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INTERNATIONAL PRICE TRANSMISSION IN CGE MODELS: HOW TO RECONCILE ECONOMETRIC EVIDENCE AND ENDOGENOUS MODEL RESPONSE?

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Abstract

The field of price transmission is dominated by econometric time-series analysis (PTA) and rather disconnected from analyses based on CGE models. This paper addresses how a certain degree of empirically determined price transmission can be met in a single country CGE model. We examine and validate seven determinants including structural characteristics of the model, the parameterization of behavioral functions and properties of the sectors concerned.

Keywords

price transmission, CGE models, international trade.

1 Introduction

The literature on the empirical analysis of the transmission of international prices to domestic markets is dominated by specific analytical methods such as cointegration analysis and the estimation of error correction models. However, the connection to the world of Computable General Equilibrium (CGE) modeling, despite its powerfulness in showing the economy-wide implications of price changes, is limited. Various empirical studies provide estimates on price transmission elasticities from world market to domestic prices (e.g. MUNDLAK and LARSON,1992; BAFFES and GARDNER (2003) which could be used as a basis for CGE validation and calibration, which is rarely done.

The missing reconciliation among the research fields of econometric price transmission analysis (PTA) and CGE analysis could be due to several reasons such as: (1) Empirical PTA being often more concerned with high frequency data and short term adjustment processes, which does not reconcile well with the typical solution period (annual averages) and simulation horizon (medium to long term) of CGE analyses; (2) Different research teams in econometric time series analysis and CGE modeling with typically little overlap; and (3) Price transmission being endogenous to CGE models and determined by a wide range of model parameters and specifications and their interaction such as trade shares, share of the sector concerned in the economy, Armingtonelasticities, elasticities of substitution among value added and intermediate inputs as well as within these input categories and factor market closures in general.

As a consequence, the calibration of CGE models to empirically observed price transmission is not straightforward: an infinite combination of model parameters and specifications allows for reaching a certain level of price transmission. This paper addresses the question of how a certain degree of price transmission from the international to the domestic market, which may be determined empirically e.g. based on a vector error correction model, can be met in a single country CGE model. To this purpose, we employ as "laboratory" a single country CGE model developed by MCDONALD (2009) and adjusted to a social accounting matrix for Israel (SIDDIG et al., 2011). We first formulate a priori assumptions on which model specifications and parameters in a CGE are the main determinants of the resulting degree of price transmission. Subsequently, we analyze in a systematic sensitivity analysis the impact of these determinants and their interaction and show how exogenously given degrees of price transmission

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can be met endogenously in a CGE based on the calibration of various parameters. As a simple and significant shock, we apply a doubling of international cereal and other crop prices, which is not far from what was observed during the years 2007 and 2008, and investigate how this translates to domestic prices in the Israeli economy, which has high import shares for these products.

The paper is organized as follows: We first describe in Section 2 the model including its closure rules and the price system, while in section 3 we highlight the database including the SAM and behavioral elasticities, and we describe the selected food sectors in Israel. Afterwards, we formulate a priori expectations on the main determinants of price transmission in Section 4. Subsequently, we present the results of a systematic sensitivity analysis in Section 5 and conclude in Section 6.

2 The Model

The single country Computable General Equilibrium (CGE) model STAGE (MCDONALD, 2009) is used as a basis of our experiments. STAGE is a Social Accounting Matrix (SAM) based model with a mix of non-linear and linear relationships that depict the behavior of the economy's agents. It is a static model with households maximizing their utility according to preferences represented by Stone-Geary utility functions. They consume commodities available in the domestic market from both domestic production and imports. The substitution between domestic and imported goods is governed by the Constant Elasticity of Substitution (CES) specification (ARMINGTON, 1969). Israel is a small country in the world market of wheat, other cereals, and other crops, which are the focus of this study; hence world market prices for imports and exports are fixed in the model.

Domestic production is modeled as a two stage production process with a CES function on the top, where intermediate input and value added are combined to generate the output of each activity. At the second stage, intermediate inputs are combined according to Leontief technology, while value added (land, labour, and capital) is combined according to CES technology, with the optimal ratio of production factors being determined by relative prices. The domestic production of commodities is sold in the domestic or the export market based on a Constant Elasticity of Transformation (CET) specification and dependent on relative prices in these markets. The model is implemented in General Algebraic Modeling System (GAMS) software and adapted to an Israeli SAM (SIDDIG et al., 2011).

The Israeli 2004 SAM is a detailed SAM that comprises one account for capital, one for land, and 36 accounts for labour. For the purpose of this paper, neither the different labour accounts nor the accounts of taxes on them are at the focus and hence are discussed as one aggregated labour account.

