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Session 1:
Agricultural Profitability in the 21st Century

Agricultural Profitability in the 21st Century

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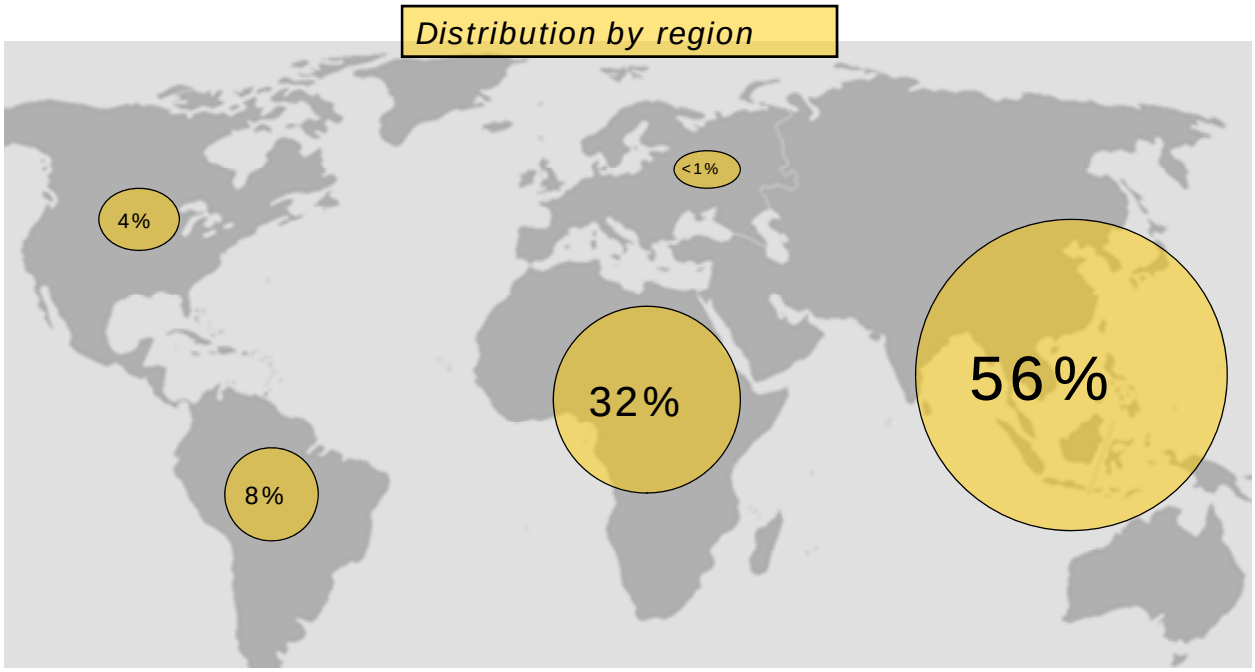
The first decade in this new century has been a very tumultuous one and a very prosperous one for North American agriculture. So it is an ideal time to step back and say, "What next? What is likely to follow? Will it be more of the same? Will North American agriculture revert to the old patterns or will it be something entirely new?"

Today, I will look at the fundamentals that are affecting the marketplace as we go into the second decade of the 21st century. First, I want to review the principal demand drivers for the food and agricultural industry and say a little bit about the characteristics of the markets. Second, I want to look at the global supply system as we see it today – what is its current condition, what are some expected changes, and what are its constraints. Third, I want to talk about some of the policy drivers that shape the business environment. Finally, I will provide some summary observations.

Let's start with the demand drivers. When you strip down to the essentials, there are really three forces that are the fundamental drivers of demand for the food and agricultural industry. First is the number of consumers in the world and where they are located– so population growth, the number of people we have today and the number we expect in the longer term. Second is the purchasing power those consumers have and where they are on the individual income ladder. Are they at the bottom, in the middle, or at the top? Their position is very important in terms of the demand for agricultural products. Third, there is a set of public policies in the aggregate that come together to very much influence the environment in which we have to do business. I want to say a few words now about each of these.

First of all is population growth. Everybody in this room is familiar with these numbers now. We've all seen these over and over, as we've talked about this subject since 2008. We have a little over 6 billion people in the world today. We are going to have 1½ billion more by 2025 and then the world population is going to plateau around the middle of the century at something just over 9 billion people. So we are going to add 1½ billion people – more consumers – in the next 15 years and we are going to add 3 billion people, or 50 percent more people than we have today, in just 40 years' time. That's not very long. When I look back over my career, which spans 40 years, that is not a very long period indeed. So one of the major forces is the number of people and where they are going to be located in the world.

