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The Variable Response of Agricultural Supply to World Price Instability in Developing Countries

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Abstract

This paper analyses the effect of world price instability on the agricultural supply from developing countries and determines to what extent this effect is dependent upon the macroeconomic environment. Producers from agricultural commodity-exporting countries are particularly vulnerable to the fluctuations of world prices: they are widely exposed to price shocks and have little ability to cope with them. Nevertheless, the effectiveness of risk-coping strategies is conditioned by the influence of macroeconomic factors (infrastructure, inflation and financial deepening). Thus country-specific price indices are established, and the response of production indices to price instability indices is estimated by using a panel model including macroeconomic variables which interact with price instability. Such analysis is based on a sample of 25 countries between 1961 and 2002. The results highlight a significant negative effect of the world price instability on supply, and further show that high inflation, weak infrastructure and a poorly developed financial system exacerbate this effect.

Keywords: *Aggregate supply*; *macroeconomic environment*; *world price instability*.

JEL classifications: *Q11, Q17, Q18*.

1. Introduction

The volatility[2] of world agricultural commodity prices and the effects on the development of poor countries have been under study for some time. Today, price vola-

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[2] 'Volatility' and 'instability' are used synonymously in this paper, both referring to a price variability measure.

tility remains a major concern for primary exporting countries that are still heavily dependent upon export revenues (FAO, 2002). World commodity price volatility is caused by shocks to both supply and demand, but shocks to supply predominantly affect agricultural commodities (Dehn *et al.*, 2005). Supply shocks can occur through damage to stored grain, strikes, embargoes, shipping disputes, wars, frosts or droughts, for example (Bond, 1984), and even small shocks to supply can have a major impact on prices because of low price elasticities of demand.

For a few decades, dramatic changes in export commodity markets have put producers in a critical situation. Indeed, the international context seems less favourable for producers, because of the extent of price volatility, their exposure to such volatility and their capacity to deal with the consequences. In the first instance, instability in world agricultural commodity prices, usually defined as the mean deviation from the trend, is high. It has been higher over the past three decades than during the pre-1973 period[3] (Dehn *et al.*, 2005). For some agricultural commodities, instability was even higher, on average, during the 1980s than throughout the 1970s[4] (FAO, 2002). It appears that instability in major agricultural commodities can easily exceed 10% (Table 1).

Second, producers have not always been entirely protected from the consequences of price volatility through price stabilisation schemes (Miranda and Helmberger, 1988; Hazell *et al.*, 1990; Knudsen and Nash, 1990), and that once such schemes disappeared, producers became exposed to the full volatility of markets (ITF, 1999; Gilbert and Varangis, 2003). Finally, producers have limited ability to deal with the consequences of price instability. Market price risk management instruments are used only in a few developing countries and, as yet, do not provide a global solution (ITF, 1999). For those reasons, we investigate the effect of world price instability on agricultural supply at the country level.

Although the issue of the price instability effect on supply has often been treated in the literature, there are few analyses at country level. The effect of price instability is typically regarded as a microeconomic issue for producers. Yet there is no reason to believe that the agricultural export sector as a whole is less affected than a single, small and isolated producer. The effect of price instability on supply at the country level is not obvious at first sight and there is no evidence that the effect of price instability on the agricultural export sector will net out when aggregated. On the contrary, if analyses at the micro-level tend to show that price instability may reduce supply by an individual producer, it is sensible to investigate whether this phenomenon occurs at the country or sector level. The issue seems all the more important because the consequences are likely to affect the overall economy. Collier (2002) explains that a drop in production, first affecting households, may then affect

[3] Dehn (2000) found that the volatility of (nominal and deflated) country-specific Deaton–Miller commodity price indices (not only agricultural commodities but also minerals, ores, metal and crude petroleum) have increased over the past 30 years. He noted that the first group of high-volatility countries includes not only most of the major oil exporters, but also some very poor non-oil exporting countries (Bhutan, Haiti, Laos and Uganda).

[4] Analyses presented at the FAO (2002) provided evidence that eight of 18 agricultural commodities (in real terms) showed a higher level of variability over the 1980–1990 period in relation to the 1970–1980 period, i.e. banana, rubber, cotton, maize, wheat, soyabeans, rapeseeds and palm oil.

Table 1
World price instability of agricultural commodities

Period	Cocoa	Coffee	Rice	Cotton	Tea	Groundnuts
1961–1967	10.12	5.72	4.47	1.33	1.21	4.41
1968–1974	13.31	4.83	9.36	5.02	4.22	6.46
1975–1981	17.98	18.79	17.01	11.03	11.87	18.65
1982–1988	7.57	8.25	9.66	9.88	11.84	13.60
1989–1995	4.98	11.80	6.24	9.46	5.22	15.49
1996–2002	11.24	15.00	4.39	7.43	9.10	6.67

Notes: Instability is the quadratic mean percentage deviation of the real price from its trend value. It is measured each year in relation to the previous five years. The figures in the table refer to average period values. The price series are taken from the IFS database. The OECD export unit value is used as a deflator.

the country as a whole: the shock to income will change the aggregate demand for domestically produced goods, which, in turn, will reduce output because of a less-than-full price flexibility. Moreover, it is well known that the agricultural commodity price volatility is also important for policy-makers who are unable to plan budgets as a consequence. As a result, the effect of price instability on agricultural supply at the country level is a major issue. It should be underlined that the gap in the literature on this issue may be explained by the potential aggregation bias in estimation. This bias usually arises when aggregate data are used to estimate a supply function parameter. The resulting estimate is not equal to the average of the individual parameter values obtained if it had been possible to estimate the same function producer-by-producer. As each producer is assumed here to face the same price (the world price), aggregation over producers does not raise this kind of bias here.[5]