2.1 Prices in the model

Figure 1 shows the interrelationships between the prices for commodities and activities as depicted by the model. The supply prices of the composite commodities (PQSc) are defined as the weighted averages of the domestically produced commodities that are consumed domestically (PDDc) and the domestic prices of imported commodities (PMc), which are defined as the product of the world prices of commodities (PWMc) and the exchange rate (ER) uplifted by ad valorem import duties (TMc). These weights are updated in the model through first order conditions for optima. The average prices exclude sales taxes, and hence must be uplifted by (ad valorem) sales taxes (TSc) and excise taxes (TEXc) to reflect the composite consumer price (PQDc).

Figure 1:   Price Relationships for the STAGE Model
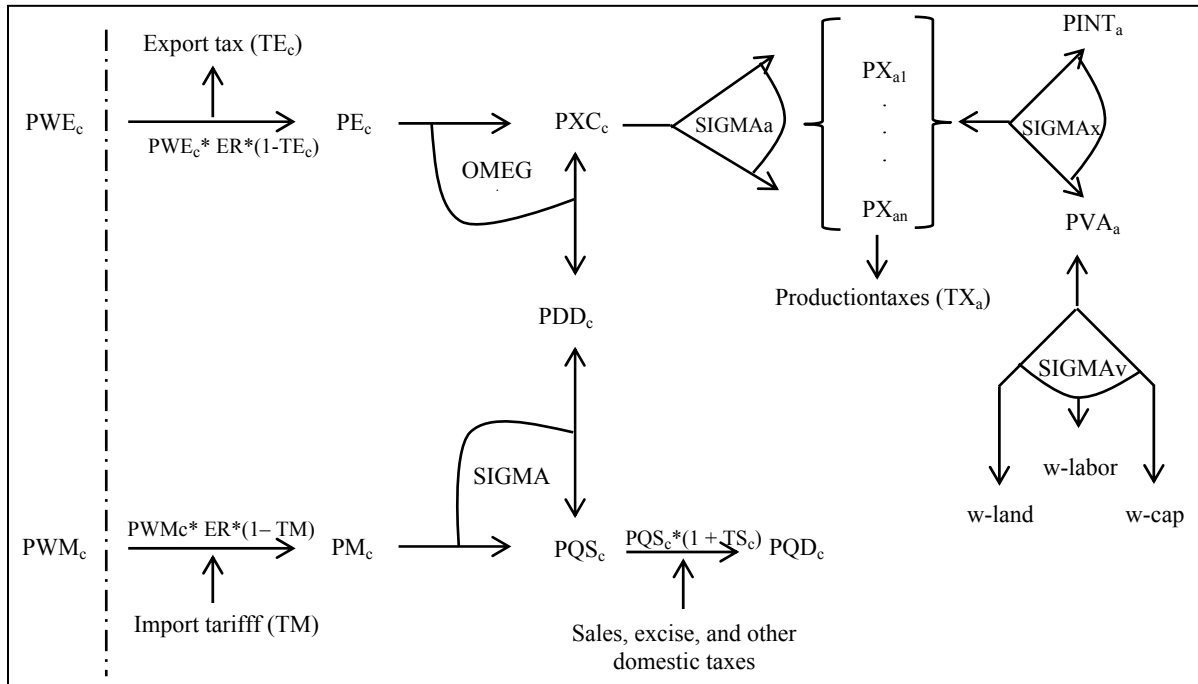
Source: Modified and extended from MCDONALD (2009).

The producer prices of commodities (PXCc) are similarly defined as the weighted averages of the prices received for domestically produced commodities sold on domestic (PQSc) and export (PEc) markets. These weights are updated in the model through first order conditions for optima. The prices received on the export market are defined as the product of the world price of exports (PWEc) and the exchange rate (ER) less any export duties due, which are defined by ad valorem export duty rates (TEc).

This study focusses on a sample of selected prices to investigate the determinants of price transmission from the rest of the world to the domestic market. The selected prices are producer prices of commodities (PXC), consumer prices for domestic supply of commodities (PDD), supply prices of composite commodities (PQS), value-added prices for any production activity (PVAa), and intermediate input prices for any production activity (PINTa). The concerned elasticities are also shown in the figure as the trade CES (SIGMA), production CES at the top level (SIGMAx), production CES at the second level (SIGMAva) and trade CET (OMEGA).

2.2   Model closures

For our analysis we apply the following standard closure: the model is investment driven with the share of investment in domestic final demand being fixed. The government account, all tax rates and government consumption expenditures and transfers are assumed fixed with the equilibrating variable being government savings. For the factor market, all production factors are assumed fully employed and mobile across sectors in the default closure. However, a modified factor closure that considers the amount of capital, skilled labour and land to be fixed and activity specific, while unskilled and semi-skilled labour is fully mobile and fully employed is also applied in the experiments. The current account balance is assumed fixed and the exchange rate is the equilibrating variable in the default closure. Import and export prices are always fixed.

