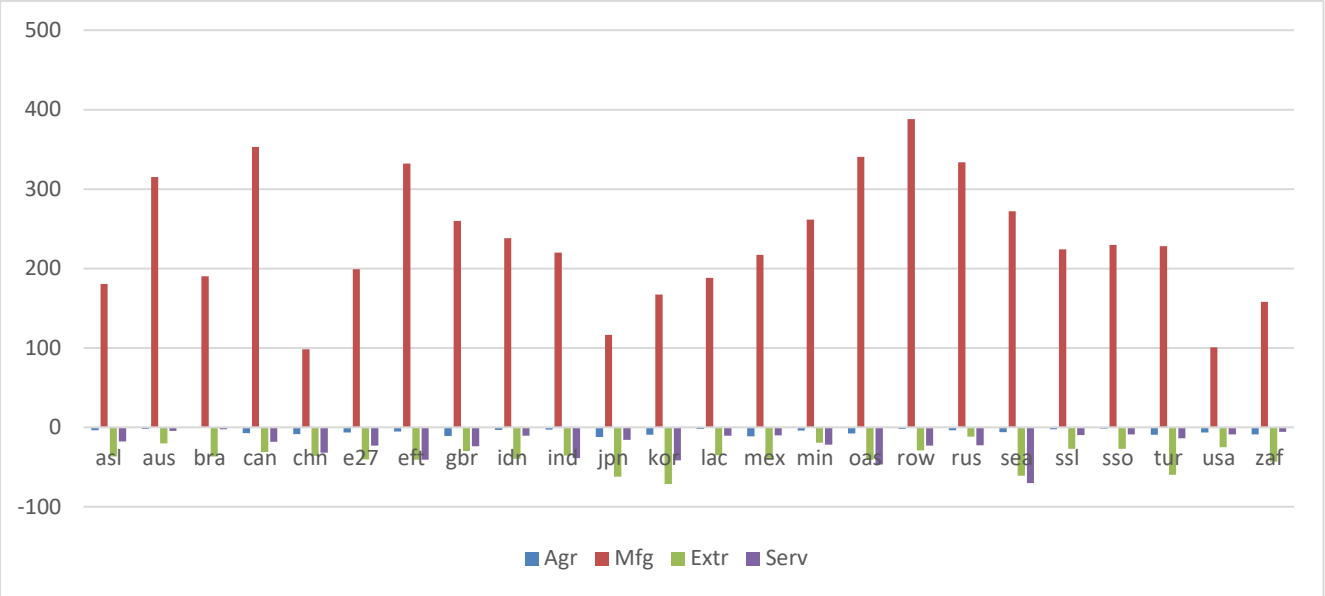
3 UNILATERAL SUBSIDIES

In this section we analye in turn the production effects of unilateral subsidies (3.1), the welfare effects of unilateral subsidies (3.2) and the spillover effects (3.3).

3.1 Simulations confirm the production promoting effect on the sector providing subsidies

Figure 1 shows the simulated gross output effects for four aggregate sectors: agriculture, extraction, manufactures, and services. The subsidizing countries are projected to raise their manufacturing output and reduce it in other sectors. As resources leave manufacturing and find employment in the rest of the economy, the composition of the economy changes significantly which may affect exports, imports, their relative prices, and also the terms of trade.

Figure 1. Simulated gross output effects for broad sectors from unilateral abolishment of manufacturing output subsidies, percent change

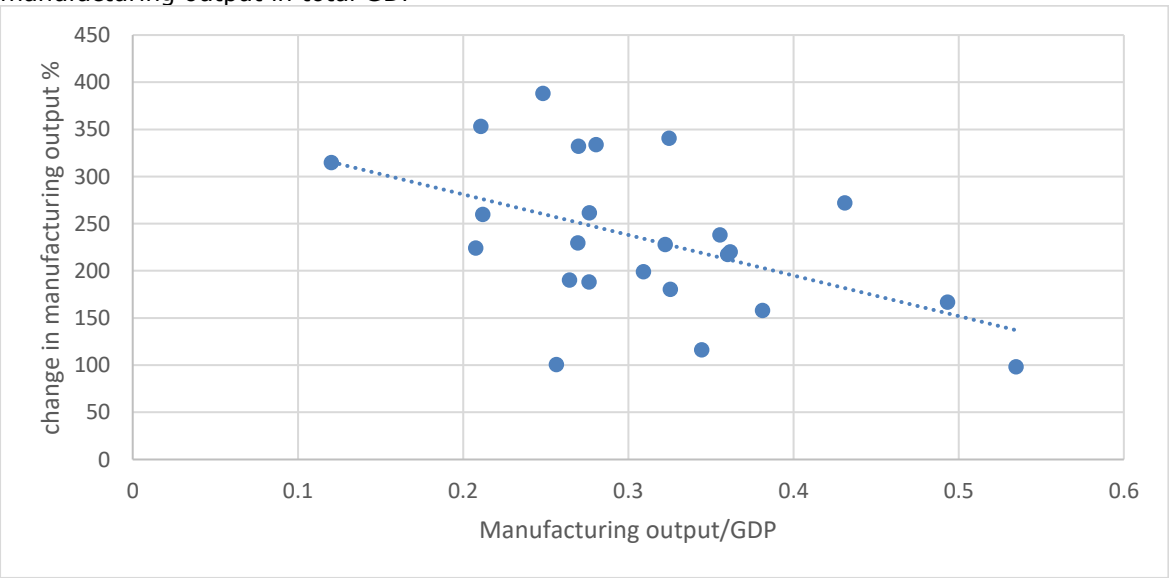


Source: Author`s calculations based on simulation results; Simulation details – results reported for 24 different simulation with unilateral subsidies in each region. Results are reported for subsidizing region only; Note: Agr refers to Agriculture; Mfg refers to manufacturing; Extr refers to extraction or natural resource sectors and Serv refers to services sectors

Since we introduce an output subsidy of 10% in all manufacturing sectors unilaterally in each of the 24 regions, the size of the subsidy would vary from region to region depending on the initial size of manufacturing in each of these regions. Figure 2 shows the relationship between the changes in manufacturing output and the initial share of manufacturing in total GDP and we see a weak negative relationship between the two, with a correlation of -0.5. This shows that regions with a higher initial size of manufacturing experience a lower increase in its output with an introduction of a 10% output subsidy in this sector. In these regions, increasing output by 1% is more expensive than other regions because in terms of factors, the manufacturing sector in these regions already employed the largest share. To shift more resources towards manufacturing would be costlier for them compared to a region with a small initial manufacturing sector.

ADD

Figure 2: Showing changes in manufacturing output, in percent terms against the share of initial manufacturing output in total GDP



Source: Author`s calculations based on simulation results; Simulation details – results reported for 24 different simulation with unilateral subsidies in each region. Results are reported for subsidizing

region only; Note: Agr refers to Agriculture; Mfg refers to manufacturing; Extr refers to extraction or natural resource sectors and Serv refers to services sectors

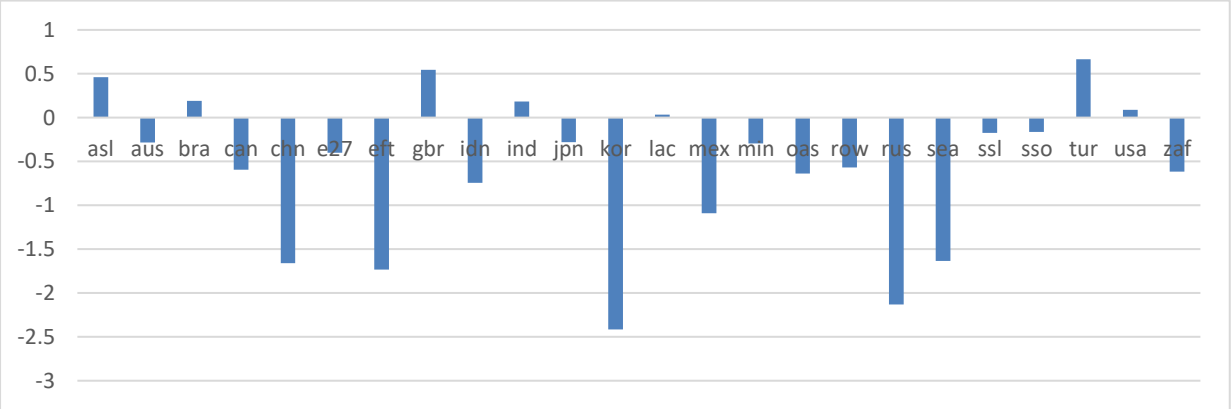
The standard effects of imposing a subsidy on production are thus, confirmed by the results of simulations where each of the 24 regions introduce the subsidy unilaterally. Subsidies can be used by regions to expand the sectors that are relatively small within their economies.

3.2 But the welfare effects of industrial subsidies in a standard trade model are complex: impact of subsidy on subsidy providing region

The impact on the real income in the region introducing subsidies is analysed in this section. Real income is defined as factor income plus tax revenues divided by the aggregate price index. Real income effects can be split into allocative efficiency effects, which measure the economic impact of distortionary taxes and subsidies on the allocation of resources in production, consumption, and trade patterns; and terms of trade effects defined as an economy's export price relative to its import price.

Figure 3 shows that the real income effects are negative for most regions, because of additional distortions of introducing subsidies. Only ASL, Brazil, GBR, India, Turkey and USA are projected to see their real income rise when imposing the subsidy and Latin America (LAC) sees negligible change. Among these, India and Turkey seem to experience improvements in allocative efficiency after introducing this subsidy, which in turn, helps improve their real income. GBR and USA on the other hand, have a positive terms of trade gains which allow them to improve their real income and GDP effects.

Figure 3. Simulated real income effects from unilateral introduction of a 10% output subsidy in the manufacturing sector, percent change



Source: Author`s calculations based on simulation results; Simulation details – results reported for 24 different simulation with unilateral subsidies in each region. Results are reported for subsidizing region only

If an economy would not have any other taxes and subsidies than those introduced, implying there would be no initial distortions, allocative efficiency would fall. However, if there are initial distortions in the economy, there are also efficiency effects of pre-existing taxes and subsidies. These additional efficiency effects may either augment, diminish, or even eliminate the efficiency gains obtained from the imposition of manufacturing subsidies. The simulated efficiency effects shown in Table 1 suggest that for all economies the efficiency effects from introducing the subsidies are negative, whereas for two regions (India and Turkey), the efficiency effects are projected to be positive as shown in Table 1.[3] Introducing manufacturing subsidies hires resources away from non-manufacturing sectors such as agriculture. If there are large initial distortions in those sectors, the welfare losses in the manufacturing sector can be dominated by rising efficiency gains in those sectors. This improvement in efficiency due to reduction in distortion accounts for the positive real income changes in these two regions.

[3] The allocative efficiency and terms of trade effects are only two components determining total real income effects in Figure 2 and Table 1. Total real income effects are also a function of changes in endowments

Table 1. Simulated welfare effects from unilateral abolishment of manufacturing output subsidies, percent change

REG	% changes in Real Income	% changes in TOT effects	Value changes in Allocative Efficiency	Value changes in TOT
asl	0.5	-0.1	-725.6	-96.8
aus	-0.3	-0.1	-3278.0	-1415.2
bra	0.2	-0.4	-574.0	-1295.2
can	-0.6	-1.3	-7415.8	-7201.3
chn	-1.7	-2.9	-33074.0	-56013.1
e27	-0.4	-0.3	-39113.3	13985.5
eft	-1.7	-0.6	-11565.1	-3677.2
gbr	0.5	0.7	-3018.1	4220.2
idn	-0.7	-1.3	-3128.1	-2826.0
ind	0.2	-0.1	2187.6	-142.1
jpn	-0.3	-0.8	-5470.0	-1981.7
kor	-2.4	-1.3	-14162.8	-7857.6
lac	0.0	0.4	-5844.2	1628.8
mex	-1.1	-2.3	-5625.0	-9490.3
min	-0.3	1.7	-18620.0	5541.2
oas	-0.6	0.7	-11988.9	4844.7
row	-0.6	-0.7	-3022.4	-2203.0
rus	-2.1	0.0	-37819.8	2252.8
sea	-1.6	-0.2	-17678.9	-856.9
ssl	-0.2	0.5	-1677.3	484.6
sso	-0.2	0.5	-2597.8	543.5
tur	0.7	0.1	979.6	296.5
usa	0.1	0.7	-27654.3	12312.3
zaf	-0.6	-0.7	-809.9	-865.4

Source: Author`s calculations based on simulation results; Simulation details – results reported for 24 different simulation with unilateral subsidies in each region. Results are reported for subsidizing region only;

For most economies the terms of trade effects augment the allocative efficiency effects resulting in significant real income losses (e.g., China) or gains (e.g., Great Britain). However, in some cases, such as the United States and United Kingdom, strong positive terms of trade effects diminish the allocative efficiency losses and result in an improvement in real income.