Recent developments in panel econometrics allow us to examine further the issue of the aggregate supply response to price instability. Indeed, panel analysis makes it possible to test the assumption of a *variable* response of agricultural supply to price instability. If the impact of price instability on supply depends upon the macroeconomic environment (in particular, the level of infrastructure development, the level of financial development and inflation), the supply response will not be identical in all countries. Thus country-specific price indices are established, reflecting the prices of agricultural commodities exported by individual developing countries. The mean deviation of these indices from their trend level, defined as price instability, is then considered. The country-specific production index response to price instability indices is estimated, using a panel model that includes macroeconomic variables interacting with price instability. The analysis determines the influence of the macroeconomic factors relating to a producer's risk management capacity on the instability–supply link. In particular, we investigate whether the producer's risk management capacity may be improved through better infrastructure, lower inflation and enhanced financial development. The *within* regression results and the

[5] The industry supply curve, in any event, is not the simple sum of the individual producer supply curves, since at the industry level, input and factor prices cannot be held constant.

system generalised method of moments (GMM) regression results show a significant negative effect of world price instability on agricultural supply. Moreover, it appears that this effect is more pronounced when the macroenvironment is characterised by a weak infrastructure, high inflation and a poorly developed financial system.

The main results of the empirical literature on the relationship between price instability and agricultural supply, and the expected influence of the macroenvironment on such a relationship, are dealt with in section 2. The hypotheses and the empirical model are developed in section 3. The creation of country-specific price and production indices and the price instability measure are shown in section 4. All results are discussed in section 5. Conclusions are drawn in section 6.

2. Main Findings of Empirical Literature

The influence of the macroeconomic environment on the agricultural supply response to world price instability combines two pieces of empirical literature: the analysis of the effect of price instability on agricultural supply and the analysis of the role of the macroeconomic environment in the agricultural supply response.

2.1. The effect of price instability on agricultural supply

For some time, risk-averse behaviour has been introduced in supply analyses (as well as in the firm theory, see Sandmo, 1971). Since the study by Newbery and Stiglitz (1981), it is now common knowledge that producers, whose only source of income is agriculture, will prefer certain income to uncertain income having the same expected value. The agricultural supply response to price instability depends upon the producers' risk aversion. Under increasing price instability, supply will be reduced if risk aversion is moderate, but will be increased if risk aversion is high, the producers having to work more in order to avoid extreme situations. Thus, the static response of producers to instability depends on their degree of risk aversion. Nevertheless, in a more dynamic framework referred to in empirical analyses, the expected supply response is more likely to be negative, with price instability discouraging investment and innovation having a more uncertain return.

In the empirical literature, many time-series analyses have underlined the importance of price instability variables in production decisions (Behrman, 1968; Just, 1974; Lin, 1977; Hurt and Garcia, 1982; Brorsen *et al.*, 1987; Aradhyula and Holt, 1989; Holt and Aradhyula, 1990; Chavas and Holt, 1990, 1996; Antonovitz and Green, 1990; Pope and Just, 1991; Guillaumont and Bonjean, 1991; Holt, 1993, etc.). Such analyses, however, typically focus on one particular commodity within a small geographic area. Consequently, the results vary considerably from one study to another. For example, Lin (1977) estimated the elasticity of wheat supply to price instability in Kansas between 1950 and 1975 at −0.06; Hurt and Garcia (1982) estimated the impact of the hog price instability on US sow farrowings between 1967 and 1978 and found an elasticity nearing −0.5; Aradhyula and Holt (1989) found that the US broiler supply elasticity to price instability was −0.045 between 1967 and 1986; Chavas and Holt (1996) found that the US corn supply elasticity to price instability was −0.033 between 1954 and 1985. By definition, such analyses do not provide much information

about the adverse effects of price volatility on the agricultural export sector as a whole at country level. However, the effects of price volatility on aggregate commodity supply at national level are important, as price instability raises systemic agricultural shocks.

Here we assume that each producer of a particular commodity is confronted with the same price (this is not necessarily the case with the producer price, which can vary from one producer to another). By using this proxy variable, we are able to circumvent the problem of aggregation over producers (see Appendix A for a simple algebraic example). The estimated parameter of the aggregate supply of agricultural commodities is not equal to the average of the individual parameter values obtained if it had been possible to estimate the same function commodity-by-commodity. However, as stressed by Nerlove (1958), there is no reason to believe that the supply function of each individual commodity is of the same form as the aggregate commodity supply function. On the contrary, we can reasonably suppose that the supply of a particular commodity will depend not only on its own price, but also on the price of competitive products. Thus, some authors estimate the aggregate commodity supply function in an alternative way, based on a complete supply system where restrictions on parameters across equations are imposed so that the system derives rigorously from a profit function. Following such a procedure, Bapna *et al.* (1984) examined the aggregate supply elasticity for five different crops in a poor agro-climatic sub-region in India. Using a cross-price elasticity matrix, the aggregate supply elasticity with respect to an overall price increase was calculated as a weighted average of the cross-price elasticities. The weighting item refers to the share of each product within the aggregate income. The results achieved provided high individual elasticities and a low aggregate elasticity (indeed, growth in one crop takes away resources from other crops and most factors of agricultural production are fixed in the short term, see Binswanger, 1989). However, such an estimation procedure, based on a complete system of supply equations, is less manageable in analyses at national level, with countries producing a wide range of products.