3   The Database

3.1   The Social Accounting Matrix

The Israeli SAM that represents the Israeli economy in the year 2004 is the main database used in this study. It incorporates 43 sectors, 36 labor accounts, 10 household groups, and 18 tax categories other than taxes on production factors (SIDDIG et al., 2011). The SAM was developed based on data obtained from different official sources in Israel including the Israeli Central Bureau of Statistics (ICBS), the Central Bank of Israel (BOI), and the Israeli Tax Authority (ITA). In addition, non-Israeli sources were used to fill-in gaps in domestic reports such as the World Trade Organization (WTO), the Organization for Economic Co-operation and Development (OECD), and the World Bank.

For this study, the details on production factors, households, or taxes are not relevant; therefore, they will be treated as aggregates throughout the discussion. What matters from the viewpoint and for the objectives of this study is how the selected food sectors are represented in the SAM and what weight they have in the entire Israeli economy.

3.2   The selected food sectors

Despite their importance in meeting domestic food demand in Israel, wheat, other cereals, and other crops do not represent big shares in aggregated economic variables such as exports, imports, and production. Table 1, shows the percentage share of each in total Israeli imports, exports, production, and factor use. The three commodities together represent only 1.7% of total Israeli imports, 0.8% of exports and only 0.4% of domestic production. However, their share in the total cultivated land is 33.1% with other crops alone occupying 23.4%. This implies that the three crops will be sensitive to the land closure, while changes in the three crops are expected to have minor influence on economic variables at the macro-level.

Table 1:   **Shares of the three commodities in selected variables of the economy (%)**

	Import	Export	Production	Land use	Labour use	Capital use
Wheat	0.37	0.00	0.03	6.97	0.03	0.01
Other cereals	0.59	0.01	0.03	2.87	0.01	0.07
Other crops	0.72	0.75	0.31	23.35	0.25	0.34
Total	1.68	0.76	0.36	33.18	0.29	0.42

Sources: SIDDIG, et al. (2011), own calculations.

The share of domestic production in total supply is lowest for other cereals, comprising all cereals other than wheat, where about 74% is imported, followed by wheat with 71% of its domestic supply being imported (Figure 2). Other crops, which is the biggest among the selected three sectors, has only 30% of its domestic supply imported. Accordingly, other crops sectors is expected to be less responsive to the international market prices from the import side compared to wheat and cereals.

Figure 2:   **The components of domestic supply**
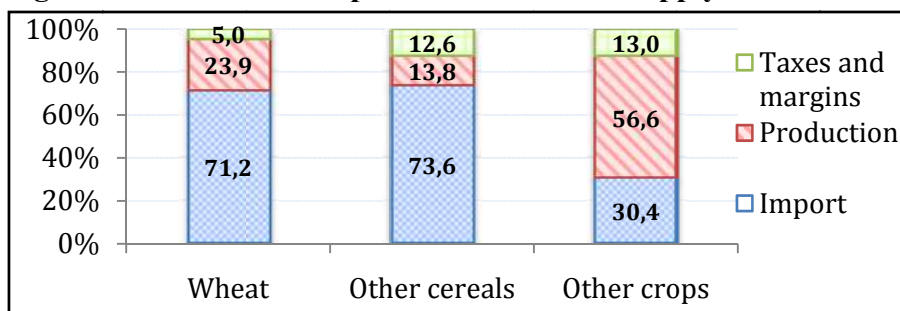
Sources: SIDDIG, et al. (2011), own calculations.

On the domestic demand side of the three sectors, shown in Figure (3), wheat and other cereals are mostly demanded as intermediates, which account for 99% and 95% of their total demand, respectively. The situation is different for other crops with 44% demanded as intermediate, 32% for exports, 20% by households, and 5% for investment. These different demand structures are also expected to result in different impacts of world prices changes on domestic markets. For example, the higher export share of other crops should result in domestic prices of this product being more responsive to changes in export prices than those of wheat and other cereals.