The terms of trade are defined as the price of exports relative to imports and an increase in terms of trade raises welfare, because a country can import a larger value of goods for the same value of exports. Introducing manufacturing subsidies raises export supply and thus reduces export prices deteriorating the terms of trade. Hence, in principle introducing manufacturing subsidies should decrease the terms of trade. However, there are also general equilibrium effects in the model. Introducing manufacturing subsidies leads to rising manufacturing production and input demands. This raises the production costs in the entire economy and thus makes exports more expensive in the non-manufacturing sectors such as services and agriculture, thus generating an overall terms of trade gain. Table 2 decomposes terms of trade effects of the regions introducing a subsidy by the four aggregate sectors, showing that positive overall terms of trade effects are driven by positive terms of trade effects in other sectors than manufacturing. For example, in the USA the terms of trade gains in the services sectors tend to dominate the terms of trade losses in manufacturing.

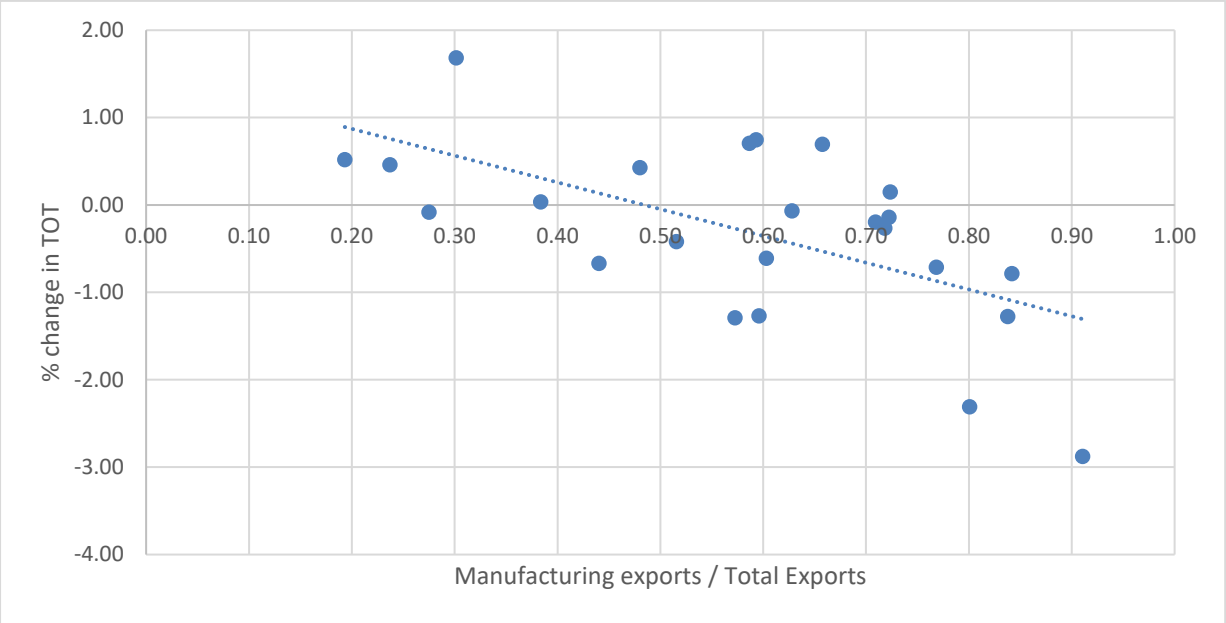
Table 2. Decomposition of terms of trade effects by four groups of products, million USD

Region	Agriculture	Manufacturing	Extraction	Services
Asia, Low Income	*421.2*	-1737.3	332.1	887.1
Australia	*817.1*	-7539.9	2682.1	2625.5
Brazil	*2052.4*	-8318.0	1753.5	3216.8
Canada	*1236.1*	-18864.2	3812.9	6613.9
China	*-7802.0*	-71492.0	-6702.1	29983.0
EU-27	*4626.1*	-90727.4	-1894.5	101981.3
EFTA	*339.2*	-18222.3	2011.6	12194.4
UK	*329.4*	-19937.1	427.9	23400.0
Indonesia	*359.7*	-6493.3	2015.9	1291.7
India	*2215.3*	-27286.2	311.7	24617.1
Japan	*2995.3*	-22370.0	-559.4	17952.5
Korea	*216.5*	-20380.5	-755.8	13062.3
Rest of Americas	*2433.4*	-12058.6	3737.8	7516.1
Mexico	*787.0*	-14344.6	1982.2	2085.0
MENA	*199.4*	-16018.9	12591.7	8769.0
Other Asia	*697.2*	-21584.5	804.0	24927.9
Rest of the world	*836.9*	-8812.0	2352.1	3420.0
Russia	*-296.9*	9828.8	-5473.1	-1806.1
Saudi Arabia	*1300.0*	-32446.7	1750.4	28539.4
South-East Asia	*682.9*	-2605.6	1393.3	1014.0
SSA, Low Income	*700.1*	-2395.8	1505.1	734.2
Other SSA	*594.5*	-4558.7	131.4	4129.4
Turkey	*4038.6*	-43019.1	808.4	50484.3
USA	*332.2*	-2819.1	512.0	1109.5

Source: Author`s calculations based on simulation results; Simulation details – results reported for 24 different simulation with unilateral subsidies in each region. Results are reported for subsidizing region only;

The general pattern is that in regions with a large share of exports in manufactures, raising manufacturing subsidies will decrease welfare through a terms of trade gain loss, whereas in regions with a large share of exports in services, agriculture and extraction, the terms of trade gains through general equilibrium effects tend to dominate (Figure 4).

Figure 4. Scatter plot of terms of trade effects against the share of manufacturing exports in total exports



Source: Author`s calculations based on simulation results; Simulation details – results reported for 24 different simulation with unilateral subsidies in each region. Results are reported for subsidizing region only

3.3 The spillover effects are also complex: impact of industrial subsidies on other regions

This section explores the spillover effects of introducing manufacturing subsidies by evaluating the impact on real income, and sectoral production in other regions. This analysis portrays a mixed picture. On the one hand, other regions tend to benefit from manufacturing subsidies in a particular region at the aggregate level generating real income gains in other regions. On the other hand, manufacturing production in other regions is adversely affected by subsidies. Starting with the last point, Table 3 shows that production in manufacturing sectors tends to fall in other regions when a specific region introduces manufacturing subsidies, whereas production in other sectors tends to rise. We illustrate these sectoral production effects in other regions for two regions abolishing subsidies, the USA and China.

Table 3 Simulated changes in sectoral production in other regions from unilateral abolishment of manufacturing output subsidies in China and the USA, percent change

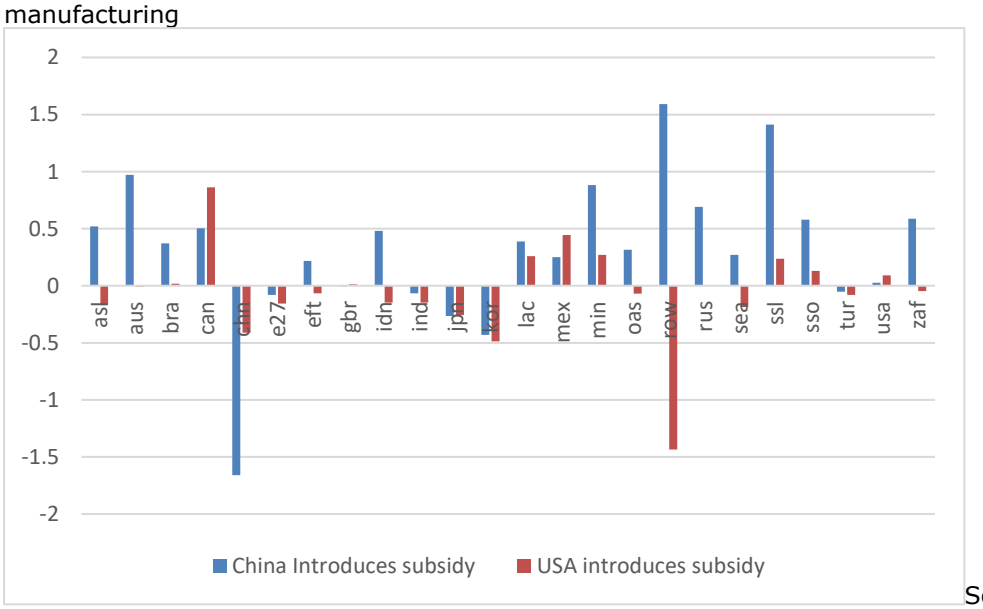
	China			USA		
Country/region	**Agriculture**	**Manufactures**	**Services**	**Agriculture**	**Manufactures**	**Services**
Asia, Low Income	-0.63	3.03	-0.12	-0.15	0.68	-0.07
Australia	-0.81	9.54	-0.43	-1.87	2.48	-0.27
Brazil	-1.93	3.10	-0.31	-0.92	1.18	-0.15
Canada	-2.68	4.07	-0.41	-1.61	7.06	-0.83
China	6.26	-10.42	4.55	-0.69	0.48	-0.03
EU-27	-3.05	3.61	-0.63	-1.40	2.60	-0.50
EFTA	-0.89	4.36	-0.63	-0.07	3.00	-0.56
UK	-2.66	3.36	-0.43	-0.77	3.96	-0.57
Indonesia	-0.55	3.01	-0.22	-0.38	0.87	-0.06
India	-0.45	2.18	-0.18	-0.23	1.44	-0.23
Japan	-3.59	1.53	-0.27	-3.48	0.74	-0.09
Korea	-1.83	1.75	-0.55	-1.49	1.05	-0.29
Rest of Americas	-1.10	3.43	-0.44	-0.89	2.31	-0.34
Mexico	-1.41	2.23	-0.47	-3.02	2.86	-0.64

MENA	-0.79	4.81	-0.67	-0.49	2.40	-0.53
Other Asia	-1.14	7.09	-1.29	-0.68	3.82	-0.74
Rest of the world	-0.73	5.32	-0.41	-0.31	2.21	-0.33
Russia	-1.14	4.03	-0.48	-0.46	1.35	-0.20
Saudi Arabia	-1.00	3.63	-0.59	-0.29	2.72	-0.38
South-East Asia	-1.74	4.44	-1.10	-0.66	2.46	-0.72
SSA, Low Income	-0.89	3.99	-0.01	-0.37	1.51	-0.13
Other SSA	-0.43	3.65	-0.27	-0.20	1.91	-0.34
Turkey	-1.65	2.70	-0.33	-1.02	1.18	-0.19
USA	-1.98	1.89	-0.25	4.63	-12.98	2.01
South Africa	-2.15	3.67	-0.44	-1.70	1.33	-0.26

Source: Author`s calculations based on simulation results; Simulation details – results reported for 2 different simulation with unilateral subsidies in China and USA as highlighted in the top row;

Turning to the aggregate spillover effects, Figure 5 displays the changes in real income when respectively the USA and China would introduce the hypothetical subsidies of 10% in manufacturing[4]. Real income is projected to rise in most regions in response to the introduction of manufacturing subsidies in case of China. But same is not true for when USA introduces the subsidy. Hence, the spillover effects vary from region to region depending on their relationship with the subsidizing region.

Figure 5. Projected changes in real income when China and the USA would introduce a 10% manufacturing subsidy



Source: Author`s calculations based on simulation results; Simulation details – results reported for 2 different simulation with unilateral subsidies in China and USA as indicated.

Interestingly, while most regions seem to gain when China introduces a subsidy, more regions seem to lose when USA introduces the subsidy. Similar variance in results is observed for the unilateral introduction of subsidies by the remaining 22 regions.

[4] This experiment follows the previously described environment with revenue neutrality maintained by allowing for taxes on factor income to rise; it also assumed a fixed trade balance and global savings rate

3.4 The spillover effects are transmitted by four main channels

Our analysis revealed the presence of four key channels through which the effects of subsidies in one region are transmitted to other regions: (i) a downstream effect through which non-subsidizing regions benefit from lower prices because of subsidies in another region; (ii) a demand upstream effect positively affecting regions selling intermediate inputs to the subsidizing region; (iii) a competition upstream effect through which other regions purchasing the same intermediates as the subsidizing region are negatively affected by higher prices of intermediates; (iv) a competition effect through which countries selling the same goods as the subsidizing region are adversely affected by more intense competition. The amalgamation of these channels results in the overall welfare change.

Figure 5a reports the changes in real income for the policy experiment we focus on. We see that real income rises in all regions except China, Korea and Japan, while the change is negligible in EU, Great Britain, India, Turkey and USA.

A manufacturing subsidy, first and foremost raises the manufacturing production for the subsidizing region and this leads to different GE effects depending on the forward and backward linkages of the subsidized sector. The forward linkages result in a reduction in prices for regions buying from the subsidized sector, leading to a positive spillover effect. We shall refer to this as the downstream effects. The backward linkages manifest itself in two types of effects, the primary being positive and the secondary negative. At the first or primary stage, the backward linkage allows for expansion of sectors supplying inputs to the subsidized sector and thus, has a positive spillover effect in regions housing such sectors. However, at a secondary stage, it also results in an increase in prices through its own forward linkages to non-subsidizing regions purchasing inputs from them, thus, leading to a negative spillover effect. We refer to these as primary and secondary upstream effects[5]. Last but not least, we have a change in competitiveness of regions in the subsidized sector in the world market. While the subsidizing region enjoys a boost in competitiveness, the non-subsidizing regions face a loss. This negative spillover effect is referred to as competition effects.