Furthermore, it seems relevant to study this effect using a panel analysis. Several panel analyses have been used to estimate the aggregate supply of agricultural products (Binswanger *et al.*, 1987; Chhibber, 1989; Schiff and Montenegro, 1997), but price instability has not been included in such models. Guillaumont and Combes (1994) estimated the effect of producer price instability on supply growth for several country–commodity pairs during 1970–1979 and 1979–1988, but they supposed that the supply response was identical in all countries. However, this assumption is implausible, especially because country supply is likely to depend on the macroeconomic environment.

2.2. Macroeconomic environment and supply response

A large literature attempts to determine the price elasticity of the aggregate commodity supply, generally demonstrating that it is quite weak. Many authors have tried to identify the constraints which prevent producers from adapting to short-term price incentives. Apart from the fixity of some production factors, several assumptions relating to the macroeconomic environment have been put forward. In a cross-country analysis applied to 58 countries between 1969 and 1978, Binswanger *et al.* (1987) estimated the short-term elasticity of the aggregate agricultural supply,

including in their models several variables likely to affect producers' technology, such as human capital and infrastructures. Their results show, in particular, the importance of the direct effect of roads, public systems of irrigation, literacy and life expectancy on supply.

In a review of the main issues relating to the supply elasticity estimation, Schiff and Montenegro (1997) explained that supply elasticity makes sense only if the conditions under which prices behave are specified. According to them, such conditions particularly depend on the expenditure on public goods and on the consequences of changes in investment, inflation and the real exchange rate.[6] Their cross-country analysis, applied to a sample of 18 countries over the period 1960–1985, clarified the complementarity of prices and expenditure on public goods, using an interaction between public investment and relative prices.

Although macroeconomic factors have often been considered when estimating agricultural supply functions,[7] the interaction between these factors and price instability has rarely been considered. Yet, the macroeconomic environment is able to modify the effect of price instability on production decisions.

3. A Model of Variable Supply Response to World Price Instability

The impact of price volatility on the aggregate agricultural supply is estimated at the country level, using aggregate agricultural commodity indices, which are country-specific. The general model of aggregate agricultural supply response to world price instability can be written:

$$Y_{it} = \alpha_0 + \alpha_1 Pw_{it} + \alpha_2 IPw_{it} + \alpha_3 X_{it} \quad (1)$$

where Y_{it} is the country i's production index in period t; Pw_{it} is the country i's world price index converted into local currency in period t; IPw_{it} is the instability of the country i's price index; and X_{it} is a vector of non-price variables.

This model assumes that instability in real-world prices affects producers *directly*. Producer prices are not well known (the FAOSTAT system only provides series of producer prices for the 1991–2002 period); thus world prices (International Financial Statistical (IFS) series) can be taken as a proxy of producer prices.[8] Although price stabilisation schemes have not been implemented in every country for all agricultural products, it is clear that the agricultural sector has been subject to significant intervention (World Bank, 1986) which, prior to market liberalisation, may have prevented producer prices from moving with world prices. Mundlak and Larson (1992) addressed this question using a set of regressions for 58 countries (both developed and developing) and for 60 agricultural products, over the period 1968–

[6] The effect of foreign exchange shortage on the price elasticity of supply has been examined in the context of rationed economies (Azam *et al*., 1991; Guillaumont and Bonjean, 1991). Guillaumont and Combes (1994) have also tested it through the real exchange rate level.

[7] Macro-economic factors are often also introduced into production functions (Mundlak *et al*., 1997).

[8] The relationship between producer prices and the prevailing world prices is summarised in Hazell *et al*. (1990). They stress that the export unit value is meant to follow world prices closely, with the difference between the export unit value in local currency and the producer price being primarily caused by government intervention.

1978. Their results showed that, in general, the estimated transmission elasticity between world and domestic prices is near unity (between 0.74 and 1.24), and that the deviation from the unitary elasticity is due to policy measures and also to domestic inputs that are not synchronised with world prices.[9] Furthermore, they showed that world prices are by far the main source of variations in domestic prices (the values of R^2 vary between 0.66 and 0.96). As a result, we deduce that political intervention does not isolate producers from world price instability, as domestic prices are never completely disconnected from world prices,[10] even during periods covered by price stabilisation schemes. Our results tend to confirm this presumption.

Macroeconomic factors are likely to affect the impact of world price instability on agricultural supply, particularly the influence of three factors, i.e. infrastructure, inflation and financial development. The development of infrastructure increases a producer's capacity to cope with price instability; inflation increases a producer's vulnerability; and financial development encourages self-financing and self-insurance.

3.1. Infrastructure

Several authors share the view that public investment in infrastructure has a positive impact on agricultural supply, especially through the influence on productivity (Binswanger and Deininger, 1997). In an analysis of agricultural policies in 18 countries between 1960 and 1983, Krueger *et al.* (1991) showed that the macroeconomic environment and the supply of public goods can influence performance in the agricultural sector. They showed that investment in rural infrastructure, in coordination with social services and viable systems of credit for small producers, enabled agricultural production to rapidly grow and reduced poverty in Southeast Asia and China. Similarly, Heath and Binswanger (1996) pointed out that, in Kenya, where infrastructure supports market access, growth in agricultural production more than compensated for growth in rural population; while in Ethiopia, a country deprived of infrastructure favourable to producers, the strong population density implied significant degradation of land.

