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The Long-Run Impact of Energy Prices on World Agricultural Markets: The Role of Macro-Economic Linkages

by

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Abstract:

The world prices of food and energy products have followed similar large swings in recent years. We investigate the long run relationship between these prices using a world Computable General Equilibrium model with detailed representations of food and energy markets. Particular attention is paid to specify macro-economic linkages which have often been overlooked in recent analysis and debate. We find that the omission of these macro-economic linkages has a substantial bearing on this relationship. A positive relationship due to the cost push effect has been identified in most analysis, but we find that the introduction of the real income effect may indeed imply a negative relationship between world food and energy prices. Accordingly, it is crucial to move from a sector-focused analysis to a system wide approach when analyzing the linkages between global energy and food markets.

1. Introduction

The world prices of crude oil, oil products, and more generally energy products, have dramatically increased over the last four years, particularly in the first half of 2008. For instance, the price of crude oil was close to 150 dollars per barrel at its highest point in July 2008. From this record in nominal terms, these prices then plummeted dramatically. In the first month of 2009 the crude oil price was lower than 50 dollars per barrel.

The world prices of the main arable crops (cereals, oilseed products and, to a lesser extent, sugar) have roughly followed the same pattern. For instance, the world price of wheat increased moderately from 2005 to 2007 and then boomed to reach as much as 400 dollars per ton in March 2008. The wheat price then returned to a more normal level in early 2009 (around 175 dollars per ton).

These extreme price evolutions have led to numerous comments in the media and to economic analysis aimed at understanding their precise causes and consequences (notably on levels of starvation in developing countries). Great emphasis has been placed on the role of biofuels as a key transmitter of energy prices to agricultural prices. The world production and consumption of biofuels have developed considerably over the past years. The rising crude oil price certainly contributed to this development by stimulating biofuel demand (Abbott et al., 2008). Public policies implemented in developed countries (the United States (US) and the European Union (EU)) also played a significant role in these price evolutions, through the application of subsidies and mandates. These latter instruments provide a valuable insurance to biofuel producers facing uncertain crude oil prices and hence secure investments in that sector (Collins, 2008).

Aside from biofuels, energy prices affect world agricultural markets through many others channels. In particular, higher energy prices imply higher agricultural production costs. In the very short run, it is doubtful that agricultural prices perfectly reflect the production costs due to the quasi fixed nature of some farm production factors (like land, capital and family labor). However, agricultural prices are more likely to be driven by production costs in the medium/long run. The impact of energy prices on world agricultural markets also occurs through the cost of processing and transporting these products. For instance, the distribution of spatially dispersed farm production to consumers more concentrated in urban areas inevitably involves some transport costs that are significantly influenced by energy prices (Chevroulet, 2008). Finally, energy prices influence world agricultural markets through what we call macro-economic effects. More precisely, energy prices have a significant impact on real income as well as on trade balances. In the case of an increase of prices, the effects are positive for crude oil producing countries, and vice versa. The effects are obviously opposite for energy consuming countries. The subsequent impact on world agricultural markets of these macro-economic effects also depends on the macro-economic policies pursued around the world (e.g. free versus fixed exchange rate regime, wage policy with respect to price inflation, etc.). For instance, Vincent et al. (1979) examine these macro-economic linkages between energy and food sectors using a Computable General Equilibrium (CGE) model for the Australian economy calibrated with short run elasticities. Their analysis shows that the Australian policy of wage indexation significantly influences the results. Hanson et al. (1993) also investigate this issue with a CGE model for the US economy. They reveal the significant effects of macro-economic closures on farm results, in particular the assumption regarding trade balances.