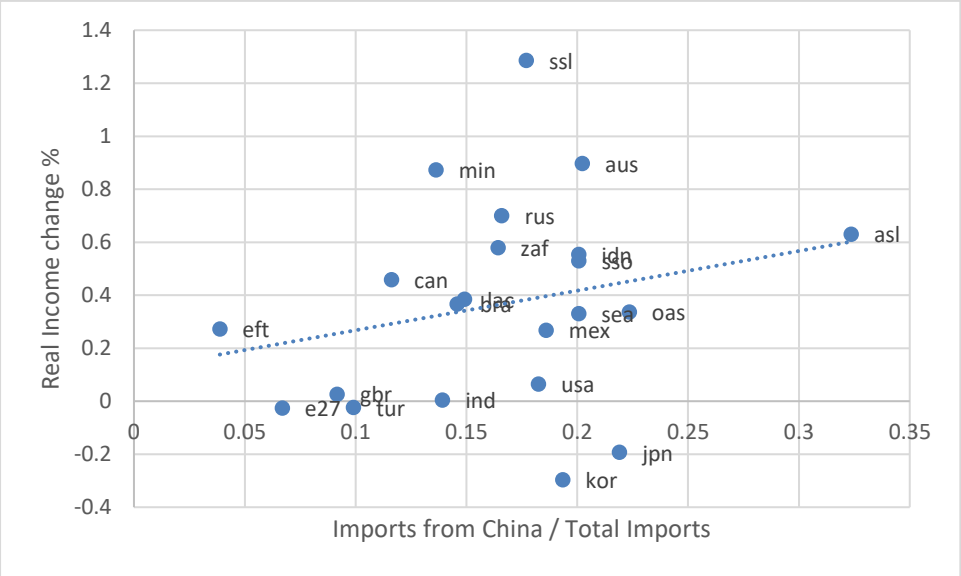
These are the four key channels which we proceed to discuss in further details by focusing on the results of one policy experiment alone – China introducing a 10% output subsidy in Manufacturing sectors. Later we analyse the importance of these four channels for the spillover effects from industrial subsidies in all regions.

3.4.1 Downstream effects result in positive spillover effects

The immediate impact of China introducing a 10% output subsidy in its manufacturing sectors, is a reduction in the output prices of these products, resulting in a reduction in export prices of manufacturing products from China. Regions importing from the manufacturing sector of China would gain from this reduction in prices. Figure 6 shows a positive relationship between the share of imports from China in non-subsidizing regions, relative to their total imports and the change in real income. This shows that regions with a higher initial share of imports from China`s manufacturing sector gain more in terms of real income after China introduces a subsidy in that sector.

Figure 6: Relationship between changes in real income and share of imports from China in total imports

[5] Please note, that we choose to stop our inclusion of linkage effects at this point. Even though there can be further backward and forward linkage changes of the discussed transmissions. This is because with each transmission, the strength of the effect weakens and beyond this level, inclusion of further linkage effects will not lead to any incremental explanations.



Source: Authors calculations based on simulation results; Note: This graph does not include China as it reports the spillover effects on non-subsidizing regions, it also doesn't report row(rest of the world) Please refer to appendix for abbreviation of regions

His forward linkage effect is what dominates the theory put forward by traditional literature according to which, a subsidy will lead to largely positive spillover effects alone. Here we see that this relationship is not very strong. Some regions gain much more than their share of imports should imply, while other regions like Japan and Korea, lose real income even though they import a fairly high share from China. This lead us to believe that there are other channels through which general equilibrium effects operate, resulting in unexpected spillover effects.

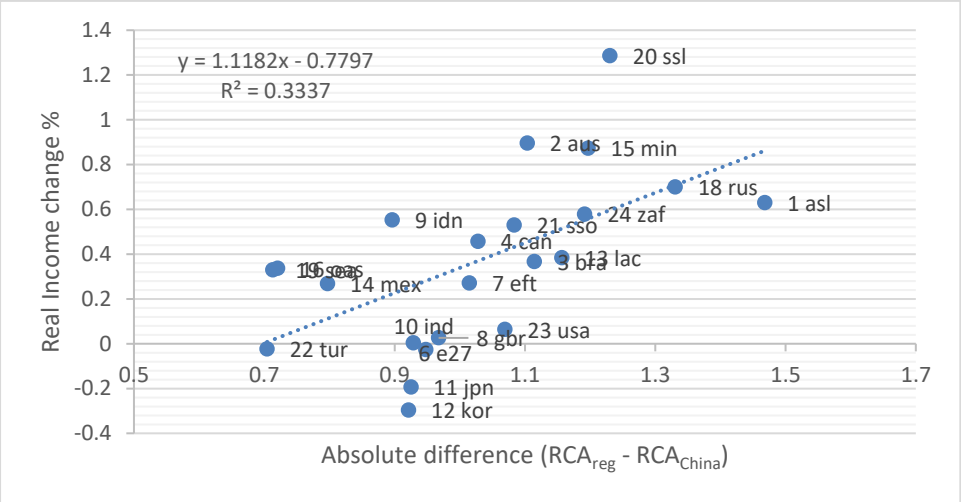
3.4.2 Competition effects result in a negative pressure on real income as it makes exports of the non-subsidizing regions, less competitive in the world market

A reduction in export prices of manufacturing sector from China, improves China`s competitiveness in the world market. However, in terms of spillover effects, it leads to a reduction in real income of non-subsidizing regions competing with China in the world manufacturing market.

To identify the existence of this channel, we first develop a metric to identify the degree of competitiveness between China and the non-subsidizing region in question. In order to do this, we calculate the absolute difference between the value of relative comparative advantage in exports for a region and that of China. Regions with a highly different comparative advantage in manufacturing sectors from China, would have the least loss in competitiveness and would hence face the least reduction in welfare.

Figure 7 shows the relationship between our measure of competition and real income changes and establishes the existence of this channel. Regions where the measures absolute difference in large, i.e. regions that don`t compete with China in the world market for manufacturing sales have a higher increase in real income than regions with a relatively similar comparative advantage as China in manufacturing.

Figure 7: Relationship between changes in real income and absolute difference between RCA in manufacturing sectors of each region with China`s RCA in manufacturing sectors



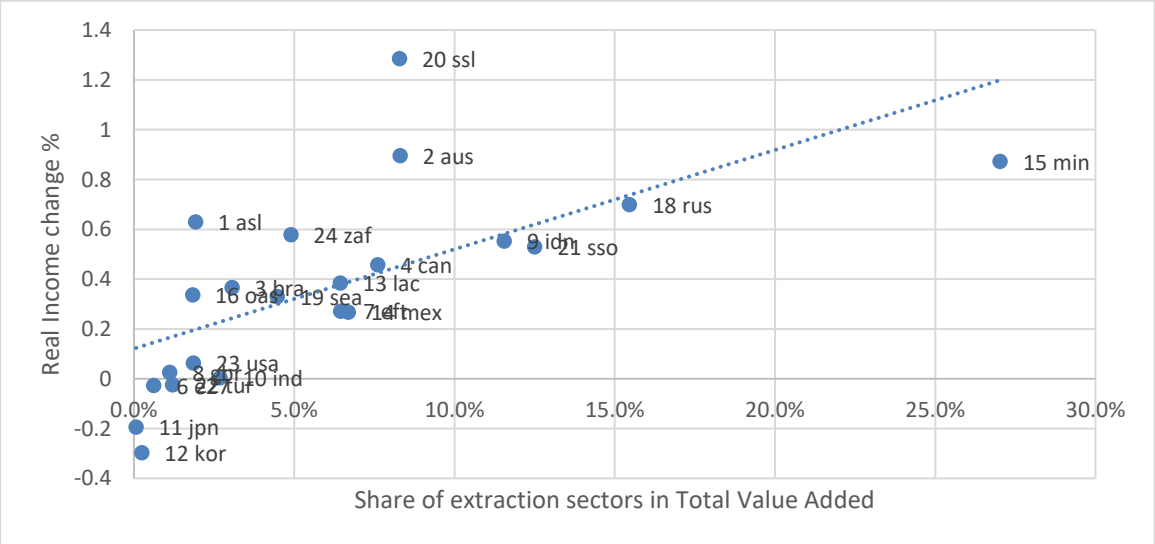
Source: Authors calculations based on simulation results; Note: This graph does not include China as it reports the spillover effects on non-subsidizing regions, it also doesn't report row(rest of the world) Please refer to appendix for abbreviation of regions

We see here that most of the regions with negligible changes in their real income like Turkey, EU, UK, India and USA have similar comparative adavantages as China. This includes, Japan and Korea as well. However, compared to the others, Japan and Korea have a more negative impact on their real income, implying the existence of another significant channel.

3.4.3 Demand upstream effects result in positive spillover effects as they allow expansion of sectors supplying intermediate inputs to the subsidized sector in China

China is a net importer of natural resources used as an input in Manufacturing sector. Subsidizing the manufacturing sector then leads to a higher demand for these inputs and consequently an expansion of these sectors in their respective regions of origin. In figure 8 we plot the relationship between changes in real income and initial share of extraction in total value added. We see that regions with a higher share of extraction in value added initially, have a higher gain in real income. Regions like SSL, gain even more than other natural resource exporters like Middle East and North Africa, Russia and SSO, because they also supply other intermediate inputs to China`s manufacturing sector.

Figure 8: Relationship between changes in real income and initial share of extraction in total value added



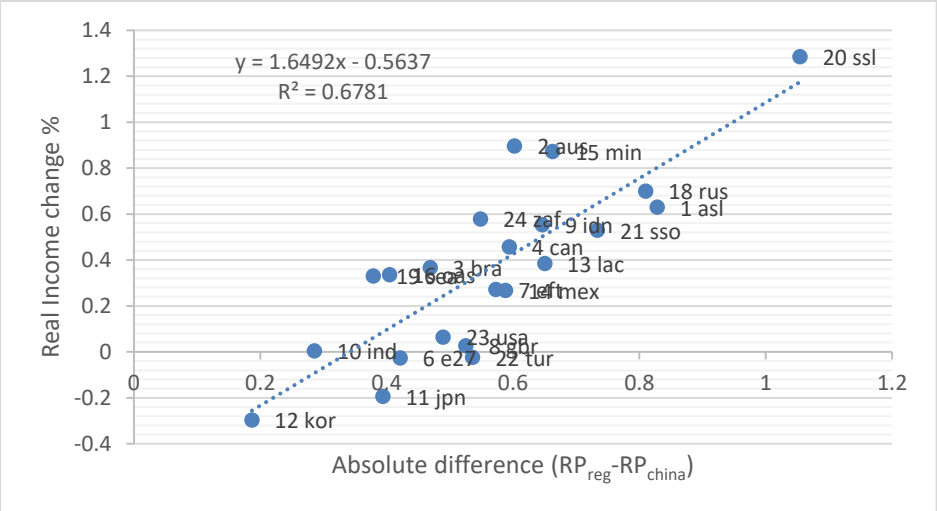
Source: Authors calculations based on simulation results; Note: This graph does not include China as it reports the spillover effects on non-subsidizing regions, it also doesn't report row(rest of the world) Please refer to appendix for abbreviation of regions

We can see that Japan and Kore do not have any of the upstream sectors and hence do not benefit from the positive spillover effects of this channel. However, they do experience the secondary upstream channel which puts a negative pressure on their income.

3.4.4 Competition upstream channel results in negative spillover effects because non-subsidizing regions importing the same intermediate inputs as China, now face a higher import cost

The primary upstream channel raises demand for upstream sectors in non-subsidizing regions, resulting in an increase in export prices for these sectors. Other non-subsidizing regions that were importing from these sectors and regions initially would now be faced with a higher import price, which would reduce their real income. Hence, non-subsidizing regions that have a similar reveal preference for imports as China, face a negative spillover effect due to this secondary upstream channel. Figure 9, shows the relationship between the absolute difference in revealed preference for imports of the non-subsidizing region and China with the real income changes. It shows that regions like Korea and Japan have the highest level of similarity with China, in terms of initial structure of imports. Hence, they experience the highest level of negative spillover effects from this channel which results in a fall in their real income. Other regions with similar competition and downstream effects as Japan and Korea, and have a lesser degree of similarity in revealed preference of imports and hence, don't experience a loss in welfare as great as Japan and Korea do.

Figure 9: Relationship between changes in real income and absolute difference between revealed preference for imports of the non-subsidizing region and that of China



Source: Authors calculations based on simulation results; Note: This graph does not include China as it reports the spillover effects on non-subsidizing regions, it also doesn't report row(rest of the world) Please refer to appendix for abbreviation of regions

3.5 Putting all four channels together: regression analysis shows that the weight of each channel differs from region to region, but are significant when all are considered together

Thus, we establish the presence of 4 different channels through which an introduction of a subsidy unilaterally in one country can affect other countries.

We run a regression to identify the varying importance of each channel as per the following model,

$$Y_{c,d} = Imp_share_{c,d} + RCA_exp_{c,d} + exp_share_{c,d} + RP_imp_{c,d} + \varepsilon$$

Where Y is the real income change in region d when region c introduces a 10% production subsidy unilaterally. Imp_share is the imports from c to d, relative to total imports in d. RCA_exp is the absolute difference between the RCA of d and the RCA of c in the manufacturing sector. Exp_share is the exports from d to the manufacturing sector in c relative to total exports of d. RP_imp is the

absolute difference between the revealed preference for imports in d and c. And ε is the error term.
.