Faini (1991) suggested that the level of infrastructure could improve the supply response to producer price changes – for example, by reducing the high costs for transporting locally produced commodities to the border for export through the development of road networks. It can be argued that developing infrastructure can also improve the efficiency of public expenditure for education and for health services. Agenor and Moreno-Dodson (2006) showed that investment in infrastructure interacts with social public services, thus influencing growth via a complementary effect. In addition, Knight *et al.* (2003) and Weir and Knight (2004) suggested that education and health services can reduce producers' risk aversion. Moreover, infra-

[9] In Mundlak and Larson (1992), domestic inputs include marketing, finance, storage, and transportation.

[10] However, trade may not be carried out continuously. As Mundlak and Larson (1992) pointed out, commodities can, in the short term, be stored to avoid domestic prices responding instantaneously to changes in world prices.

structure can help develop risk-sharing networks (Dercon, 2002; Fafchamps, 2003) and improve, in turn, a producer's capacity to deal with price instability.[11]

3.2. Inflation

Mundlak *et al.* (1997) have studied the direct effect of inflation on agricultural production in a cross-country analysis covering 37 countries between 1970 and 1990. Inflation can influence agricultural productivity directly as an incentive and indirectly via investment. However, it can also affect a producer's capacity to cope with price risk by reducing real producer prices and the real value of their savings.

When inflation reduces the real value of a producer's revenues and assets and devalues precautionary savings, producers may be forced to reduce their supply. Furthermore, producers may be forced to liquidate their productive assets – land, cattle, bullocks, and tools – in the face of price shocks, even though inflation makes such liquidation less profitable. Thus, inflation can exacerbate producers' responses to price instability.[12]

3.3. Financial development

There have been many attempts by the international community to deal with commodity price volatility, though these stabilisation or compensatory mechanisms[13] have been abandoned as financially unsustainable. International commodity agreements have either collapsed (sugar, tin), or they have been replaced by agreements whose primary role is to improve information (cocoa, coffee) (Gilbert, 1995). While market instruments[14] can reduce uncertainty arising from volatile prices, they are typically less effective for inter-year volatility. They are only used in a very few developing countries (having relatively low levels of governmental intervention in terms of commodity production and trade of commodities), and, as yet, hardly provide a global solution.

Microfinance can help producers cope with price instability. Better access to credit markets helps improve productivity, through increased savings and investment

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[11] It nevertheless implies that members of such risk-sharing groups are not exposed to a common risk.

[12] Deaton (1991) highlighted the advantages of self-insurance when the credit market is imperfect. Nevertheless, as noted by Dercon (2002), the return of productive assets is itself risky and a self-insurance strategy cannot prove effective should the real value of the assets fall. Rosenzweig and Wolpin (1993) described the liquidation of the productive assets as an *ex post* risk management strategy frequently adopted by producers subjected to violent price shocks without any liquid savings. Fafchamps (2003), however, noticed that producers may prefer to reduce their consumption, in the event of the productive assets' liquidation becoming disastrous.

[13] These mechanisms refer to the IMF's Compensatory and Contingency Financing Facility, the Common Fund for Commodities, and the European Community's STABEX and SYSMIN schemes.

[14] Grain traders at the Chicago Board of Trade (CBOT) invented the to-arrive contract allowing farmers and buyers to lock in a price for future delivery. The CBOT instruments were later standardised, the exchange was set up, and they soon became the futures contracts that we know today (ITF, 1999).

(Levine, 2004), and can attenuate supply response to price shocks, by buffering income and revenue shocks. Although informal mechanisms of credit and insurance are most common, see Besley (1995), the development of formal credit institutions can influence the risk-coping capacity of producers in an indirect manner. Guillaumont Jeanneney and Kpodar (2005) argue that the development of informal credit, which is often the only source of borrowing for the poor, is made easier by improving the formal financial system, which offers profitable investment opportunities to informal financial institutions which are not directly offered to small producers (Beck *et al.*, 2004). Furthermore, the formal financial system offers producers financial opportunities for savings. Producers who are forced into self-financing and self-insurance can have access to interest-linked deposits, providing a savings incentive (McKinnon, 1973). Thus, by facilitating the build-up of savings, financial development may also contribute to reducing the supply response to price instability.

3.4. The econometric model

Our supply function includes macroeconomic variables interacting with price instability. The general model (1) is augmented with an interaction term between the macroeconomic environment and the world price instability:

$$Y_{it} = \gamma_0 + \gamma_1 Y_{it-1} + \gamma_2 Pw_{it} + \gamma_3 IPw_{it} + \gamma_4 X1_{it} + \gamma_5 X2_{it} + \gamma_6 (X2_{it} * IPw_{it}) + \varepsilon_{it} + \mu_i \quad (2)$$

where $X1_{it}$ is a vector of non-price variables; $X2_{it}$ is a vector of macroeconomic variables likely to influence the impact of price instability on supply; $X2_{it}$*IPw_{it} is an interaction term; ε_{it} is the residual term; and μ_i represents unobservable country-specific characteristics.

4. Designing a Price Index and Measuring Instability

Aggregate commodity indices are established according to the methodology used by Dehn (2000), who noted that studies of commodity price volatility should be based on a country-specific index of prices, as individual commodity prices, terms-of-trade indices or international aggregate indices of commodity prices are not appropriate.