Figure 3: **Components of domestic demand**
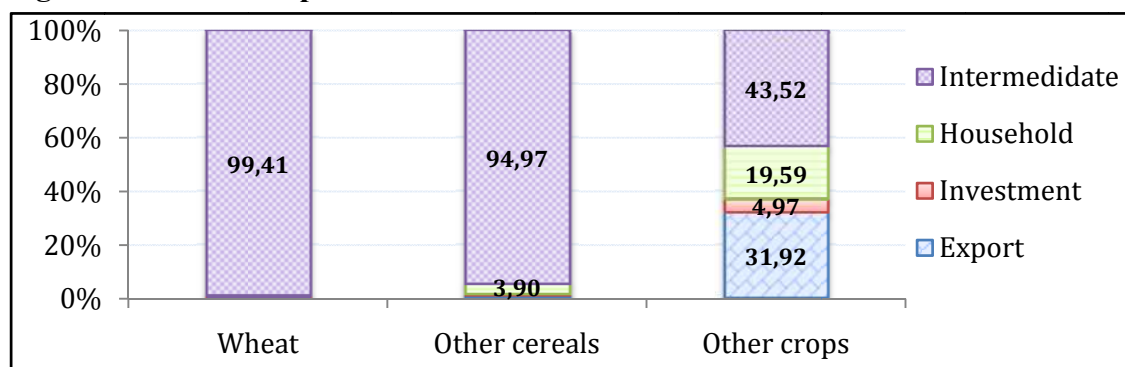
Sources: SIDDIG, et al. (2011), own calculations.

The cost structure of the three sectors does not differ very much. The share of intermediate demand by wheat, cereals, and other crops in the total cost structure is 62%, 54%, and 56%, while the share of the demand for primary factors is 37%, 43%, and 43%, respectively. The remaining share is devoted to taxes on production and factors of production.

3.3 Elasticities

Four sets of elasticities are considered crucial in the determination of the level of price transmission from the world into Israel through imports. Namely, the constant elasticity of substitution (CES) between imports and domestic goods, the CES between value added and intermediate inputs, the CES for the substitution among the different value added components, and the constant elasticity of transformation (CET) between exports and domestic goods. Section 4 will further add on the assumptions related to the influence of elasticities on the transmission of the world price of imports and exports to domestic markets, while the results section will assess and validate these assumptions based on our empirical findings.

For the default version of our model analysis (pre-sensitivity analysis), the values of the four elasticities are assumed to be 2.0 for the trade elasticities (CES and CET) and 0.8 for production CESs at top and second levels. The selection of these values is based on educated guesses governed by our knowledge about the Israeli economy and guided by the elasticity ranges recommended by SADOULET and DE JANVRY (1995).

4 A Priori Assumptions on Drivers of Price Transmission

A priori, we hypothesize the following model components, parameters, and specifications to be crucial in the determination of the degree of price transmission between international and domestic prices:

First, trade share (import and export): the higher the trade share of the sector, the higher the transmission of world market price changes to the domestic market (imperfect substitutes; if the initial trade share is very small, it can't become large; substitution with domestic products is therefore limited (HANSLOW, 2001; KUIPER and VAN TONGEREN, 2006).

Second, value share in the domestic economy: the higher the share of the sector in the domestic economy, the higher the impact created by the change in world price on the domestic market price. This is because the domestic price increase is dampened by more production, which happens more easily with smaller sectors. Therefore, if the sector is large, the increase in the price can be dampened to a lesser extent by domestic production.

Third, share in domestic factor use: The higher the domestic production, the higher the demand for factors by producers. This could further differentiate sectors according to their use of the different factors of production with different implicit price elasticities of factor supply. In case a sector relies heavily on aninelastic factor, price transmission is likely to be higher because with increasing domestic production the cost of production would increase more than with a higher factor supply elasticity.

Fourth, degree of factor mobility among sectors: the higher the factor mobility, the lower the price transmission. This is because increasing domestic supply in case of increasing international prices dampens the increase in domestic prices. But the more immobile factors are, the less this mechanism can work.

Fifth, Armingtonelasticities and CET elasticities between domestic demand/import demand and domestic supply/export supply: the higher the trade elasticities, the higher the price transmission. This is because higher elasticities allow for higher degrees of substitution, resulting in more demand for the domestically produced product in the case of an increasing world market price.

Sixth, elasticities of substitution among value added and intermediate inputs: the higher the elasticities, the more options producers have to substitute primary factors by intermediates and vice versa, and therefore, the less is the price transmission. In addition, also elasticities of substitution within input categories matter, as higher elasticities of substitution enable producers to adjust production and thus dampen the price shock domestically.

Seventh, the prevailing exchange rate policy: the domestic currency tends to appreciate if world prices of commodities which are predominantly exported increase and tends to depreciate in case of rising prices for predominantly imported products. From a price transmission point of view, an increasing world price together with a flexible exchange rate would reduce the pass-through of that increase in case of a currency appreciation and increase the pass-through in case of a currency depreciation. The following section tries to empirically assess and validate the described hypotheses.

5   Results of the Sensitivity Analysis

As a first step, we apply our shock of a 100% increase in world prices for wheat, other cereals, and other crops to the model in its standard parameterization and model closures as described in Section 2. This model is found to transmit the 100% increase in the world price to the domestic prices of the three commodities at very different magnitudes. (Table 2).