Table 5: Regression results for above model with data for non-subsidizing regions when China introduces a subsidy in its manufacturing sector

	(1)	(2)	(3)	(4)	(5)
Imp_share	5.008***				1.030
	(5.50)				(0.53)
RCA_diff		0.866***			0.973**
		(8.17)			(2.97)
Exp_share			20.06***		0.190
			(4.11)		(0.03)
RP_imp				0.904***	-0.299
				(5.95)	(-0.77)
R-sq	0.58	0.75	0.43	0.62	0.76

t statistics in parentheses
* p<0.05 ** p<0.01 *** p<0.001

Table 5 reports the results for the discussed regression, for only one simulation, i.e. China introducing a subsidy of 10% to its manufacturing sector. While each of the channels have a significant co-efficient, when combined the competition effect for this simulation dominates all other channels. There exists some level of multicollinearity between the variables and hence the co-efficient values of the complete regression may be biased, explaining why significant co-efficients in individual regressions don't crop up in the combined regression. However, the high R-squared value of ~0.8 allows us to believe that these four channels explain a considerable portion of the spillover effects caused by China`s subsidies.

To establish the direction and significance of the above channels for all cases, we re-ran the policy experiment with the other 23 (23 more simulations) regions introducing a unilateral 10% output subsidy in manufacturing sector and realized that the weight of these channels vary not only from region to region but also from simulation to simulation, i.e. the results depend on the region introducing the subsidy in addition to the spillover effects experienced by a particular region. We run the same regression as above but with country fixed effects included now for the subsidizing region and the non-subsidizing region. The specification for this model is,

$$Y_{c,d} = Imp_share_{c,d} + RCA_exp_{c,d} + exp_share_{c,d} + RP_imp_{c,d} + \alpha_c + \beta_d + \varepsilon$$

Where α , β are region fixed effects for c and d.

Table 6 reports the results of this regression. The R-squared of all the channels together is 0.60 which does not show an extremely strong fit. The co-efficients for RCA and RP are not significant when regressed individually, but are significant in the complete model.

Table 6: Regression results of regression real income changes on the metrics used to measure the four channels discussed above.

	(2)	(3)	(4)	(5)	(6)
Imp_share	2.899***				2.369***
	(13.94)				(7.20)

RCA_diff		-0.0459			-0.0831**
		(-1.41)			(-2.70)
Exp_share			12.73***		3.644*
			(11.47)		(2.17)
RP_imp				0.0227	0.105*
				(0.49)	(2.38)
R-squared	0.59	0.44	0.55	0.43	0.60

t statistics in parentheses
* p<0.05 ** p<0.01 *** p<0.001"

The initial data showed that the co-efficient values differ when different regions subsidize. For instance, the co-efficients of RCA and RP in individual regressions for only China subsidizing its manufacturing sector are positive and significant (Table 5). However, with increased dataset of 24 different simulations where each region introduces a subsidy unilaterally, the co-efficient is no longer significant in the individual regressions, nor are they positive. The co-efficient of RCA is negative, implying that when the difference in comparative advantage is large, real income falls more. However, this co-efficient is not significant. Interestingly, including all variables in a complete regressions makes the co-efficient for all channels significant.

The intuition behind the existence of the secondary upstream channel is that when the subsidizing region significantly raises the demand in upstream sectors it succeeds in modifying the prices in these sectors which then affect other regions buying from them. However, the subsidizing regions`s manufacturing sector is relatively small, this effect even when significant will not result in a significant change in prices. The same holds true for competition effects. A country will be able to change the world prices only if it is a large economy. Keeping this in mind, we change our regression model to take into account the size of the subsidizing region.

$Y_{c,d} = Imp_share_{c,d} + int_RCA_exp_{c,d} + exp_share_{c,d} + int_RP_imp_{c,d} + \alpha_c + \beta_d + \varepsilon$

where int_RCA_exp = Absolute difference in RCA * size of manufacturing sector
and int_RP_imp = Absolute difference in RP * size of manufacturing sector

With this new specification the results change and are reported in the table below.

Table: Regression results of regression real income changes on the metrics used to measure the four channels discussed above.

	(1)	(2)	(3)	(4)	(5)
Imp_sh	2.899***				2.596***
	(13.94)				(7.98)
int_RCA_exp$_c$		1.891***			1.602***
		(4.84)			(4.56)
Exp_share			12.73***		2.007
			(11.47)		(1.20)
int_RP_imp				0.977	0.710
				(1.89)	(1.57)
R-sq	0.59	0.46	0.55	0.44	0.62

t statistics in parentheses

**

="* p<0.05 p<0.01 *** p<0.001"

The change between Table 6 and this table to be noted is the co-efficient for absolute difference in RCA. It is now positive and significant. The co-efficients for absolute difference in RP is also positive, albeit insignificant. Hence, once we account for the size of the economy our initial logic of the channels is verified. The competition and secondary upstream effects are significant for China which has a large manufacturing sector and would hold true for other large economies like EU and USA. But this channel is insignificant for smaller economies.

Given the variation in co-efficient size, significance and sign, we realized a need for allowing co-efficients to differ from simulation to simulation. Hence, we also ran a pooled regression of the above model that allows for different co-efficients for each metric depending on the region introducing the subsidy and were able to establish the above conclusion[6].

4 MULTILATERAL SUBSIDIES: PRODUCTION, WELFARE, AND SPILLOVER EFFECTS

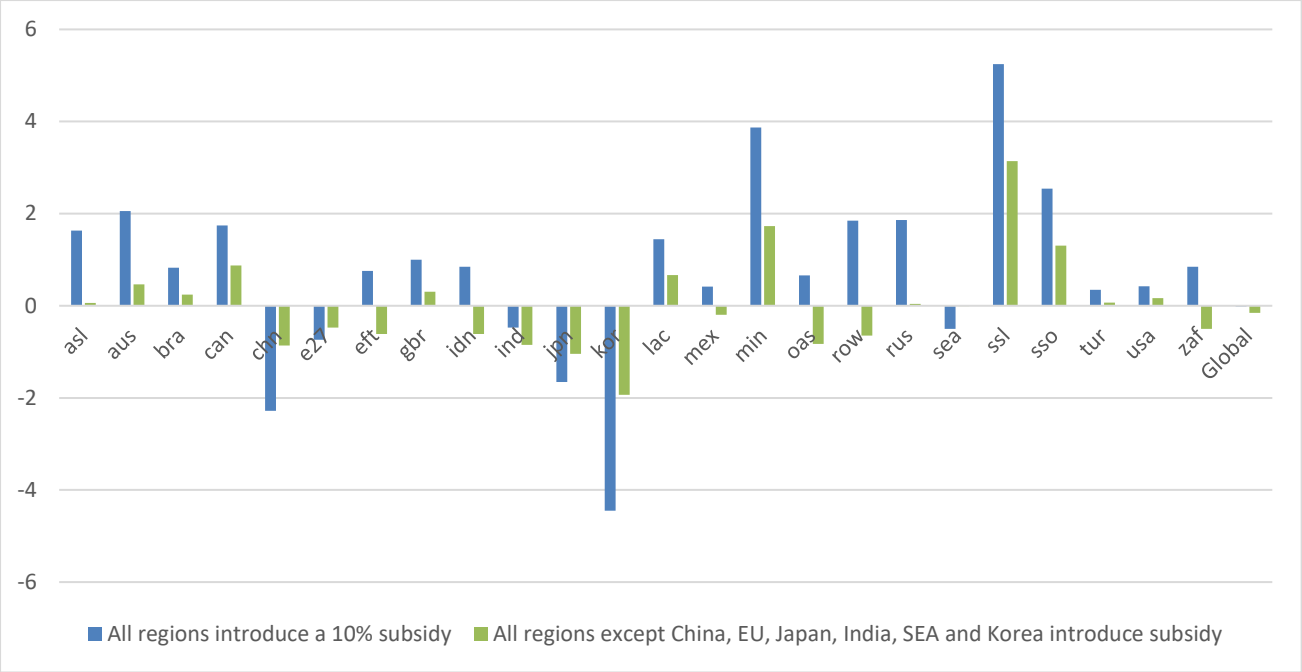
We have analysed the welfare and spillover effects when a single country introduces a revenue neutral output subsidy in the manufacturing sector. However, what concerns governments and policy makers today are scenarios where the introduction of a subsidy by one country leads to other countries responding till the entire world gets caught up in a subsidy war. We use the results from unilateral subsidy policy experiments and analyse how they change when multiple countries introduce subsidies simultaneously in their manufacturing sectors.

4.1 Subsidies introduced by all regions simultaneously result in heterogenous changes in welfare across regions

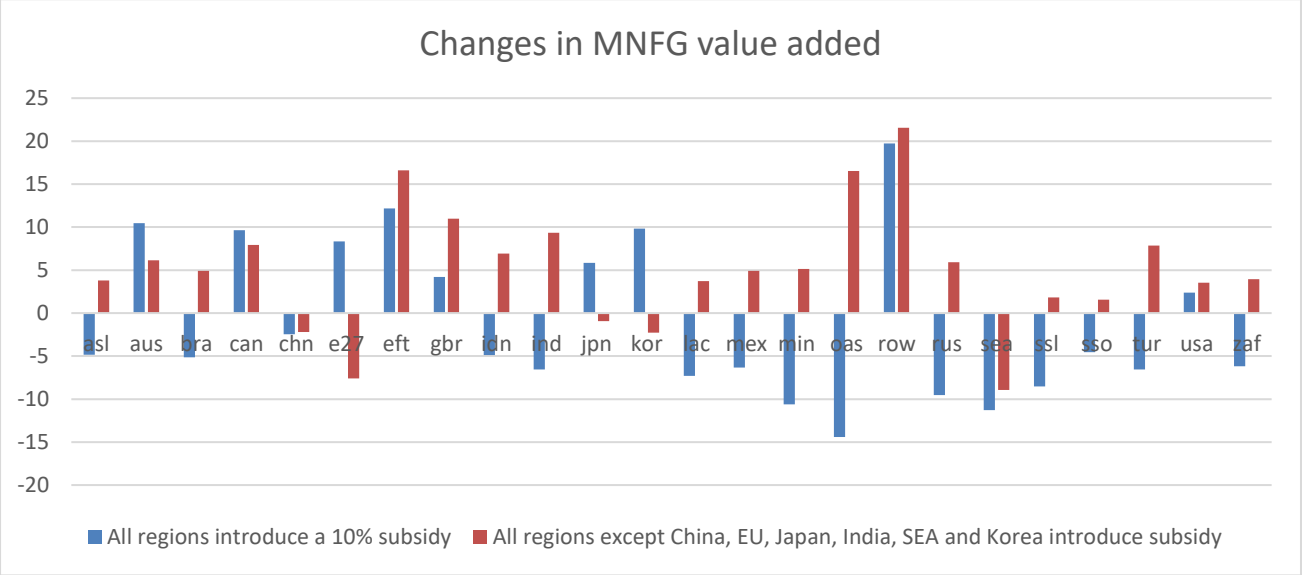
In this subsection we analyse the results of the policy experiment where all regions introduce a revenue neutral 10% production subsidy in an environment like that described in the previous experiments.

Figure 12: Changes in Real Income compared to the baseline in percent terms for two scenarios

[6] The results of this regression showed that the co-efficients for competition and secondary upstream effects are positive for larger economies like China, Korea and EU.



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions



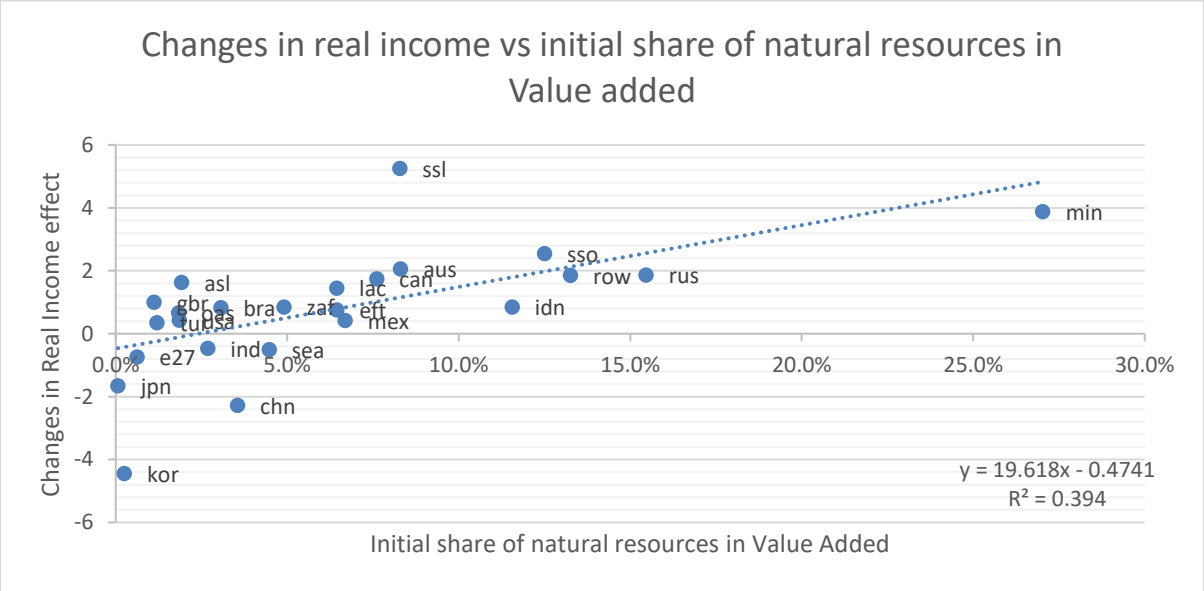
Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

A 10% production subsidy in all regions results in gain in terms of Real Income in most regions in the long run. However, China, EU, Japan, India, South East Asia and Koreaseem to lose. The channels discussed previously continue to function in this scenario as well. However, there are now multiple layers of spillover effects felt in each country coupled with the cost and impact of the subsidy introduced by them. It is the combination of all these GE effects that lead to the final results observed. It is evident from Figure 12, that regions with a loss in real income may not necessarily be facing a loss in manufacturing output and vice-versa. Hence, it both changes in demand due to shift of the demand curve as well as change in price due to movement along that curve that affect gains from introducing a subsidy in this scenario.