In summary, the impact of energy prices on world agricultural markets is complex and the various effects can pull in opposite directions. Moreover, the forces of these different effects depend on the time horizon considered in the analysis. To our knowledge, recent studies consider some of the effects but generally fail to include macro-economic effects. Tokgoz et al. (2008) measure the impact of an increase of crude oil price by 10 US dollar per barrel (equivalent to 18 per cent) on US farm prices using the FAPRI system of Partial Equilibrium (PE) models. This system includes the effects occurring through biofuels, production costs and transportation costs but not the macro-economic effects. They find that the impacts in 2016 differ considerably across products, from a 20 per cent increase for corn prices to 1.2 per cent for milk prices. The OECD/FAO (2008) also examines the long run impacts of oil prices on world agricultural markets using the AGLINK/COSIMO system of PE models. The same effects are included in this system while macro-economic effects are again excluded. On the other hand, this study isolates the sole effects of crude oil prices occurring through production and transport costs while assuming exogenous (policy driven) biofuel production. They simulate a 29 per cent decrease of crude oil price (from 104 to 74 US dollars per barrel) in 2017 and find that this induces a decrease in the price of vegetable oils by about 10 per cent and of cereals by about 7 per cent. In other words, the world arable crop prices are highly sensitive to petroleum price assumptions according to this study. This comes solely from a cost push effect as the world biofuel production is fixed.

Our objective in this paper is to measure the long run impacts of energy prices on world agricultural markets taking into account macro-economic linkages. The main theme of this paper is to find out whether the largely ignored macro-economic effects of energy prices can reverse the other effects on world agricultural prices. We do this by using a CGE model defined at the world level and with detailed farm and energy sectors. CGE models are obviously relevant economic tools for performing such analyses because they capture the interactions among the different economic sectors and macro-economic identities. More precisely, we start from the standard GTAP model (Rutherford, 1998) calibrated on the GTAP 6 database representing economic flows of the year 2001. We depart from this textbook version by developing more relevant specifications for the agricultural sectors (following the GTAP-Agr specifications described in Keeney and Hertel, 2005) and for the energy sectors (following the

GTAP-E specifications described in Burniaux and Truong, 2002). In this updated version, we assess the importance of macro-economic linkages by running the model with and without some macro-economic identities. We simulate the same energy shock (a 20 per cent reduction in world oil reserves) on these different frameworks. As anticipated we find that the world agricultural effects are highly dependent on the inclusion of macro-economic linkages. For instance, the positive impact on the world wheat price is reduced by half while the impact on the world beef price simply moves from positive to negative.

Before turning to the description of the modeling framework (section two) and the analysis of simulation results (section three), one remark is in order. In this paper, we assume that the world production of biofuels is fixed for three main reasons. First, our main purpose is to expand on current analysis by stressing the importance of macro-economic linkages. Second, the relative contribution of increased oil prices and biofuel public policies in the current development of biofuels is highly uncertain (Collins, 2008). Like the OECD/FAO analysis, assuming biofuel production reduces the number of controversial assumptions without fully preventing our analysis. Third, we consider scenarios where the real crude oil price remains lower than 60 US dollars per barrel. Even without the uncertainty considerations raised above, this is a level where biofuel profitability with currently available technologies is highly dependent on public support (de Gorter and Just, 2008).

2. The modelling framework

a. The starting point

The GTAP framework consists of a detailed database representing the world economic flows (incomes, production, demand, imports and exports of many products in many regions) and a CGE model to simulate scenarios. This framework has been widely used to investigate many global issues (such as climate changes, multilateral trade liberalization, etc.) as well as sectoral issues, including agricultural and energy policies. To our knowledge, the interaction of agricultural and energy markets/policies at the world level has not been analyzed within this framework. Here we briefly report the main characteristics of the standard version of this model. Then we explain the modifications introduced to capture agricultural and energy specificities. We also describe the new specification of household preferences we develop to capture more realistic substitution patterns between these products. We finally discuss the different macro-economic closures we use in our analysis.