Table 2:   Changes in prices using the default settings (%)

Prices	Wheat	Other cereals	Other crops
World price of imports (PWM)	100.0	100.0	100.0
Domestic price of imports (PM)	96.5	96.5	96.5
Supply price of composite commodity (PQS)	68.5	72.8	65.0
Consumer price for domestic supply (PDD)	23.8	27.8	45.1
Producer price (PXC)	25.1	31.7	73.9
Value-added price (PVAa)	88.7	123.7	252.8
Intermediate input price (PINTa)	0.8	3.5	8.4

As a first observation, the percentage increase in PM and PE is only 96.5%, which results from the appreciation of the domestic currency against the dollar by about 1.8%.

While the change of the prices of imports and exports is equal over all products, the transmission to the other domestic prices differs heavily among products. For example, producer prices of wheat, cereal, and other crops increase by 25.1%, 31.7%, and 73.9%, respectively, due to the 100% increase in their world market prices (Table 2). We make an effort to explain differences among products in Section (5.1) based on sectoral shares in the domestic economy as well as the trade shares in total production/use.

5.1   Sector shares

The first a priori hypothesis assumes that the higher the trade share, the higher would be price transmission. The reaction of the selected sectors to the world price increase measured at the domestic supply price (PQS) ranks the sectors according to trade import share as cereals, wheat and other crops with73%, 69%, and 65% increases in PQS, respectively (Table 2). For other crops, the impact on PQS also stems from a strong increase in the export price. Wheat and other cereals though are virtually not exported and the size of the domestic sectors is comparable, such that it seems as if the higher increase in PQS for other cereals stems from its higher import share. For other prices, the picture is less homogeneous. For both, PDD and PXC the price change is strongest for other crops, which can be explained by the high export share and the direct impact of the export price on PXC (see Figure 1). The strong increase in the producer price for other crops motivates the domestic producers to produce more which dampens the domestic price increase and results in a higher increase in its value added price than for other products.

5.2   Factor mobility

We ran the world price shock on the model under the assumption of full factor mobility versus the immobility assumption in order to investigate the impact of factor mobility on the transmission of the world prices in the domestic market. Our expectation is that the level of price transmission is low with high factor mobility. This assumption is validated by our results as shown in Figure 4, where the percentage changes in the prices of the three commodities under the assumption of factor mobility and immobility are shown. Other crops and cereals have particularly shown huge differences in the degree of transmission under the mobility and immobility assumptions. As expected, the highest reactions are at the level of the value added prices, where the percentage changes are 267% and 133% for other crops and cereals under the immobility, respectively, compared to 139% and 67% for the two commodities, respectively under the mobility assumption. The consumer and supply prices of other crops would even deteriorate in response to the 100% increase in the world market price under the factor mobility assumption. This is because other crops would be able to attract production factors and increase production fourfold, driven by the increase in export prices. The strong increase in production would result in a fall of PQS and PDD.

Figure 4: **Changes in prices with factor mobility versus immobility assumptions (%)**
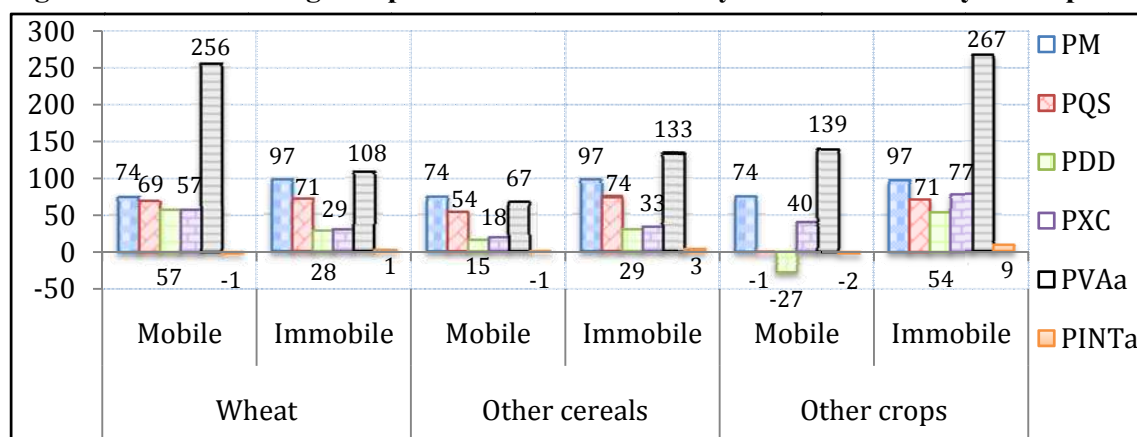

5.3 Substitution elasticities

To analyze the impact of our proclaimed determinants (5) and (6) we perform a sensitivity analysis with several values for the major related elasticities. They are the trade elasticities (CES between imports and domestic goods and the CET between exports and domestic goods) and the production CESs (the one between aggregate primary factors and aggregate intermediate inputs and the CES between the disaggregated primary factors of production). In order to enhance the level of price transmission, the default factor market closure is adjusted to consider the amount of capital, skilled labour and land used to be fixed and activity specific, while unskilled and semi-skilled labour are fully mobile and fully employed. Accordingly, the baseline to which the different sensitivity scenarios are compared relies on this modified factor market closure.