Interestingly, when these regions that lose choose not to partake in this subsidy war, they continue to lose real income. In fact, India seems to lose more real income when it does not subsidize compared to when it does. Global weighted average also reveals that the world is worse off when these mega manufacturers do not subsidize while the rest of the world does.

Figure 12 shows the relationship between initial share of natural resources in value added and real income changes. We see that regions with higher production in sectors thar supply intermediate inputs to manufacturing sectors world wide, have the highest increase in real income. In these regions, the costs of introducing a subsidy in manufacturing sector themselves is clearly absorbed by the positive upstream effects of manufacturing sectors being subsidized worldwide.

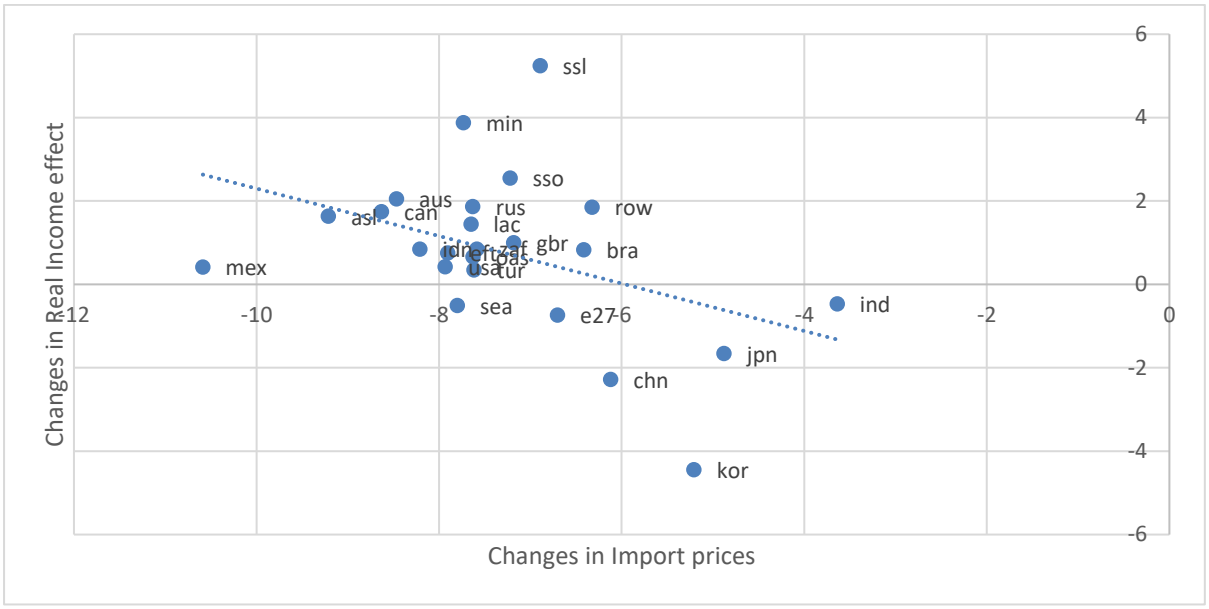
Figure 12: Relationship between changes in real income and initial share of natural resources in Value Added



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

Downstream effects combined with the secondary upstream effects would manifest itself in import prices of regions. Figure 13 shows the relationship between changes in real income and changes in import prices. Regions that experience a higher fall in import prices, gain more in terms of their real income. Regions like China, Japan, Korea and India do not face high drops in their import prices and hence, face a fall in their real income. Change in import price would be driven by reduced export prices of manufacturing sector from regions subsidizing it. However, it would also be accompanied by a rise in import prices of inputs used for manufacturing sector.

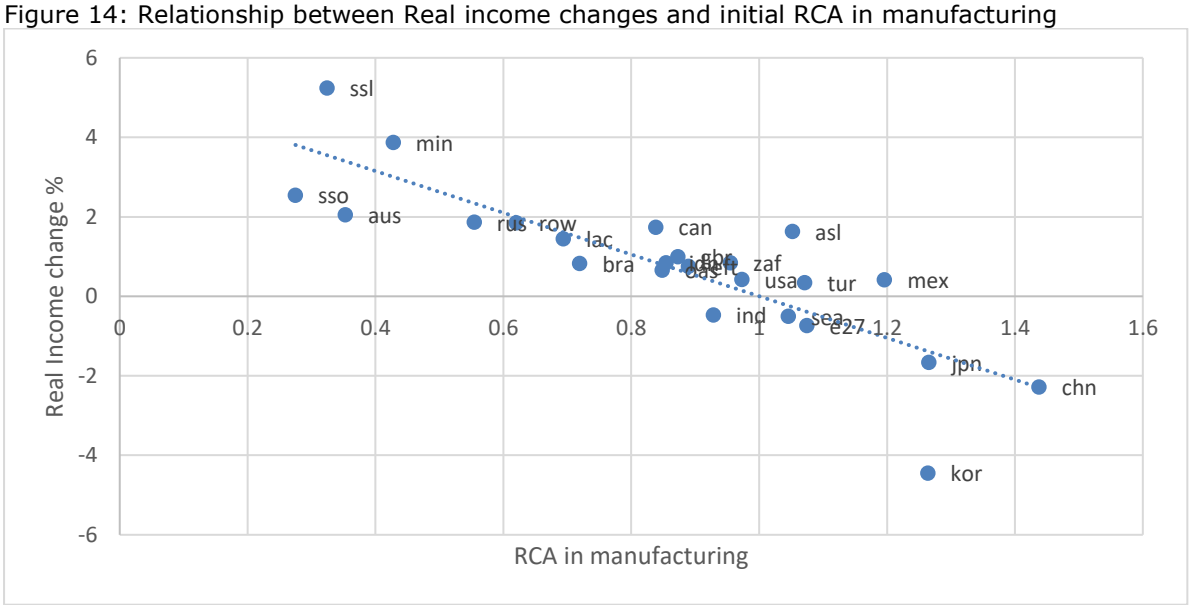
Figure 13: Relationship between changes in real income and changes in import prices



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

Since China, Japan, Korea, EU and India are regions that have a relatively big manufacturing sector as seen in Figure 14, the secondary upstream effect dominates for them resulting in a lower drop in import prices compared to other regions like Mexico. Additionally, regions with a larger initial manufacturing sector bear higher costs from introducing the subsidy and also the brunt of direct competition effects. Figure 14 shows a negative relationship between changes in real income and the initial revealed comparative advantage (RCA) of regions in manufacturing sector. Hence, regions with a higher RCA in manufacturing, or larger sized manufacturing sector initially, have higher costs and hence lesser welfare gains.

Figure 14: Relationship between Real income changes and initial RCA in manufacturing



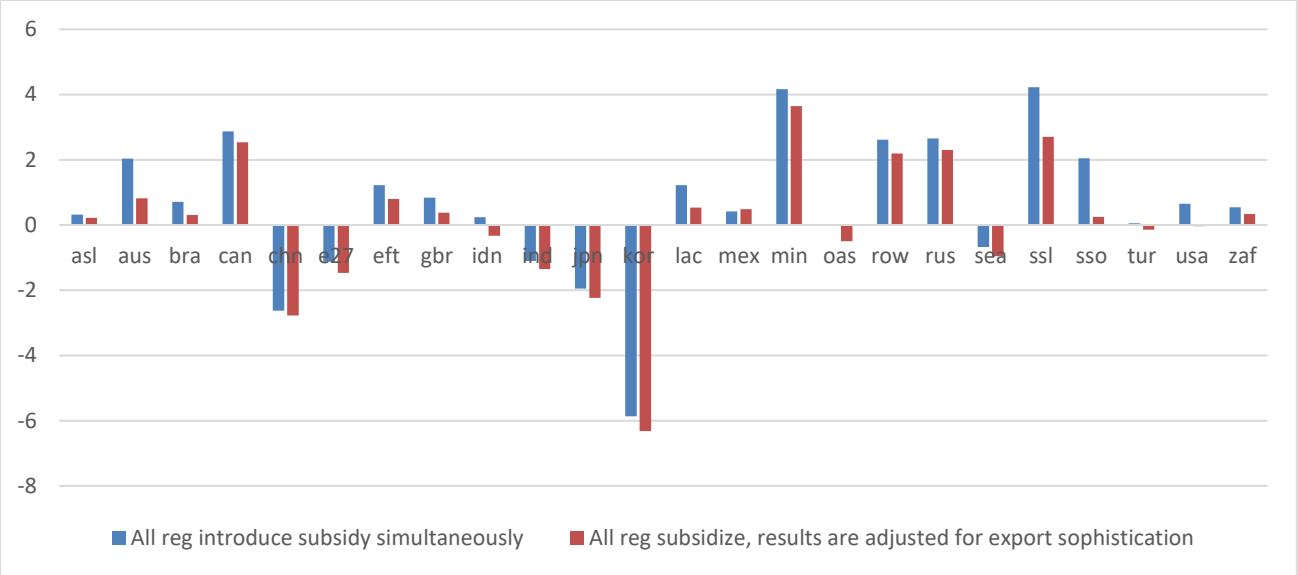
Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

The above results help establish that an important channel of positive growth in real income from global subsidies comes from expansion of upstream sectors. However, these sectors are capacity restrained as they are heavily dependent on the geographic presence of certain natural resources. Specialization in these sectors, would not aid the growth of regions in the long run. These are the sectors referred to as primary sectors by Hausman et. al. 2006.

Increased sale in these sectors in current years may lead to reduction in income in later years due to this capacity constraint or lack of increased contribution to growth. Given the changes in production pattern, it is expected that in the long run, some regions would have specialized in these natural resource specific sectors and would hence lose from specializing in non-sophisticated sectors. Hence, what you export currently, matters in the long run (Hausman et. al. 2006). To account for this, we adjust our model by introducing a shock that accounts for the shift in export sophistication designed based on Hausman et al (2006) and described in detail in Section 2.

To analyse thus, the effect of loss in export sophistication on the spillover effects, we run two dynamic experiments. The first mimics the previous static experiment and allows all regions to subsidize their manufacturing output by 1% simultaneously for the period 2021-2030. The second experiment includes an additional export sophistication shock in the first experiment. The following figure shows the changes in real income in year 2040 for both these experiments.

Figure 15: Changes in real income in Year 2040 for dynamic scenarios with export sophistication shock and without



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

We see now that the gains in all regions are lesser and the declines are higher. Regions with higher initial share of extraction in value added like Min, OAS, SSL, SSO face extremely high reductions in their gains, leading to a decline in the global value of real income change for the scenario where all regions subsidize. This goes to show that in an absolutely plain model with no bells and whistles, all regions subsidizing their manufacturing sector may not necessarily be negative. However, when we adjust for intuitive changes such as accounting for the importance of change in sophistication of sectors that one specializes their exports in, we see that there is a decline in gains globally and subsidies prove to be more harmful. With the addition of further elements that bring the model closer to reality, this gain may decline more and show how subsidies that are beneficial in theory may be harming regions in reality.