The standard GTAP model adopts some simple assumptions such as perfect competition, constant returns to scale technologies, static behavior with no risk consideration, and no financial markets. Functional forms to represent production technologies, household preferences over goods and sources (domestic/imports as well as over different exporting regions) and factor mobility across production sectors are mostly of the Constant Elasticity of Substitution (CES) / Transformation (CET) type with elasticities ranging from 0 to infinity. In particular, imports are modeled according to the highly disputed CES-based Armington specification which assumes that goods are differentiated by sources.

The standard GTAP model can theoretically be simulated for any commodity aggregation ranging from 1 to 57 and any number of regions up to 85 using the version 6 GTAP database. In practice the dimensions of the model are often reduced and highlight the sectors/countries of interests. Our region and commodity aggregation (table 1) isolates the main actors and commodities in the world energy and agricultural markets.

b. Modelling agricultural specificities

Keeney and Hertel (2005) argue that the standard GTAP model is not specifically designed to analyze agricultural issues. They then develop a special version nicknamed GTAP-Agr. Most differences between the standard GTAP and the GTAP-AGR model lie in the values of some transformation elasticities (agricultural primary factors are less mobile) and final demand elasticities (with calibration to more recent estimates). Also different is the nesting of the CES function in the description of agricultural production technologies (substitution possibilities between inputs are higher and more differentiated across couples of inputs). In a very general way these changes allow a better calibration of the price elasticities of agricultural supplies and thus a better representation of the farm problem. Basically we implement all these changes in the standard GTAP model with one little exception regarding the final demand specification (see below).

c. Modelling energy specificities

In the same vein, the GTAP framework has been widely used to analyze energy issues and researchers often depart from the standard version to include more realistic substitution patterns between energy products. Burniaux and Truong (2002) develop a special version nicknamed GTAP-E to introduce these specificities. This involves two main modifications. First, the derived demand of energy products by firms is specified using a top-down approach allowing capital and energy to be either substitutes or complements in an augmented value added nest. The substitution between energy products in this nest is captured by different CES functions. Second, the final demand for energy products by households is also modified assuming a strong separability between energy products and other final products. The substitution between energy products at the final demand level is again captured by different CES functions. Again we implement all these changes in the standard GTAP model with still the one little exception regarding the final demand specification (see below). It should be mentioned that there is much more uncertainty about the true values of substitution elasticities between energy products (Beckman and Hertel, 2009). Here we adopt the "validated" medium to long-run elasticities used in the GEMINI-E3 model (Bernard et al., 2008).

d. Modeling household preferences

The standard GTAP model is based on the assumption of a representative household which first allocates its income across savings, private and public consumption in fixed proportions. Private expenditures are then split across the different commodities using a Constant Difference of Elasticities (CDE) expenditure system. This expenditure system is flexible enough to allow independent information on own-price and income elasticities to be used in the calibration of preferences parameters. However, cross price elasticities are derived from the above information and this may result in strange substitution patterns across goods. This is one reason why some nesting in final demand preferences has been developed in some GTAP versions (like the GTAP-E). Private expenditures are still first allocated according to a CDE demand system across commodities or groups of commodities. In a second step, commodity demands inside these groups are modeled with CES functions.

In this paper, we depart from this traditional specification in two important ways. First, we remove the first stage decisions and assume that both real public consumption and real domestic investment are fixed. Domestic savings adjust to change in nominal domestic investment. This implies that we maintain the initial trade imbalances in the simulations and thus the real exchange rate is endogenous. In other words, we assume that the economies are initially in a steady state with trade imbalances matched by foreign capital account and investment equal to capital depreciation. This macro-economic closure makes sense in the long run horizon considered in this analysis.

Second, we remove the CDE specification in the allocation of private expenditures. We specify a flexible functional form where all substitution patterns across goods (or groups of goods) can be calibrated. We make use of the latent separability concept explained in Gohin (2005). This concept considers that commodities (or groups of commodities) can appear in different nests because they potentially have different functions. When we implement this concept with regular functional forms (like CES), we end up with globally flexible and regular functional forms. A third nice property of this solution is that substitution possibilities are preserved even with large price changes.