4.1. Constructing price and production indices

Following Dehn (2000), countries are labelled as exporters of a particular type of commodity (either agricultural foodstuffs or agricultural non-foodstuffs), when exports of that commodity constitute 50% or more of their total commodity exports. Thus, for each country, depending on the types of agricultural commodity mainly exported, a Deaton–Miller index[15] is established (Deaton and Miller, 1995). Table 2 shows the resulting country classification with their type.

[15] The country-specific world price index is constructed as follows: $P\$_i = \prod_j P_j^{w_{ij}}$ where w_{ij} is the weighting item and P_j the dollar international commodity price for the commodity j in the country i. As w_{ij} is country-specific, each country's aggregate commodity price index $P\$_i$ is unique.

Table 2
Sample

Country	Agricultural type	Country	Agricultural type
Argentina	Food	Niger	Non-food
Colombia	Food	Pakistan	Non-food
Costa Rica	Food	Panama	Food
Côte d'Ivoire	Food	Paraguay	Food
El Salvador	Food	Philippines	Food
Gambia	Food	Samoa	Food
Guatemala	Food	Senegal	Food
Haiti	Food	Sri Lanka	Food
Honduras	Food	Sudan	Non-food
India	Food	Thailand	Food
Kenya	Food	Turkey	Non-food
Madagascar	Food	Uruguay	Food
Myanmar	Non-food		

Table 3 shows the 25 commodities used in establishing the indices. The world price series are extracted from the IFS (2004) database. The indices are weighted according to the share of each commodity within the total value of the country's agricultural production in 1990. The data on the quantities used to weight the price indices are extracted from the FAOSTAT (2004) database are also shown in Table 3.

The world price indices are then deflated using the Organisation for Economic Cooperation and Development (OECD) export unit value (World Development Indicators (WDI), 2004). Finally, they are converted into local currency:

$$Pw = \frac{P\$}{\text{EUV}}\text{RER} \quad \text{with} \qquad \text{RER} = \text{NER}\frac{\text{EUV}}{\text{CPI}}$$

Pw refers to the real price index in local currency. *P$* refers to the world price index, deflated by the export unit value index from OECD countries (EUV). NER refers to the nominal exchange rate (WDI, 2004). CPI is the consumer price index (WDI, 2004), and RER is the bilateral real exchange rate (IFS, 2004). The countries' production indices are constructed by weighting each specific commodity production by its relative world price in 1990.

4.2. Price instability measurement

A standard measure of price volatility is used: the mean deviation from the trend level.[16] The trend level is estimated from a mixed trend, combining deterministic and

[16] For example, in the recent literature, Dehn (2000) measured the volatility of commodity price indices as the standard deviation of the residuals of a GARCH model applied to each country's aggregate commodity price index. Sarris (2000) measured the volatility of the real maize, wheat and rice prices using the residuals of the regression of the price index on a linear temporal trend with an ARMA specification for the residuals. In the Commodity Price Statistics, the UNCTAD measured price volatility as the percentage deviation of price from its exponential trend level (UNCTAD, 2003).

Table 3
Commodities used in price and production indices

Data sources for world prices		Data sources for production	
BANANAS LAT/AMER.US.P.	IFS 24876U.DZ...	BANANAS	FAO 486
BEEF ALL ORIG. US PORTS	IFS 19376KBDZF...	BEEF and BUFFALO MEAT	FAO 1806
COCOA NY & LONDON	IFS 65276R.DZFM44	COCOA BEANS	FAO 661
COCONUT OIL PHILIPP. NY	IFS 56676AIDZF...	COCONUTS	FAO 249
COFFEE OTHER MILDS (NEW YORK)	IFS 38676EBDZF...	COFFEE, GREEN	FAO 656
GROUNDNUT OIL CIF EUROPE	IFS 69476BIDZF...	OIL OF GROUNDNUTS	FAO 244
GROUNDNUTS NIGERIA/LONDON	IFS 69476BHDZF...	GROUNDNUTS in SHELL	FAO 242
LAMB N.ZEALAND (LONDON)	IFS 19676PFDZF...	MUTTON and LAMB	FAO 977
MAIZE US (GULF PORTS)	IFS 11176J.DZFM17	MAIZE	FAO 56
PALM KERNEL OIL	UNCTAD	PALM KERNELS	FAO 256
PALM OIL MALAYSIA (UK)	IFS 54876DGDZF...	OIL OF PALM	FAO 257
RICE THAILAND (BANGKOK)	IFS 57876N.DZFM81	RICE, PADDY	FAO 27
SORGHUM US (ROTTERDAM)	IFS 11176TRDZF...	SORGHUM	FAO 83
SOYBEAN OIL US (ROTTERDAM)	IFS 11176JIDZF...	OIL OF SOYBEANS	FAO 238
SOYBEANS US (ROTTERDAM)	IFS 11176JFDZF...	SOYBEANS	FAO 236
SUGAR EEC IMPORT PR.	IFS 11276I.DZF...	SUGAR	FAO 162
TEA AVERAGE AUCTION (LONDON)	IFS 11276S.DZF...	TEA	FAO 667
WHEAT US GULF PORTS	IFS 11176D.DZF...	WHEAT	FAO 15
COTTON US LIVERPOOL	IFS 11176F.DZFM40	SEED COTTON	FAO 328
JUTE BANGLADESH (CHITT-CHAL)	IFS 51376X.DZF...	JUTE	FAO 780
LINSEED OIL (ANY ORIGIN)	IFS 00176NIDZF...	OIL OF LINSEED	FAO 334
RUBBER MALAYSIA (SINGAPORE)	IFS 54876L.DZF...	NATURAL RUBBER	FAO 836
SISAL E.AFR UG LONDON	IFS 63976MLDZF...	SISAL	FAO 789
TOBACCO	UNCTAD	TOBACCO LEAVES	FAO 826
WOOL AUSTRALIA-N.ZEALAND (UK) 50S	IFS 11276HDDZF...	WOOL GREASY	FAO 987