Section addition:
- Each region introduces a subsidy in the sector within manufacturing most optimum for them. (include changes in real income and changes in overall mnfg output changes for unilateral subsidies)
- Each region introduces their optimum size of subsidy in all mnfg sectors

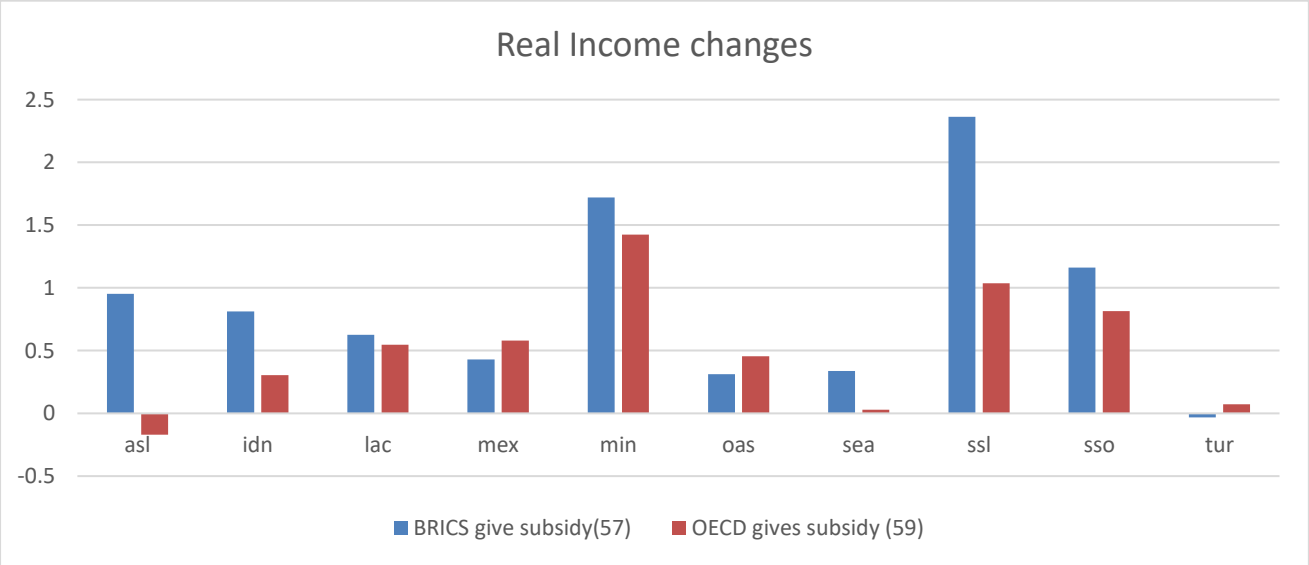
4.2 Subsidies introduced simultaneously in blocks of regions show that the impact of subsidies by the BRICS are more likely to generate positive spillover effects to third countries

We now compare two scenarios – First where all the BRICS nations introduce a 10% subsidy in their respective manufacturing sectors simultaneously (Scenario 57) and Second, where all the OECD

nations introduce a 10% subsidy in their respective manufacturing sectors simultaneously (Scenario 59).

Figure 15 shows us the real income changes in the two scenarios. Evidently, when the BRICS nations introduce a 10% production subsidy (Scenario 57) all non-subsidizing regions seem to gain more relative to the scenario where the OECD nations introduce a 10% production subsidy Scenario 59). Turkey and Mexico are the only two regions where the trend is the opposite.

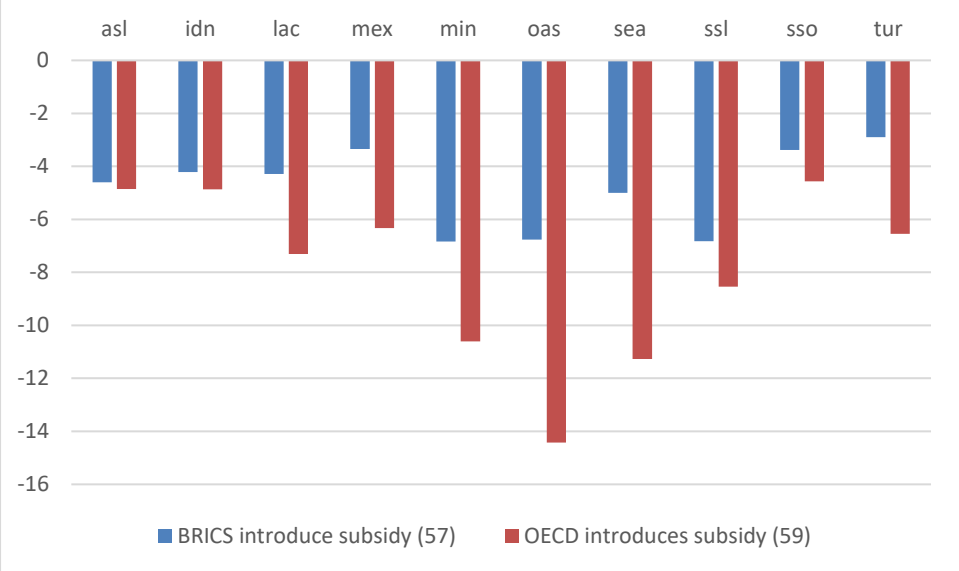
Figure 16: Changes in Real income from the baseline in percent terms for scenarios 57 and 59



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

The first thing we can confirm is that non-subsidizing regions gain in both scenarios, implying positive spillover effects overall. However, we can also establish that developing regions gain more when the subsidy is introduced by BRICS nations compared to OECD nations. We look at each of the upstream, downstream and competition channels to establish the channel that leads to the final results observed by us.

Figure 17: Changes in output in manufacturing sector in non-subsidizing regions

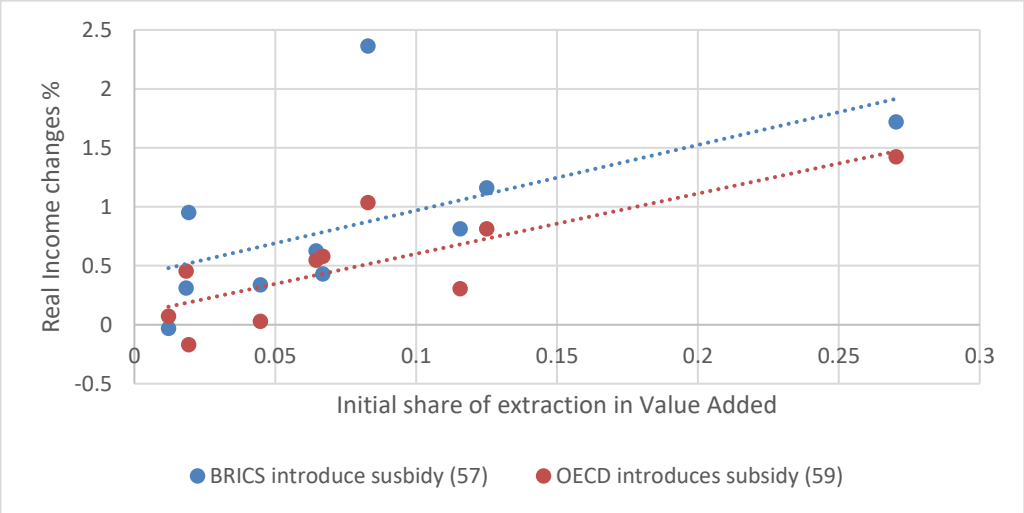


Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

We can see that output fall in manufacturing sectors is greater for the scenario where OECD introduces a subsidy explaining why real income changes are more positive for BRICS introducing the subsidy. The number and size of Oecd countries is larger than BRICS. This could be an additional contributing factor in OECD subsidies succeeding in reducing manufacturing output in non-subsidizing regions by a greater value than BRICS subsidies.

Figure 18 helps describe the upstream results by showing the relationship between changes in real income and initial share of extraction in value added in non-subsidizing regions. We see that this effect is clearly stronger when the BRICS nations introduce the subsidy vs when the OECD introduce it. This is the primary reason for the higher real incomes observed in MIN, SSL, SSO, IDN. This effect is relatively small in both Mexico and Turkey where the initial share of extraction in value added is low.

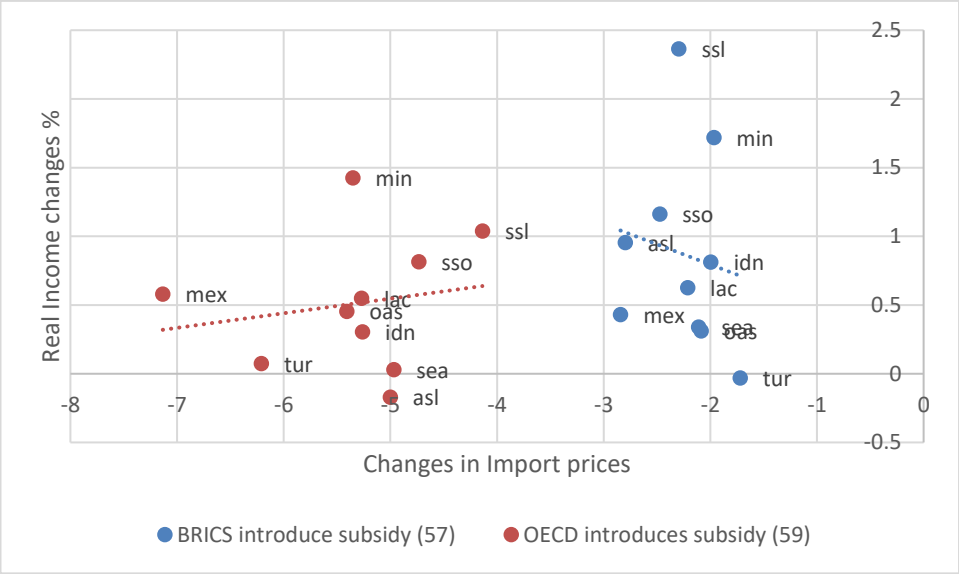
Figure 18: Relationship between changes in real income and initial share of extraction in value added



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

Figure 19 shows us the downstream and secondar upstream effects by showing the relationship between real income changes and changes in import prices. OECD subsidies result in a much higher reduction in import prices across all regions. However, while this result is negative for the BRICS subsidies, it becomes positive in the case of OECD subsidizing. Regions like SSL, SSO AND MIN which have extremely low reductions in import prices, have high welfare gains driven by upstream effects of expansion of natural resource oriented sectors in these regions. If we were to include the real income and import price changes for all 24 regions, the OECD scenario also have a negative relationship. This figure, helps establish the dominance of upstream effects in these two scenarios further.

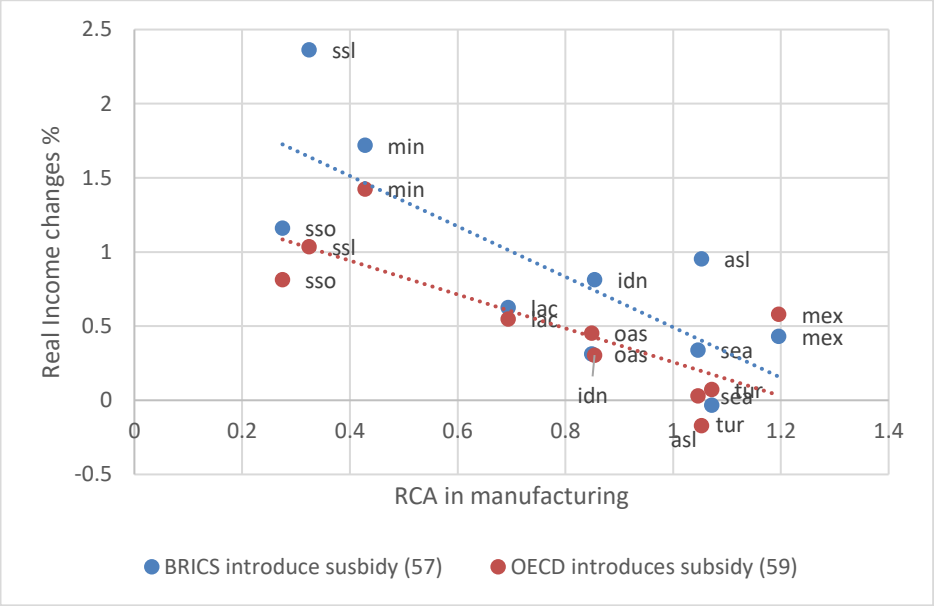
Figure 19: Relationship between changes in real income and changes in import prices



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

Finally, figure 20 shows the competition effects and we see that for regions with a higher RCA in manufacturing initially, the gains from OECD subsidizing is greater. While the reverse is true for the regions with lower initial RCA in manufacturing. This explains why Mexico and Turkey which have extremely low upstream effects gain more when OECD introduces a subsidy.

Figure 20: Relationship between real income changes and initial RCA in manufacturing sectors



Source: Authors calculations based on simulation results; Simulation details: All regions introduce a subsidy of 10% in all manufacturing sectors simultaneously; Please refer to appendix for abbreviation of regions

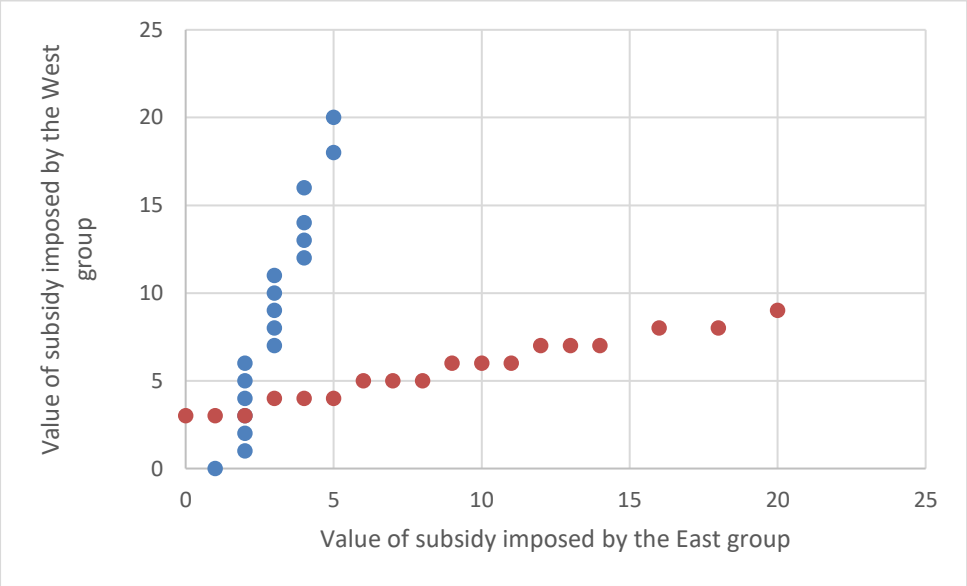
These two scenarios help show that when block of regions introduce subsidies simultaneously, the spillover effects are not the same as unilateral introduction of subsidies and depends on how the block interacts with the non-subsidizing regions, thus, determining the sizes of each of the channels through which spillover effects can be measured.