Chart 1: World Population Growth

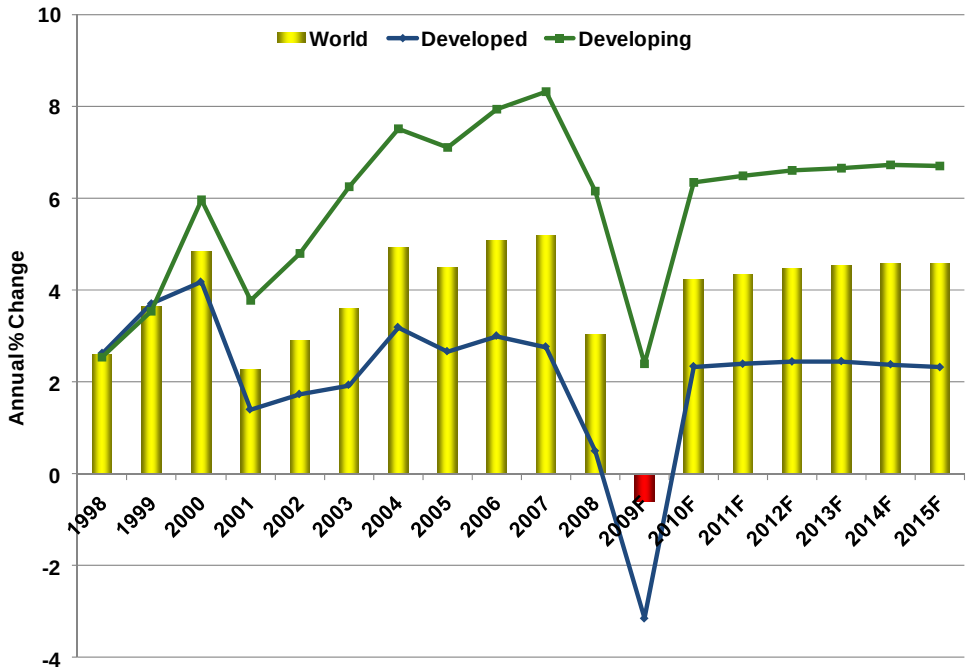


Source: United Nations, World Population Prospects 2008 Revision

This chart breaks down the number of new people to 2025 (Chart 1). The trends are slow to change and relatively stable, so this distribution roughly holds if you extend it on to 2050. Most of the new people in the world, over 80 percent, are going to be in the Greater Asian region and in the African region. In the upper latitudes of the world, there will be very little population growth and you can see a decline in the number of new people in parts of Europe and the former Soviet Union. So the distribution is going to be largely in the Greater Asian region and in Africa, and those happen to be parts of the world where the diets are the least adequate at this point in time.

We have this expectation for all of these new consumers. The big question is what is the purchasing power going to be as we look forward? Chart 2 shows GDP growth for the world, a proxy for income growth. These data are from the International Monetary Fund. The IMF is widely acknowledged as one of the most credible forecasters. They are also seen as reasonably conservative.

Chart 2: World GDP Growth



Source: International Monetary Fund (IMF), World Economic Report, April 2010

So there are a couple of points in terms of the income driver we can take from Chart 2. First of all, we have to recognize what happened in the first part of this decade. We were seeing global growth as we had never seen it before. Global GDP was growing in the 4 to 5 percent range, which is absolutely phenomenal. There were more countries exhibiting positive GDP growth at the same time than ever before in history. Jobs were being created. Incomes were rising. People at the bottom of the income ladder were seeing their incomes increase, and much of that increase was being spent for food.

Then we come to 2008. We see precipitous slowing in the global economy. We first started experiencing the cyclical downturn. Then came the credit crisis. The upshot of that was the global economy in the aggregate actually contracted about a half percentage point in 2009.

Now, here we are almost halfway through 2010 and, as the bar indicates, the forecast is for global GDP growth to exceed 4 percent. The IMF is reasonably bold and has forecasted for the next five or six years. You can see the forecast is for a return to what's called the trend growth potential for the global economy to grow in the 4 to 5 percent range.