We implement this latent separability solution on three aggregates, namely food, energy and other products. Income elasticities of these aggregates are derived from the GTAP database. However, we assume that the substitution elasticity between the food aggregate and the energy aggregate is zero in all countries. We have not been able to find significant econometric evidence supporting the view that energy and food products are net complements or substitutes. Moreover this is often an implicit assumption in sectoral PE models (like agricultural PE models). The substitution elasticities between the food and other products aggregates on the one hand, and between the energy and other products aggregates on the other hand, are calibrated in order to obtain estimated own price elasticities for these different aggregates (as in the GTAP database). Finally the energy and other products aggregates are further decomposed across commodities according to CES functions. Then the food aggregate is further decomposed with a Linear Expenditure System (LES) using income elasticities of the GTAP database. As expected this implies that all food commodities are net substitutes.

e. Alternative macro-economic closures

By definition, CGE models include macro-economic identities. In particular household income is given by the rewards of primary factors, corrected by taxes/subsidies, government net transfers, foreign debts, etc. In PE models, notably those focusing on agricultural sectors, the identities are not specified. Accordingly macro-economic variables are exogenous and most often assumed to be fixed in policy simulations. Typically private household incomes are fixed like in the FAPRI or OECD/FAO analysis mentioned in the introduction.

In order to assess the importance of macro-economic linkages, we develop two variants of the model just described. In the first variant, we assume that private income in each region is fixed. Accordingly we remove the corresponding equation and other macro-economic identities (such as the balance of payments, etc.) are no longer enforced. In this first variant, we maintain the final demand system and thus we still capture the cross price effects in energy and food demand for instance. We call this first variant "fixed income". In the second variant, we still remove the income variable and equation. Furthermore we slightly modify the final demand specifications by removing the cross price relationship between the three aggregates as well as the budget constraints. We thus mimic most agricultural PE models where food final demand responds in line with food prices only. We call this second variant "no budget constraint". In these two variants, we maintain the price of the numeraire (unskilled labor in the Rest of the World) as in the full CGE model so that price impacts can be compared across modeling frameworks.

3. Simulations

a. Definitions

We are now in a good position to evaluate the role of macro-economic linkages when assessing the impacts of energy prices on world agricultural markets. We implement the same shock in our three modeling frameworks. Because a CGE model derives prices and does not usually impose them, we assume in all frameworks that the crude oil reserves around the world are lower than initially anticipated by 20 per cent. The results discussed below are the steady state impacts of a long run decrease in crude oil reserves. These results are obviously dependent on the initial point. As already underlined, we make use of the GTAP 6 database calibrated to the year 2001 where the world crude oil price amounts to 25 dollars per barrel.

b. Market results

The simulated price of crude oil depends on the framework. It appears that the world price of crude oil increases by 114 per cent in the "no budget constraint" framework, by 119 per cent in the "fixed income" framework and finally by 126 per cent in the full CGE framework. In this last case, real income decreases by 3.8 per cent in the EU15, by 2.9 per cent in the US while it increases by 31.2 per cent in Russia. The world real income decreases by 1.2 per cent.

Let us now examine the impacts on world agricultural markets. Under the no budget constraint framework, the wheat market price increases by 3.6 per cent in the EU15, 3.0 per cent in the US and as much as 6.2 per cent in Russia (table 2). This mainly comes from the cost push effect. As expected these price increases penalize final demand and finally production. For instance, the EU15 wheat production decreases by 1.6 per cent. Basically the same effects occur on the beef market (table 3) and dairy market (table 4) as far as the EU15 and US results are concerned. However, the Russian impacts are qualitatively different and can be explained as follows. The reduction of crude oil reserves implies less crude oil extractions and hence less labor opportunities in this sector. This in turn puts downward pressure on wages that finally overcomes crude oil price increases in food processing costs.