Sources: IFS (2004), UNCTAD (2003), FAOSTAT (2004).

stochastic elements, fitted for the 1961–2002 period. The root mean square (RMS) deviation from trend is calculated, emphasising the importance of large divergences compared with small ones (MacBean and Nguyen, 1980). Price instability is defined here as the rolling five-year average RMS deviation, as follows (in percentage terms), where t in the price determination equations is the time trend variable:

$$IPw_t = 100\sqrt{\frac{1}{5}\sum_{k=0}^{5}\left(\frac{Pw_{t-k} - \hat{P}w_{t-k}}{\hat{P}w_{t-k}}\right)^2}$$

with

$$Pw_t = a + bPw_{t-1} + ct + e_t \quad \text{and} \quad \hat{P}w_t = \hat{a} + \hat{b}Pw_{t-1} + \hat{c}t.$$

Table 4 shows the average instability of the country-specific price indices over six sub-periods. It is to be noted that instability reached a peak (approximately 10% of the trend level) during the 1975–1981, 1982–1988 and 1996–2002 periods.

4.3. Other data sources

The infrastructure variable is extracted from the Database of World Infrastructure Stocks (Canning, 1998). The index is an average of four measures (per inhabitant): kilometres of roads; kilometres of paved roads; kilometres of railway lines; and number of telephones. Although the Canning database also includes reference to the quality of the infrastructure (percentage of roads in poor condition, percentage of local phone calls that are unsuccessful, percentage of diesel locomotives available and percentage of electricity lost from the system), these have only been measured in recent years and thus cannot be used for this analysis.

Two indicators of financial development are used: the ratio of liquid assets of the financial system (or M3) to GDP and the ratio of the value of credit granted by financial intermediaries to private sectors to GDP. The first reflects the capacity of the financial system to provide loans; the second reflects the extent of credit and thus the capacity of the informal sector to buffer price shocks. The other variables are described in Appendix B.

5. Results

A fixed-effects model is estimated first, using the *within* regression estimator, enabling non-observable country-specific effects to be taken into account. Then a dynamic panel-data model is fitted using the Arellano-Bond estimator.[17] This system GMM estimator not only takes account of non-observable country-specific effects as well, but also the lagged endogenous variable and potentially endogenous explanatory variables (for large countries, domestic production can affect world prices). The system GMM results are thus preferred to the *within* results. Moreover, the inclusion of the lagged endogenous variable is more realistic for the underlying mechanisms of supply response.

[17] Arellano and Bond (1991) developed a GMM estimator. An augmented version of this estimator is used, as outlined by Arellano and Bover (1995) and fully developed by Blundell and Bond (1998). The original estimator is sometimes referred to as the 'difference GMM', with the augmented version as the 'system GMM'.

Table 4
Mean instability of the sample

Period	Instability (% of trend)
1961–1967	6.34
1968–1974	6.15
1975–1981	10.15
1982–1988	9.41
1989–1995	10.74
1996–2002	6.97

5.1. *The unconditional effect of real-world price instability*

The unbalanced dataset covers 25 countries over six consecutive periods: 1961–1967, 1968–1974, 1975–1981, 1982–1988, 1989–1995 and 1996–2003. The main results are shown in Table 5. The first column of Table 5 shows the system GMM regression results, prior to introducing the macroenvironment variables likely to influence the impact of price instability. Instability has a negative and significant effect, which is the expected result. Producers' exposure to world price instability is sufficiently important to influence production decisions. The short-term elasticity[18] of supply with respect to price instability is near to −0.23, which implies a 23% decrease in production when instability doubles, which is important considering the variation in price instability through time. The system GMM results also show significant long-term effects, given by the elasticities adjusted by the $(1-\gamma_1)$ parameter. The long-term effect of instability is near to −0.37.[19]

5.2. *The effect of the macroenvironment on the instability impact*

The second column of Table 5 shows the results with the inclusion of infrastructure as an explanatory variable. At the mean value of the infrastructure variable, the supply elasticity is near to −0.23, which implies that the instability effect can be reduced by 35% if the mean value of infrastructure is multiplied by two, conforming to the hypothesis that the impact of price instability is reduced when infrastructures improve.[20]

[18] The *within* results can be interpreted as short-term effects too, nevertheless these estimates are likely to be less reliable than the system GMM estimates and are presented here by way of a robustness test only.

[19] Appendix C reports the *within* regression results. The first column of Appendix C also shows a significant though smaller supply elasticity, nearing −0.1.

[20] Table 5 shows the results of including the macroeconomic factors separately because they are highly correlated, making the results unclear, as column 6 shows. There are various strategies to deal with multicollinearity problems: one of them is to drop the variables with very low *t*-ratios when included together (Maddala, 1992). Actually, this may raise some bias in the *within* estimates, as the *within* estimator does not take into account endogeneity bias. Nevertheless, each macroeconomic factor does not seem to modify the specification much here, as the adjusted R^2 shows. In any event, the system GMM estimator takes account of endogeneity bias caused by the omission of some variables.