4.3 Subsidies introduced with coordination within groups of regions and noncoordination within groups of regions leads to equilibriums that may not be beneficial for all regions

We divide the world into two groups – East which includes ASL, CHN, IDN, IND, KOR, MIN, OAS, RUS, SEA, SSL, SSO, ZAF. And the remaining 12 regions in the West group. Our objective is to mimic a two-country model and identify reaction curves that plot the best response of one group`s policy to the subsidy policy of the other group. In order to do this, we assume that regions within each group give the same size of subsidy and introduce it simultaneously. Regions in the other group may give a different subsidy but focus on the same sector that everyone is looking to capture welfare benefits from. Each country can introduce a subsidy at any point of time and the experiment begins with no subsidies imposed by either region.

We run simulations by raising the subsidy with 1% from 0 to 14% and then for 16%, 18% and 20% in each group and identify the best response of each group to the other`s choice of subsidy. This gives a total of 18*18 simulations. We process the results by calculating the changes in real income of each group for each simulation and then for each level of subsidy introduced by the other group, finding the optimal subsidy levels within self-group that maximized own real income. Given that the income effect of the same subsidy is different in the different regions within a group, we employ an income weighted average of these effects to calculate the best response of each group[7].

Figure 21: Best response functions of the east and west groups to the other`s selection of subsidy

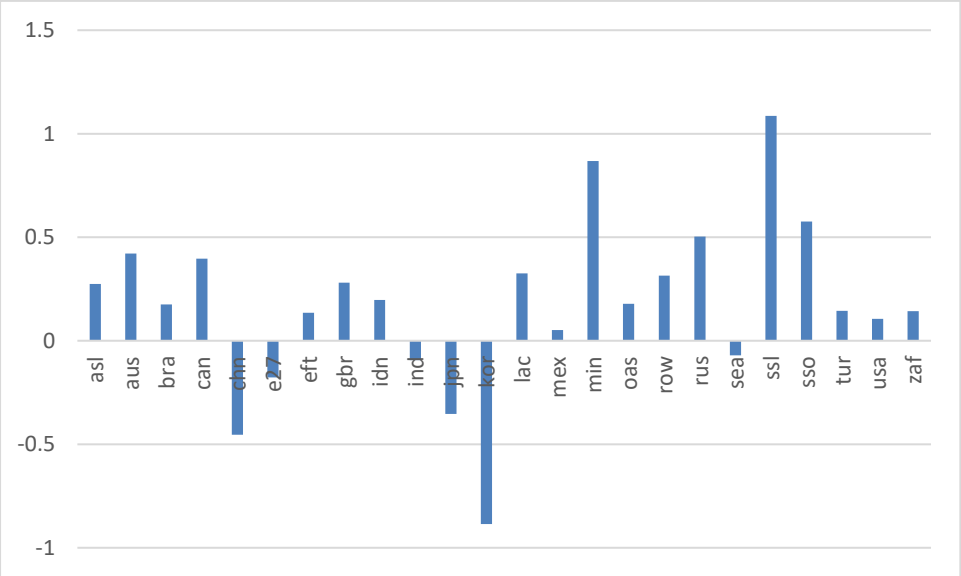


Source: Authors calculation based on simulation results; Note: Each data point in the above graph corresponds to a separate simulation

The two response functions reveal an equilibrium point which exists at the East block giving a 2% subsidy and the West block giving a 3% subsidy. The following figure shows the regional changes in real income at this equilibrium point. Global income weighted average change in welfare inclusive of all regions is an increase of 0.01%. However, taking this metric to be a measure of success of this equilibrium would be flawed as there is regional variation in welfare results, as is evident from Figure 22.

Figure 22: Changes in real income at equilibrium where East group introduces a subsidy of 2% and West group introduces a subsidy of 3%

[7] Note that in this scenario we assume that the political objective function being maximized by policymakers comprises solely of real income changes



Source: Authors calculation based on simulation results; Note: simulation for which changes in real income are presented is a comparative static simulation where regions in the east block give a subsidy of 2% and those in the west block five a subsidy for 3%

We term this equilibrium a semi-cooperative Nash equilibrium as it has some degree of cooperation but is not completely coordinated as Nash solutions are supposed to be. Such an equilibrium is a theoretical exercise run by us to explore the possibility of groups or lobbies of regions in the world, and does not follow theoretical methodologies completely. At this equilibrium, the East as a group loses real income while the West gain. Since this is not a scenario where both groups lose, it does not deter the west group from going ahead with a subsidy policy. However, if the entire East group, were to identify this loss and retaliate in the form of increased taxes on other sectors like extraction which serve as inputs to the expanding manufacturing sectors in the west, They would be able to improve their welfare effects with a terms of trade gain. The game could then become zero sum again with all regions losing.

Similar scenarios can be designed with more than one group, or by creating the response functions of each region individually as well. However, we avoid the tedium of running the numerous simulations requisite for such scenarios and choose to take the above results as sufficient proof that excessive subsidies can be harmful for the world. Subsidies introduced by state governments to incentivize firm relocation in USA, reveal that the states have an incentive to subsidize but the levels of subsidy imposed are closer to a cooperative nash equilibrium. However, the potential costs of current subsidy levels escalating into a non-cooperative equilibrium among states, are immense for all states (Ferrari and Ossa, 2023).

Literature discussing similar trade war scenarios with tariffs also reach the conclusion that non-cooperative nash equilibriums are rarely beneficial for the world. In fact, coordinate equilibriums always allow global welfare to fare better, whether we use a grid-search methodology to identify the equilibrium point (Ossa 2011) or draw response curves and use them to find the equilibrium (Bekkers et. al. 2022).

5 THE IMPACT OF MODELLING CHOICES

In the previous section we discussed the welfare and spillover effects for general scenarios as well as with a specific example of China introducing a production subsidy of 10%. In this section, we wish to analyse how the different choices of closure and elasticity parameters affect the results derived by us.

5.1 The projected welfare and spillover effects depend on modelling choices and assumptions

Table 5 reports the results of change in real income for different scenarios for China, the subsidizing region, Japan and USA among the non-subsidizing region and a global weighted value of change in real income.

The first row of Table 6 reports the results of the Benchmark scenario used by us the in sections above to identify the various channels for spillover effects. In row 2, we report a variation of the benchmark scenario where China gives a 10% capital subsidy instead of an output subsidy. We see that the directions of the result remain the same. However, the size of the effects now change as the size of the subsidy itself has changed.

In row 3, we run the scenario 2, but we change our assumption regarding trade balance and allow it to change. With a flexible trade balance, China`s real income improves post the subsidy introduction instead of decreasing. A flexible trade balance allows China to benefit from stronger exports through capital inflows thus, raising real income. In the next scenario, we remove the condition of revenue neutrality. This means that now when China introduces the capital subsidy in question, it doesn`t have to raise its tax on factor income proportionally. Removal of revenue neutrality raises real income further as there is no cost to the subsidy now. In the next scenario, scenario 5, we allow investment to be converted to capital instantaneously, thus making capital an endogenous variable. Endogenous capital allows China to reap full benefits of increased investment that come with a flexible trade balance and hence, we see China`s gains improve further. In scenario 6, we allow countries to fix their rate of return, which makes the global savings rate flexible. Flexible global savings rate allows investment across the world to get redistributed resulting in all regions gaining. Finally, we change our assumption regarding the elasticity of substitution of inputs in the production function. We shift from a Leontief structure to a Cobb-Douglas combination. Higher substitutability in inputs allows for a greater increase in real income as it allows increased use of subsidized sector.

Table 6: Changes in real income for specific regions, for different scenarios

	Scenario	China	USA	JPN	Global[1]
1	Benchmark Scenario	-1.39	0.06	-0.19	-0.02
2	Scenario 1 with 10% Capital subsidy (38)	-0.09	0.00	-0.02	0.00
3	Scenario 2 with flexible trade balance (36)	0.24	-0.04	-0.05	0.01
4	Scenario 3 with no revenue neutrality (3)	0.50	-0.07	-0.08	0.01
5	Scenario 4 with endogenous capital (5)	2.16	-0.20	-0.98	-0.37
6	Scenario 5 with flexible savings rate (40)	2.58	0.07	0.22	0.52
7	Scenario 6 with Cobb-douglas prodn function (78)	2.73	0.07	0.22	0.54

In terms of spillover effects, we find that with each change in assumption, as China`s own welfare goes up, its spillover effects become more negative till we reach scenario 6. This scenario allows all regions to start gaining. The flexible global savings rate allows for redistribution of funds which results in an increase in global real income.

Each of the assumptions that we vary above have important implications on our result and hence, it is important for us to be aware of the correct choice of closure when modelling the welfare and spillover effects of subsidies. In most scenarios, the choice of closure proceeds from the objective of the policy experiment and whether we are interested in analysing the long run or short-run results. In all the above changes, revenue neutrality is the only condition which should not be manipulated. Without this condition, our model fails to take into consideration the excess fiscal pressure that a

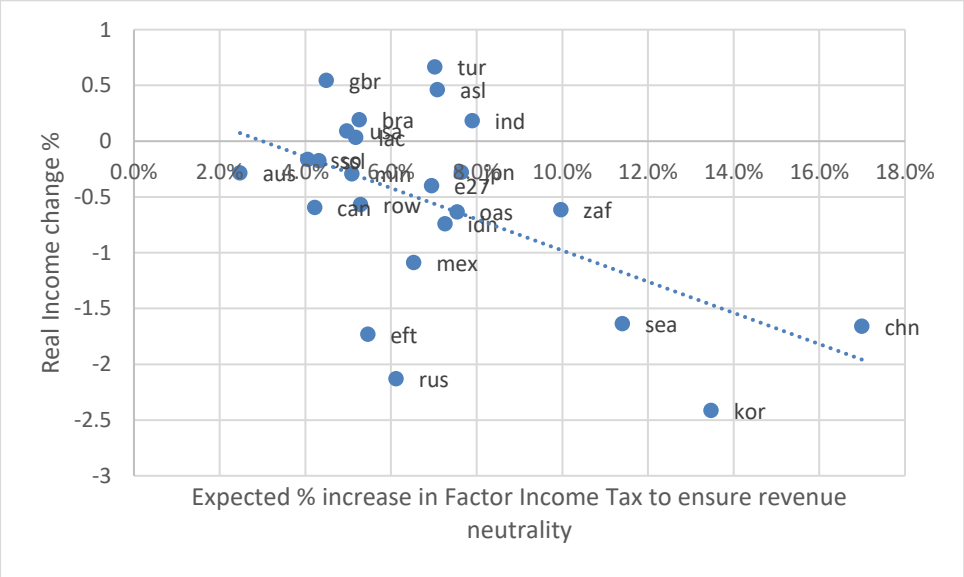
subsidy is accompanied with and hence, says nothing about its sustainability. For this reason, we feel that this condition is imperative and must not be removed.

The assumption on elasticity of input substitution has hardly any impact on spillover effects. It improves welfare in the subsidizing region, but the size of this impact depends on the size of the subsidy. We choose to employ a Leontief production structure in our benchmark scenario as is popular in the CGE literature. As for the above assumptions, given that we want to identify the long run welfare and spillover effects of a subsidy, we choose to keep the trade balance and global savings rate fixed in our model.

5.2 Impact of size of subsidy on welfare and spillover effects

Real income effects are also affected by the cost of the subsidy imposed. Regions with large initial manufacturing sectors would have to raise the tax on factor income by a higher margin than those with a smaller initial manufacturing sector. Figure 23 below shows a negative relationship between the increases in tax on factor income and change in real income.

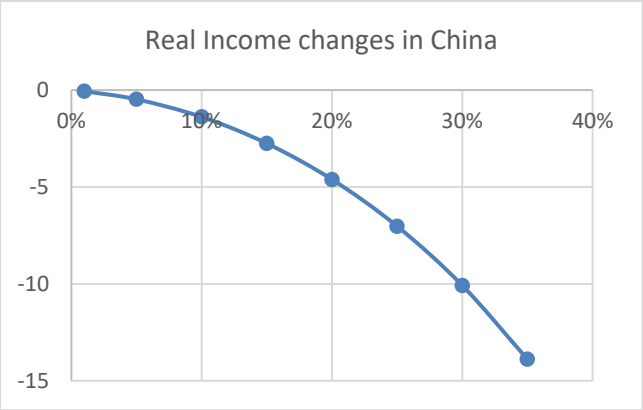
Figure 23: Relationship between Real Income changes and changes in factor income required to make the subsidy revenue neutral



Source: Authors calculations based on simulation results; Simulation details: 24 simulations, each with a unilateral subsidy for a particular region; Please refer to appendix for abbreviation of regions

In this section, we aim to explore the response of welfare effects to the level of subsidy imposed. The change in welfare effects when we change levels of subsidy is non-linear in the subsidizing region but linear for the rest of the world. We see this in the results shown in Figure 10. Once we are reminded that a subsidy and its corresponding increase in tax, change the level of distortion in the subsidizing economy, it becomes self-explanatory why the welfare response to size of subsidy is non-linear. This same distortion which is absent in the rest of the world, makes its response linear.