Now we move towards to the full CGE model by introducing the household budget constraint with the assumption of fixed real income. In that second framework (second parts of table 2 to 4), it appears that the absolute market price impacts are lower (they increase less or decrease more). For instance, the EU15 market price of wheat increases by 2.6 per cent compared to 3.6 per cent in the first framework. This simply comes from the fact that the price increases of oil products is taken into account in household decisions and thus private expenditures on food products are now lower. For instance, the EU15 private expenditures on dairy products increase by 0.7 per cent in the first framework while they decrease by 0.4 per cent in this second framework.

When we use the full CGE model with consistent real income effects and macro-economic linkages, the world agricultural effects are even more dramatically modified. In the net importing oil countries like the EU15 and the US, the real income decreases. Accordingly the final expenditures of food products in these developed countries decrease more. For instance, the EU15 private expenditures on dairy products decrease by 2.3 per cent. It even appears that the price impacts on food products generally turn from positive to negative. For instance, the EU15 market price of dairy products decreases by 2.1 per cent, while the market price of beef decreases by 1.5 per cent. This means that the cost push effect is lower than the contraction effect due to real income losses. The crucial role of macro-economic linkages also prevails for Russian results. The Russian prices of beef and dairy products increase in this last framework (by 5.0 and 4.1 per cent respectively), simply because Russian real income increases.

Impacts on production are also interesting to analyze. As an example, take beef production in the US and Russia and compare the first (no budget constraint) and last (full CGE) frameworks. In this last framework, the US production of beef expands while the Russian one decreases. The results are reversed with the first framework. This can be explained as follows. In the last framework, the increased Russian real income stimulates beef demand but the Russian beef production sectors are unable to completely satisfy this new demand (in fact milk production increases partly to the detriment of livestock production). Accordingly the Russian net imports of beef significantly increase (by 20 per cent). The US sectors partly benefit from this foreign demand: US net exports of beef increase by 43 per cent (compared to a decrease of 8 per cent in the first framework). Globally there is a redistribution of world real income following this shock that favors food demand. Real income increases in regions with higher marginal propensity to consume food products, while it decreases in regions with lower marginal propensity. This explains why we obtain a slight (0.3 per cent) increase of the world beef consumption in this last framework (compared to a small decrease in the first framework).

c. Farm income results

We also assess the effects on the farm incomes computed as net of tax factor rewards (labor, capital and land). As expected the increase of oil prices has a negative effect on total farm incomes due to a cost push effect. For instance the EU15 total farm income decreases by 2.6 per cent in the first framework (table 5). Surprisingly the US total farm income increases slightly (by 0.2 per cent). This is due to the fact that the US farm sector appears less energy intensive in the initial database.

Once we introduce cross sectoral relationships in the budget constraint, we obtain more severe reductions of total farm incomes. For instance the EU15 total farm income decreases by 3.8 per cent. The US total farm income now decreases by 1 per cent.

Finally if we introduce all macro-economic identities, income results are even worse for the EU15 and US farm sector. By contrast the Russian farm sector (with the exception of wheat farming) appears to gain from the oil price shock because the Russian economy experiences a real income growth, leading to an increase of Russian farm prices sufficient to cover the increasing energy costs.

4. Concluding comments

The world prices of food and energy products have followed similar patterns with large fluctuations in recent years. We investigate the long run relationship between these prices using a world CGE model with detailed representations of food and energy markets. Particular attention is paid to include macro-economic linkages which have often been overlooked in recent analyses and debate. We find that the omission of these macro-economic linkages has a substantial bearing on this relationship. Although a positive relationship due to the cost push effect has been identified in most analyses, we find that the introduction of the real income effect may indeed imply a negative relationship between world food and energy prices. Accordingly, it is very important to broaden sector focused analysis to a system wide approach when analyzing the linkages between global energy and food markets.

The increases in world energy prices are obtained in our simulations by assuming a reduction of estimates of crude oil reserves. While supply factors are certainly fundamental in the long run evolution of energy prices, the role of energy demand factors should not be underestimated. For instance, the rapid economic growth experienced in Asian countries also contributes to higher energy demand and prices. As an extension of this paper, it will thus be useful to consider the relationship between energy and food prices under alternative sources of shocks.