Table 5
Aggregate agricultural supply estimates (system GMM regression results)

Dependent variable: ln Y	(1)	(2)	(3)	(4)	(5)	(6)
ln $Y_{(t-1)}$	0.38***	0.41***	0.35***	0.36***	0.334***	0.51***
	(0.09)	(0.09)	(0.09)	(0.08)	(0.11)	(0.1)
ln Pw	0.04**	0.04*	0.03*	0.04**	0.17*	0.04**
	(0.02)	(0.02)	(0.01)	(0.02)	(0.10)	(0.02)
ln IPw	−0.23***	−0.31***	−0.12*	0.08	−0.89***	−0.73*
	(0.05)	(0.09)	(0.07)	(0.09)	(0.27)	(0.43)
infra		−0.84				0.02
		(0.52)				(0.39)
infra * ln IPw		0.35*				0.06
		(0.20)				(0.18)
ln CPI			0.02			0.03***
			(0.01)			(0.01)
ln CPI * ln IPw			−0.01*			−0.01***
			(0.005)			(0.004)
ln credit				−0.07		−0.17
				(0.07)		(0.16)
ln credit * ln IPw				0.08**		0.10
				(0.04)		(0.07)
ln M3					−0.27	−077***
					(0.19)	(0.23)
ln M3 * ln IPw					0.22**	0.24**
					(0.09)	(0.11)
Constant	0.36***	0.57***	0.27**	−0.44**	0.60	2.57***
	(0.13)	(0.21)	(0.13)	(0.22)	(0.58)	(0.05)
No. obs.	125	120	125	117	117	112
No. countries	25	24	25	25	25	24
Hansen test	0.164	0.576	0.421	0.606	0.684	1.000
F-test	0.000	0.000	0.000	0.000	0.000	0.000

***Notes*:** *** (resp. **, *): rejection of H0 at 1% (resp. 5%, 10%). Standard errors in parentheses. ln Y is the production index in logarithms, ln $Y_{(t-1)}$ is the lagged production index in logarithms, ln Pw is the price index in logarithms, ln IPw is the price instability variable in logarithms, T denotes the period ($T = 1,\ldots,6$), 'clim' is the climate risk, 'infra' is the infrastructure index, ln CPI is the consumer price index in logarithms, ln credit is the ratio of private credit by deposit money banks to the GDP in logarithms, ln M3 is the ratio of M3 to the GDP in logarithms.

The third column of Table 5 shows the results of including inflation as an additional explanatory variable. The influence of the consumer price index on the effect of price instability is significant and the supply elasticity is near to −0.15 (using the mean value of CPI). The producer's capacity to deal with price instability seems to be helped by precautionary savings: if the level of inflation impoverishes the producers or simply does not encourage them to save, they reduce their supply as price instability increases.

The fourth and fifth columns of Table 5 show the results relating to the influence of financial development on the instability–supply relationship. The private credit effect and the effect of the general lending capacity of the financial sector, as

Table 6
Supply elasticity with respect to price instability at quartile values of the macro-variables

Quartile value	Infrastructure	Inflation	Financial development
Lower quartile	−0.28	−0.14	−0.19
Median	−0.25	−0.15	−0.15
Higher quartile	−0.19	−0.16	−0.17
Difference between lower and higher quartile	0.10	0.02	0.12

***Notes*:** Calculations from the system GMM regression results.

reflected by the ratio of M3 to GDP, interacting with price instability, are positive and significant, suggesting that financial development can assist in buffering the supply effects of instability. The *within* regression results (shown in Appendix C) also show a significant influence of the infrastructure level, the inflation level and the private credit as well. On the other hand, the general lending capacity of the financial system is not significant, though is of the expected sign.

In order to evaluate more precisely the extent to which the instability effect can be modified by macroeconomic factors, the supply elasticity with respect to price instability is calculated at quartile values of the macro-variables (Table 6). At the median value of the infrastructure variable, the supply elasticity is near to 0.25. When moving towards the lower quartile, the instability effect becomes stronger. The difference between the lower and the higher quartile is seemingly important as the effect of instability is 1.5 times stronger for the lower quartile. The difference between the lower and the higher quartile for the financial development variable (the ratio of M3 to GDP) is important as well. As for the inflation variable, results show that the difference between the lower and the higher quartile is less important.

The empirical analysis thus shows that aggregate agricultural supply is directly affected by world price instability, which suggests that political intervention has not isolated producers from world price instability, domestic prices never being completely disconnected from world prices. Moreover, it appears that the supply response is not the same in all countries as it depends upon the macroenvironment, particularly on the development of infrastructures and the financial system.[21]

6. Conclusions

While a large empirical literature deals with the impact of price volatility on agricultural supply at micro-level (time-series analyses of one particular commodity within a small geographic area), analyses of the aggregate agricultural supply response to price instability at country level are scarce. Yet, the volatility of world agricultural commodity prices remains a crucial issue for producers in many developing countries.

This paper contributes to the literature by addressing the topical issue of the price volatility impact on supply at country level. The analysis shows several specific fea-

[21] An alternative functional form specification of these models (semi-log) has also been estimated, which supports the results presented here. Results are available from the author if required.

tures. First, it enables us to estimate the aggregate supply of agricultural products to price instability at country level, by using country-specific indices reflecting the prices of the commodities exported by individual countries. Second, it tests the effects of world price instability on agricultural supply *directly*. Third, it explores a *variable* supply response to price instability between countries.