Depending on the sensitivity of the model to the four elasticities (trade CES and CET as well as the production CESs) and its ability to converge, 10 different values are selected for the trade CES and CET covering the range between T1 (0.5) and T10 (9.5), assuming similarity between both of them in each stage. In addition, another 10 values are selected for the production CESs assuming similarity between both of them in each stage, which are ranging between P1 (0.05) and P10 (3.0).

Figure 5 shows the results obtained from the described combination of elasticities. Trade CES and CET are presented at the horizontal axis, while the vertical axis shows the percentage change in prices and the production CESs are identified by the different colors. The results of the sensitivity analysis confirm our fifth proclaimed assumption with respect to the trade elasticities as shown in Figure 5 with all the lines sloping up as T values moves from T1 towards T10. The exception is the composite supply price of wheat where prices keep increasing only if the production elasticity is less than the value of (1). The sixth a priori assumption of that the lower the production elasticities the higher the pass-through is also validated according to our results: According to Figure 5, the percentage change in the price series increases as the production elasticities are moving towards T1 (the smallest value: 0.05). This could easily be observed from the wide vertical spaces between (P) values, which becomes even wider as the elasticity is closer to P1 (see for instance PXC for wheat and cereals).

This being said, the strength of pass-through also differs among the different commodities. Figure 5 shows wheat prices reacting stronger to the production elasticities, which is reflected in the wider spaces between the different lines compared to cereals and other crops. On the contrary, other crops show the lowest reaction among these three selected commodities as the lines are closer to each other for all the price series.

Figure 5: **Percentage increase in prices according to the elasticity combinations**

Wheat | Cereals | Other crops
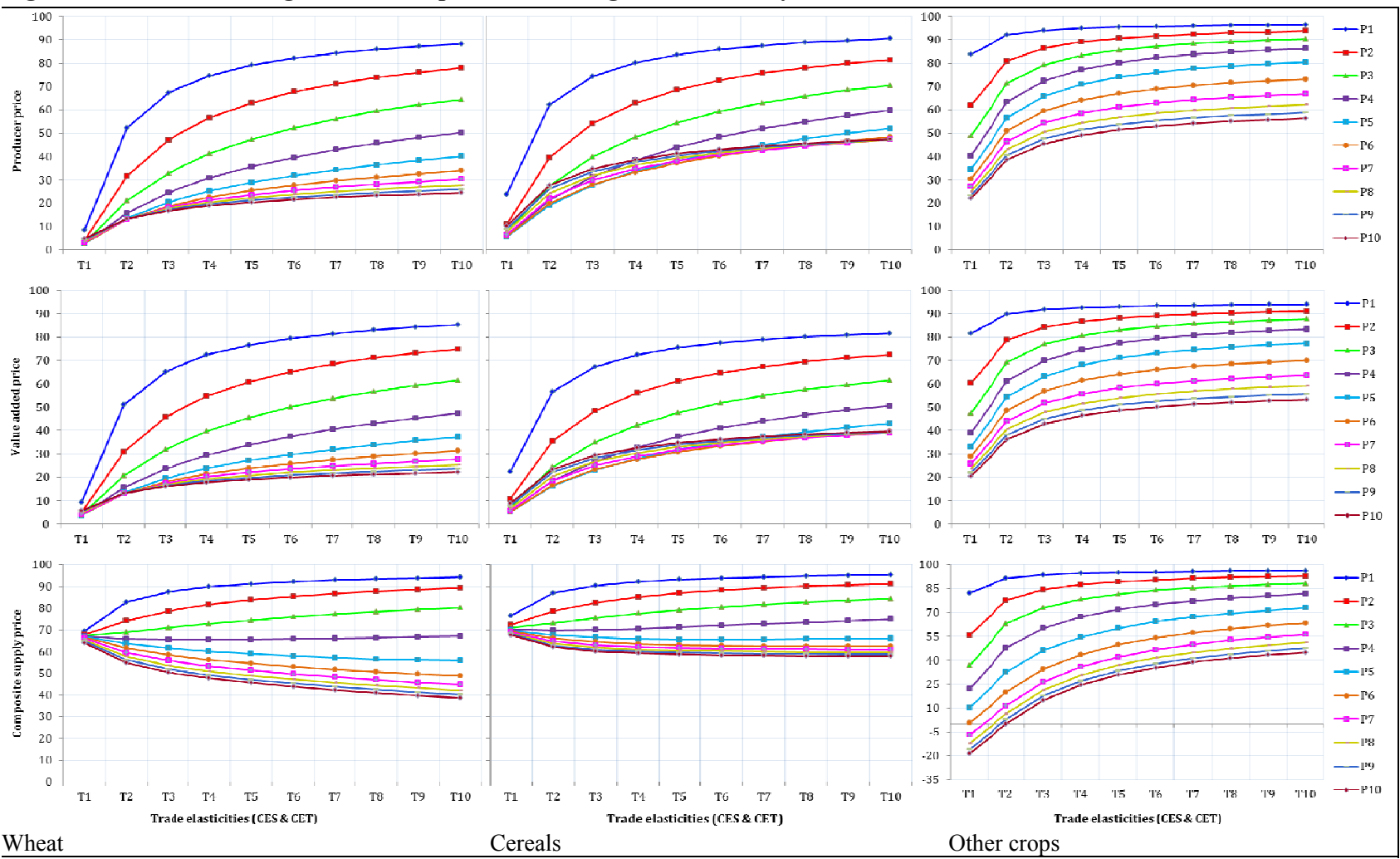
Despite the differences among the three commodities in their size, cost structure, demand components, and factor demand, their overall reaction to the elasticity combinations is found to be consistent with the elasticity-related a priori assumptions. The justification for that the pass-through increases as trade elasticities (CES and CET) increase is that domestic producers would realize higher demand for their products due to domestic supply cuts caused by the higher world prices as imports decline and exports expand. If the domestic goods in this case are not good substitutes for the imported ones, the reduction in imports and the increase in exports would hardly happen. The higher the production CES, the stronger the reallocation among production factors and intermediates which allows for a stronger response to the higher world prices. Thus, the higher the production CES, the more the ability of the producers to react and dampen the domestic price increase by additional supply and vice versa.