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Table 1. Aggregation of Sectors and Regions used in the model

Food products (19): Rice, wheat, cereals, vegetables and fruits, oilseeds, sugar cane/beet, plant based fibers, other crops, cattle, milk, other animal products, beef, other meats, vegetable oils and fats, dairy products, processed rice, sugar, other food products, beverages and tobacco
Energy products (5): Coal, oil, gas, petroleum products, electricity
Other products (9): Chemical, fishing, forestry, mineral products, leather products, other manufactures, trade, transport, other services
Regions (11): Australia and New Zealand, Canada, China and Hong Kong, Argentina and Brazil and Uruguay, European Union 15 old members, European Union 12 new members, India, Japan, Russian Federation, United States, Rest of the World

Table 2. Impact on the wheat markets of a 20 per cent decrease of oil reserve (in percentage with respect to the 2001 initial point)

	EU15	US	Russia	World
No budget constraint				
Production	-1.6	-2.1	-3.0	-0.5
Final demand	-0.2	-0.3	-0.8	-0.3
Market price	3.6	3.0	6.2	2.9
Fixed income				
Production	-1.5	-2.6	-2.8	-0.5
Final demand	0	-0.5	-0.6	-0.3
Market price	2.6	2.1	4.8	1.8
CGE model				
Production	0.4	-0.8	-5.4	-0.6
Final demand	0.5	0.3	-1.2	-0.4
Market price	1.8	1.8	11.6	1.3

Table 3. Impact on the beef markets of a 20 per cent decrease of oil reserve (in percentage with respect to the 2001 initial point)

	EU15	US	Russia	World
No budget constraint				
Production	-0.3	-0.3	3.8	-0.1
Final demand	-0.1	-0.1	0.1	-0.1
Market price	1.3	1.4	-0.8	1.0
Fixed income				
Production	-0.1	-0.4	5.3	-0.1
Final demand	0	-0.2	0	-0.1
Market price	0	0.5	-3.0	-0.1
CGE model				
Production	0.5	0.4	-2.3	0.4
Final demand	-0.3	0.1	6.2	0.3
Market price	-1.5	-1.1	5.0	-0.9

Table 4. Impact on the dairy markets of a 20 per cent decrease of oil reserve (in percentage with respect to the 2001 initial point)

	EU15	US	Russia	World
No budget constraint				
Production	-0.2	-0.1	3.7	-0.1
Final demand	-0.1	-0.1	0.8	-0.1
Market price	0.8	1.0	-1.8	0.8
Fixed income				
Production	0	-0.2	4.8	0
Final demand	0.1	-0.1	0.8	0
Market price	-0.5	0.2	-4.2	-0.4
CGE model				
Production	0.6	0	1.6	0.1
Final demand	-0.2	-0.1	5.6	0.1
Market price	-2.1	-1.6	4.1	-1.5

Table 5. Impact on the farm incomes of a 20 per cent decrease of oil reserve (in percentage with respect to the 2001 initial point)

	EU15	US	Russia	World
No budget constraint				
Wheat farming	-2.8	-2.7	-4.8	-0.7
Cattle farming	-2.3	0.2	-2.9	-0.7
Milk farming	-1.8	0.0	-2.7	-0.5
Total	-2.6	0.2	-2.8	-0.4
Fixed income				
Wheat farming	-4.0	-4.3	-6.4	-1.9
Cattle farming	-3.6	-1.0	-4.9	-1.9
Milk farming	-3.0	-1.0	-4.8	-1.6
Total	-3.8	-1.0	-4.7	-1.6
CGE model				
Wheat farming	-3.1	-2.9	-2.7	-2.8
Cattle farming	-4.2	-1.1	5.7	-1.9
Milk farming	-3.8	-2.1	7.4	-3.8
Total	-4.2	-1.1	2.8	-2.6