The results support our propositions that producers' responses to price instability depend on macroeconomic factors which influence their risk management capacity. The results show that the supply effect of world price instability is accentuated by a high rate of inflation, a low level of infrastructure and a poorly-developed financial system. This suggests that producers' vulnerability to world price volatility may be reduced through the improvement of the macroenvironment.

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Appendix A

Aggregation over producers

In accordance with the pioneering works of Theil (1954), Barreto and Howland (1998) developed a straightforward case of aggregation of two individual income functions (the classic model in the aggregation bias literature). The same simple algebra can be done in the case of two individual supply equations. Let the following equations be two individual supply functions:

$$Y_1 = a_1 + b_1.P_1$$

$$Y_2 = a_2 + b_2.P_2$$

where Y_1 is the production of producer 1 and Y_2 the production of producer 2. P_1 is the price faced by producer 1 and P_2 the price faced by producer 2. If the prices are different, then the aggregation over producers leads to a potential bias, in the sense that when aggregate data are used to estimate the aggregate supply function parameter, the resulting estimate is not equal to the average of the individual parameter values obtained when estimating the individual supply functions. Let the aggregate supply equation be written as:

$$Y_m = a_m + b.P_m$$

where Y_m is the aggregate average of Y_1 and Y_2, P_m the aggregate average of P_1 and P_2, and a_m the aggregate average of a_1 and a_2, but obviously b is not the aggregate average of b_1 and b_2. Instead, we have:

$$b = \frac{1}{2}\left(b_1\frac{P_1}{P_m} + b_2\frac{P_2}{P_m}\right).$$

Theil (1954) showed that the parameter b from the aggregate regression was actually equal to the desired average of the individual parameters (b_m) plus a covariance term:

$$b = \frac{1}{2}\left(b_1\frac{P_1}{P_m} + b_2\frac{P_2}{P_m}\right) = b_m + \mathrm{cov}(b_i, \mathrm{slope}P_i\mathrm{on}P_m).$$

The aggregation bias is thus equal to the covariance term. Having said that, there are several ways to get a zero covariance term. One of them is the equality of P_1 and P_2.

Appendix B

Variable description, labels and data sources

Variable's name: *Y*
Description: Country-specific production index (Laspeyres).
The weighting item refers to world prices in 1990. Average period values.
Source: FAOSTAT (2004), IFS (2004).

Variable's name: *Pw*
Description: Country-specific price index in local currency.
Average period values.
Source: IFS (2004), WDI (2004).

Variable's name: *IPw*
Description: Instability of the price index. Quadratic mean deviation of the price index from its trend value (in percentage). Measured each year, with respect to the previous five years. Average period values.
Source: Author's calculations.

Variable's name: 'clim'
Description: Climate risk. Quadratic mean deviation of the production index from its trend value (in percentage). Measured each year, with respect to the previous five years. Average period values.
Source: Author's calculations.

Variable's name: 'infra'
Description: Infrastructure index. Arithmetical average of four variables: kilometres of roads, kilometres of paved roads, kilometres of rail track and the number of telephone lines per inhabitant. Average period values.
Source: Canning (1998).

Variable's name: 'CPI'
Description: Consumer price. Average period values.
Source: WDI (2004).

Variable's name: 'credit'
Description: Private credit by deposit money banks to GDP. Average period values.
Source: Financial Structure Database (2003).

Variable's name: 'M3'
Description: Liquid liabilities (M3) as a percentage of GDP. Average period values.
Source: WDI (2004).

Appendix C

Aggregate agricultural supply estimates (*within* regression results)

Dependent variable: ln Y	(1)	(2)	(3)	(4)	(5)
ln Pw	0.07**	0.10**	0.03	0.06**	0.06**
	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)
ln IPw	−0.10*	−0.18***	−0.09*	−0.16	−0.43
	(0.05)	(0.07)	(0.06)	(0.13)	(0.29)
T	0.28***	0.32***	0.30***	0.24***	0.26***
	(0.06)	(0.07)	(0.06)	(0.06)	(0.06)
T^2	−0.02**	−0.02**	−0.02**	−0.01	−0.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
clim	−0.01*	−0.01**	−0.01*	−0.01*	−0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
infra		−0.24			
		(0.42)			
infra * ln IPw		0.37**			
		(0.18)			
ln CPI			0.02		
			(0.02)		
ln CPI * ln IPw			−0.01*		
			(0.02)		
ln credit				0.09	
				(0.09)	
ln credit * ln IPw				0.10*	
				(0.05)	
ln M3					−0.11
					(0.16)
ln M3 * ln IPw					0.12
					(0.09)
Constant	−0.93***	−1.06***	−0.75***	−1.14***	−0.52
	(0.17)	(0.21)	(0.20)	(0.28)	(0.48)
No. obs.	150	144	150	141	142
No. countries	25	24	25	25	25
Adjusted R^2	0.62	0.64	0.63	0.69	0.66

Notes: *** (resp. **, *): rejection of H0 at 1% (resp. 5%, 10%). Standard errors in parentheses. ln Y is the production index in logarithms, ln Pw is the price index in logarithms, ln IPw is the price instability variable in logarithms, T denotes the period ($T = 1,\ldots,6$), 'clim' is the climate risk, 'infra' is the infrastructure index, ln CPI is the consumer price index in logarithms, ln credit is the ratio of private credit by deposit money banks to the GDP in logarithms, ln M3 is the ratio of M3 to the GDP in logarithms.