Generally, a certain level of price transmission can be achieved by various combinations of trade and production elasticities which result in the desired level of price transmission. If, for example, the time series analysis confirms that a world market price increase by 100% would transmit fully to the producer price of other crops, then the CGE model should be able to generate an increase in producer price close to 100% in response to such a world price shock. E trade elasticities at T10 and production elasticities at P1 would result in the desired result. However, the selected values of trade elasticities are higher than the recommended range of elasticities that CGE modelers tends to rely on (SADOULET and DE JANVRY, 1995)[1]. Thus, these results indicate the importance of considering the specifics of individual countries and commodities in judging plausible elasticity values. Furthermore, calibrating a certain degree of price transmission would typically be only one of many objectives in the parameterization of a CGE.

With these results we confirm and validate our fifth and sixth hypotheses, which assume that trade and production elasticities have significant influence on the degree of price transmission from the world to the domestic market within the CGE framework. It is also shown that the transmission is higher if we increase the value of the trade elasticities, while it is lower if we increase the value of the production elasticities. Therefore, the elasticity combination that allows the CGE model to generate the highest level of pass-through is always the one that considers high trade elasticities together with low production elasticities.

5.4   The prevailing exchange rate regime

To examine the influence of the prevailing exchange (EXR) rate regime of the prices pass-through, an updated model closure is applied with fixed EXR regimes. As discussed above, the domestic currency appreciates under our 100% world market price shock. This implies that the domestic import and export price changes would be smaller than the world market price changes. A fixed exchange rate regime in contrast would assure that changes in the domestic prices of imports and exports would remain similar to the changes in world prices as the EXR would remain fixed at the value of 1. Figure 6, compares the pass-through of a 50% increase in the world prices of exports and imports for the three selected commodities.

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[1]   Experience has shown that the empirical results obtained from simulations with CGEs are quite insensitive to the specific values of elasticities, while, they crucially depend on their order of magnitude. The possible range of substitutability is relatively well represented by four values: 0.3 for very low substitutability, 0.8 for medium low, 1.2 for medium-high, and 3.0 for very high (SADOULET and DE JANVRY, 1995).