Figure 24a: Real Income changes when China introduces different sizes of production subsidy in the benchmark scenario



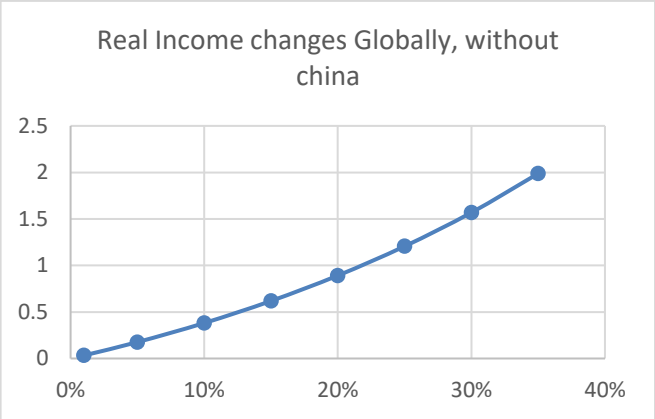
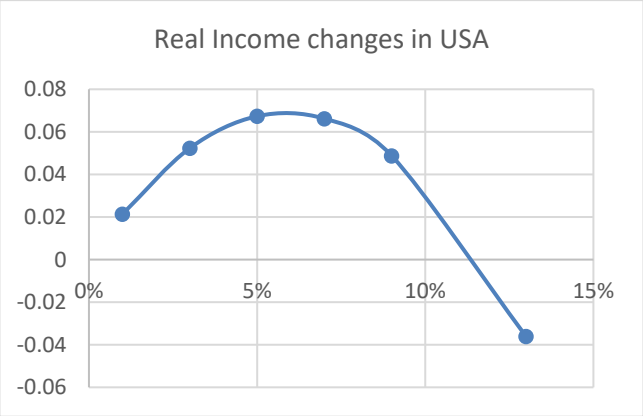


Figure 24b: Real Income changes when USA introduces different sizes of production subsidy in the benchmark scenario



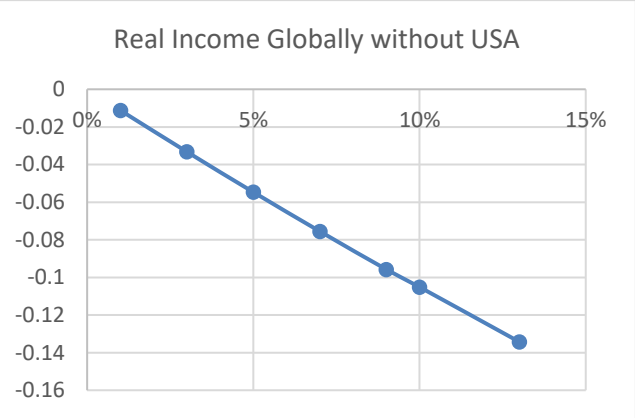
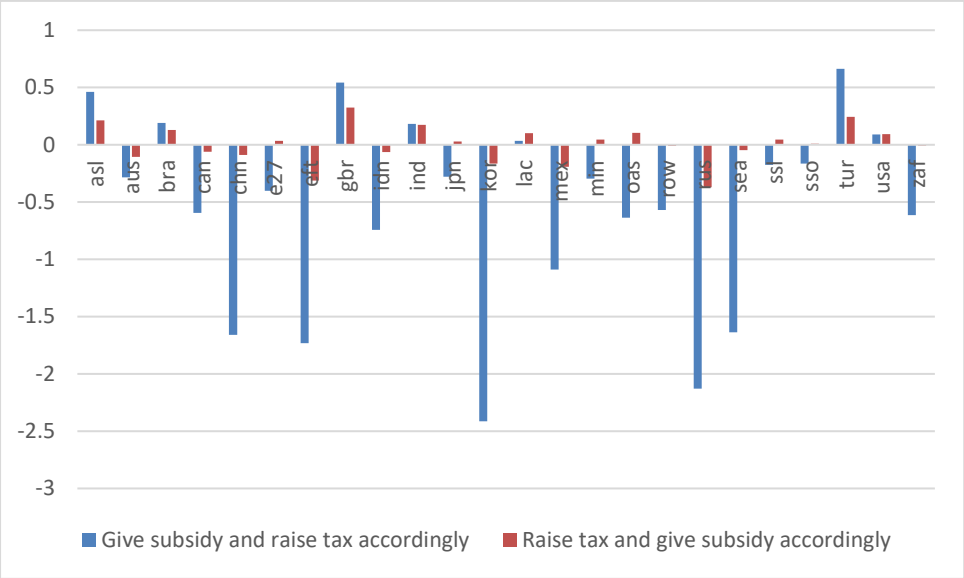


Figure 23 shows two different scenarios of China introducing a subsidy and USA introducing a subsidy. The difference in their real income changes are not just due to differences in terms of trade and allocative results, but also because the cost of a 10% output subsidy is not the same in both economies. Th relationship between real income changes and expected rises in tax on factor income reveal that regions that face a higher increase in factor income tax, also experience a large loss in welfare. China has to increase its factor income tax by ~17% to give a 10% subsidy, while USA only has to increase it by ~5% (Figure 23).

It would be interesting then to reverse the experiment and give a subsidy by raising the factor tax by the same amount in all regions. Upon doing so, the real income effect changes. Figure 25 shows the two scenarios. The blue lines are similar to the Figure 3 shown in the previous section. The red line shows the results for the new closure where we raise factor income by 2% in each region and the money raised by this excess tax collection is transferred as a subsidy to the manufacturing sector. The first difference is the reduction in magnitude of results. This is because we raise factor income tax by only 2%, while the average required change in tax on factor income for the previous analysis in Figure 3 was 4%. However, the overall results continue to largely be similar - the effects reverses direction for some regions like, EU and Japan. From figure 24 we can see that the level of subsidy for which the welfare effects move from positive to negative differ for China and USA. Similarly, it also differs for EU and Japan. In going from one type of closure to the other, for EU and Japan we reduce the value of subsidy sufficient for welfare to become positive.

Figure 25: Changes in real income when the policy experiment makes the subsidy revenue neutral in two different methods



Source: Authors calculations based on simulation results; Simulation details: 24 simulations, each with a unilateral subsidy for a particular region; Please refer to appendix for abbreviation of regions

5.3 Exploring effects of various forms on revenue neutrality

The following figure shows the changes in GDP for different methods of revenue neutrality employed when introducing a 10% production subsidy in the WTO-GTM with the trade balance fixed. We see that making the subsidy revenue neutral always results in a higher decrease in GDP. But of the various methods available to finance the subsidy, consumption tax results in the least amount of decrease in GDP.

Each tax introduces a different level of distortion in the economy. Literature shows how an indirect tax is proved to be more distortionary than a direct tax. Hence, financing the subsidy by increasing consumption tax would lead to higher allocative efficiency losses compared to raising direct taxes. This change causes the loses in the experiment raising consumption tax, to be higher. Change in total Allocative efficiency in China for the three scenarios is reported in Table 7, which validates the theory that a consumption tax raises distortion more than a factor income tax.

Figure 27: Changes in real income % for different experiments introducing a 10% subsidy and financing it by raising different kinds of taxes

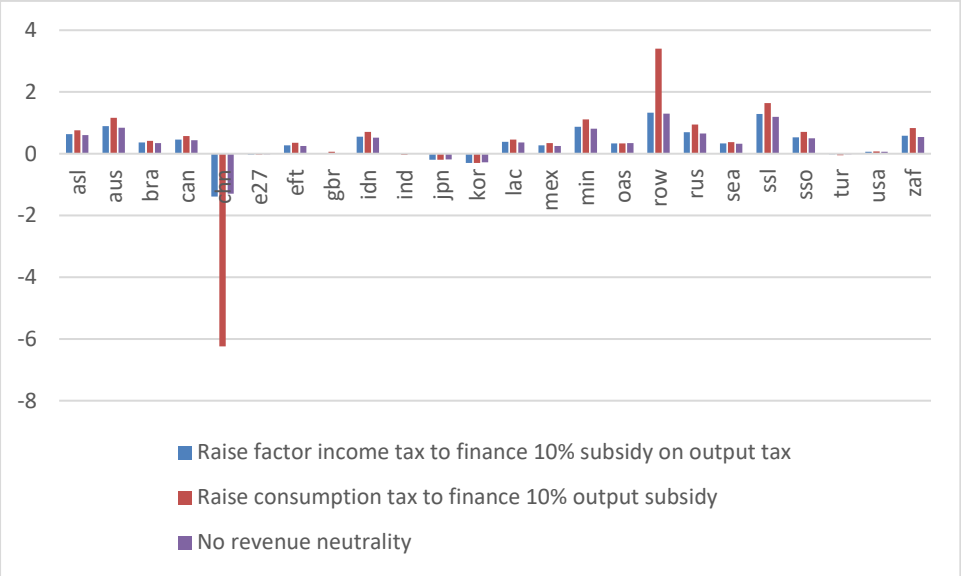


Table 7: Changes in Allocative efficiency, TOT, EV and residual in China for the three different scenarios

Scenario	EV change	Allocative efficiency change	TOT change	Residual
Raise factor income tax to finance 10% subsidy on output tax	-128828	-27880.3	-72114.1	-28833.6
Raise consumption tax to finance 10% output subsidy	-576996	-447918	-91704.9	-37372.7
No revenue neutrality	-119673	-25217.5	-68584.6	-25870.6

6 CONCLUDING REMARKS

With a focus on the airline industry, Europe succeeded in challenging the dominance of Boeing by the creation of Airbus using its industrial policy. More recently though, China`s industrial policy with an investment of over 70 billion dollars failed to create a Chinese commercial aircraft to become a competitor to these age-old companies, showing the fickleness or unpredictability of industrial policy (Agarwal, 2023). The conclusion our paper reaches is similar to the lesson learned from the above example. Europe`s success with airbus shows us that the traditional idea that all subsidies will lead to a decline in economic welfare may not be true. However, China`s experience teaches us that subsidies may not always be the solution.

Our analysis of subsidy policy using a standard general equilibrium model with data based on GTAP v11, shows that the traditional hypothesis that unilateral subsidies harm the subsidizing region holds for a large number of cases but is highly sensitive to the design of the policy – the size of the subsidy, whether the subsidizing region is a small or a large economy, how one chooses to ensure revenue neutrality – as well as the assumptions made in the model environment – endogeneity of capital, whether or not the trade balance is held fixed and assumptions on the savings rate. This high dependence of the result on assumptions and policy design, leads us to believe that the traditional point of view holds under specific conditions alone. It is important to note however, that while literature contesting the traditional notion focuses on introduction of competition or externalities in the model, we find that within a perfectly competitive model as well, subsidies may lead to increases in economic welfare.

In terms of spillover effects as well, the traditional view that spillover effects of subsidies are positive holds for many regions. However, the abundance of exceptions to this rule makes it clear that this view presents only a partial picture of the reality. Our establishment of the four channels – downstream effects, upstream demand effects, upstream competition effects and competition effects – helps understand the complete picture and identify why some regions benefit from positive spillover effects, while others face negative spillover effects.

Changing the model assumptions shows that under a flexible trade balance, or endogenous capital or flexible savings rate it is more likely that a region benefits in terms of economic welfare effects from the provision of unilateral industrial subsidies. The next set of analyses shows that the welfare effects in the subsidizing region responds to the size of subsidy in a non-linear manner. Additionally, the size of the economy itself affects the level of welfare changes as it determines the level of influence the economy exercises on world prices. Furthermore, indirect taxes are more distortionary and increase the cost of the subsidy and may lead to a fall in overall economic welfare.

All these conclusions for unilateral subsidies however, do not take into account the effect of responses of other regions to their subsidies. Such responses are the major deterrent to governments implementing subsidies with ease as they reveal the real threat to the economic welfare of the subsidizing region which is the possibility of too many subsidies. As our results establish all regions introducing a subsidy simultaneously leads to economic gains in most regions, with a select few regions bearing the economic costs of these gains. Interestingly, however, the regions with a decline in welfare like India, would lose more if they were to not join this subsidy race. This shows that the size of an economy as well as its competence in the manufacturing sector affects the impact on their welfare of a subsidy war. Furthermore, it indicates that there is a clear risk of reaching an outcome with excessive subsidies.

Our results provide valuable insights into the operating mechanisms of subsidies helping identify conditions under which such subsidies might benefit regions. However, it also establishes that there is always a risk of retaliation in identifying winners and implementing an industrial policy. A subsidy war based on the sector being subsidized can harm or aid regions. But which regions benefit and which are harmed is uncertain and it would thus, be beneficial for all regions to avoid a subsidy war.