Figure 6: **The pass-through of 50% increase in world prices under flexible and fixed exchange rate regimes**
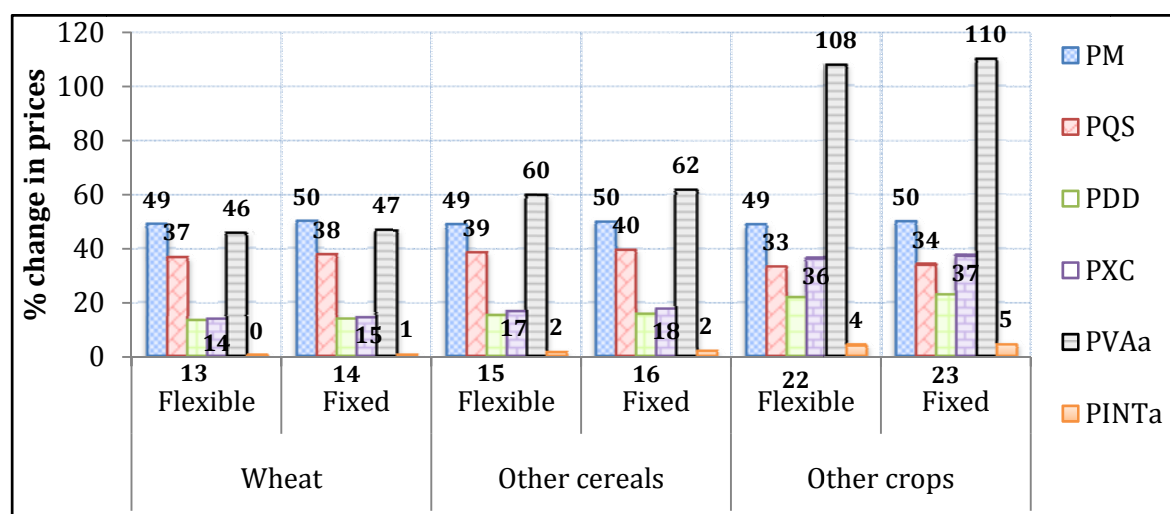

Figure 6 confirms our seventh a priori assumption that a fixed exchange rate results in a higher pass-through of world price increases to domestic markets in case of a currency appreciation and an increase in world market prices. However, if world prices decrease, the pass-through of that decrease would be higher in the case of a fixed EXR compared to a flexible EXR.

6   Conclusions

Despite the growing number of studies analyzing the pass-through of international prices to domestic markets, particularly after the 2006-2008 food price increase, the empirical methods applied are concentrated on econometric time series analysis such as cointegration analysis and the estimation of vector error correction models. These are powerful methods to describe and forecast price relationships through time, yet compared to economy-wide models such as CGE models, they are less informative regarding implications a certain level of price transmission might have on different actors of the economy.

It therefore seems adequate to use a variety of tools that connects both techniques and harmonizes their linkages in a way that captures and reflects the strength of each. An attractive approach is to calibrate CGE models to meet the level of price pass-through empirically determined by time series analyses, which is our motivation to conduct this study. We hypothesize seven different determinants, based on general economic sense and trade theory, of the pass-through of international prices to domestic markets. They are grouped in four major categories: (1) structural characteristics, such as the size of the concerned commodity in the domestic economy in terms of supply, demand, production, and trade, as well as its share in the use of domestic factors of production; (2) model closure and basic assumptions related to the mobility of production factors; (3) model parameterization, including assumptions related to the substitution possibilities among domestic and traded goods, as well as producers' options to substitute primary factors by intermediate inputs or to substitute different primary factors for one other; and (4) the prevailing exchange rate regime.

We use a single country CGE model developed by MCDONALD (2009) together with a detailed Israeli SAM for 2004 (SIDDIG et al., 2011) as the basis for our experiments. Our findings confirm that the price pass-through from international to the domestic markets in CGEs can be controlled for by configuring its closure rules, production and trade elasticities, factor market closures, and exchange rate regime. General conclusions include the following: (1) higher trade shares of the sector result in greater transmission of the world market price to the

domestic market; (2) increasing export prices together with low CET elasticities and high production elasticities may even result in negative effects on domestic consumer prices; (3) greater factor mobility results in lower price transmission; (4) higher trade elasticities result ingreater price transmission; (5) higher production elasticities (top and second level) result in more substitution options for producers and less price transmission; and (6) the pass-through of an increasing world price is higher under a fixed exchange rate regime compared to a flexible one if the domestic currency appreciates due to the world market price shock.

The described approach to depict the observed transmission of international commodity prices to domestic markets may be helpful in considering a combination of PTA and CGE modeling. The possibilities of combining the different assumptions on the model structure, elasticities, and closure rules to meet a certain degree of price transmission are manifold. The modeler therefore has considerable freedom to choose a model formulation which targets a certain degree of price transmission. This freedom is helpful, as achieving a certain degree of price transmission will typically be just one target among others, such as capturing the real economy accurately in the choice of factor market closures or basing behavioral parameters on empirical analysis.

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