Taking GDP growth and breaking it down a little bit more, where that growth is going to occur is exceedingly important to our industry. You can see the world is broken into the developing countries and the developed countries, with the developing countries being the green line at the top. In the first part of the past decade, you can see the developing countries were

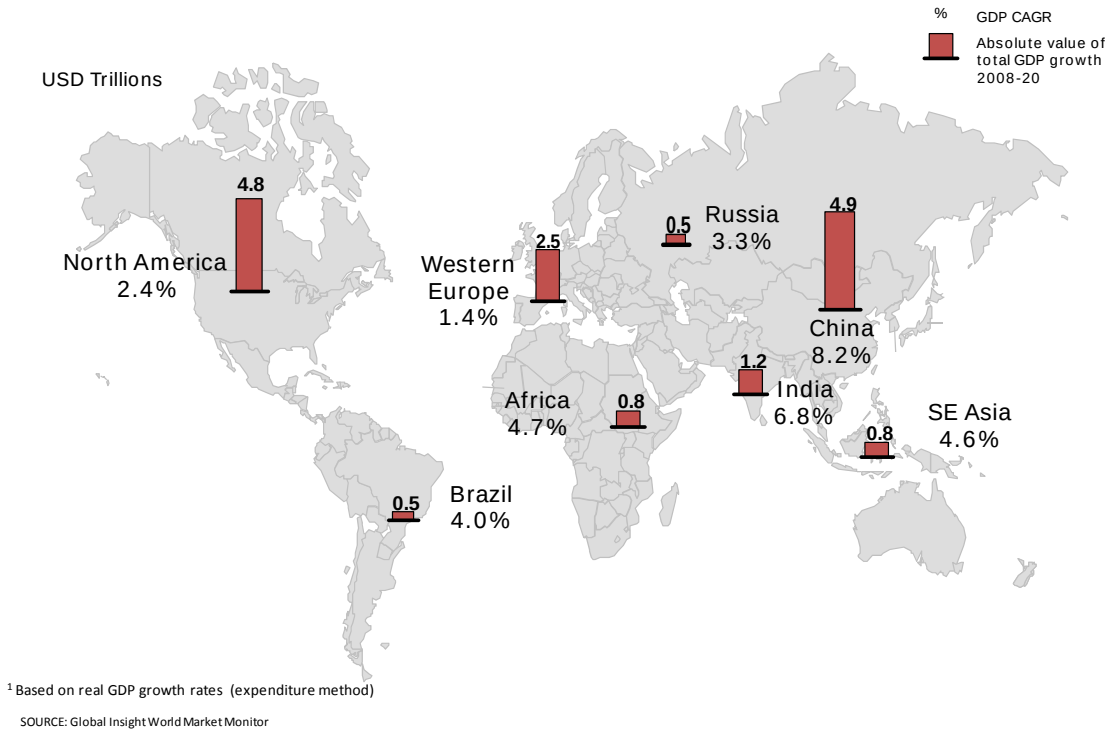
growing at about twice the pace of the developed world. When the recession came, it was certainly a slowdown in growth for the developing countries but not a contraction for them as a group. Led by India and China, growth slowed but it didn't contract, which is exactly what happened for the developed countries, shown by the blue line at the bottom.

The IMF is showing here a V-shaped recovery (there was a lot of talk about what size this would be). You can see pretty clearly they are expecting a bounce-back to the trend growth path and for that to be true for the developing countries, as well as for the developed countries that produce that overall growth in the 4 to 5 percent range. It's extremely important the growth in the developing countries continues apace.

Chart 3 projects in both absolute value of GDP and in the rate of growth. You can see the map of the world faintly in the background. There are a couple of things that are evident from this chart. First of all, the growth rates in the lower latitude of the world are much higher than they are for the developed countries in the upper latitudes.

The second thing is, if you add the absolute value of GDP growth for the Asian region – for China, India, Southeast Asia, you see it amounts to about $7 trillion. If you add the absolute value of GDP growth for North America and Western Europe – the developed part of the world – you can see it amounts to about $7 trillion. What we are seeing emerge in this century is a multipolar economy. No longer do you have the First World and the Third World, but you now have several poles of economic activity and that, again, is extremely important for the food market and extremely important for the food and agricultural business. This is something we have not had before.

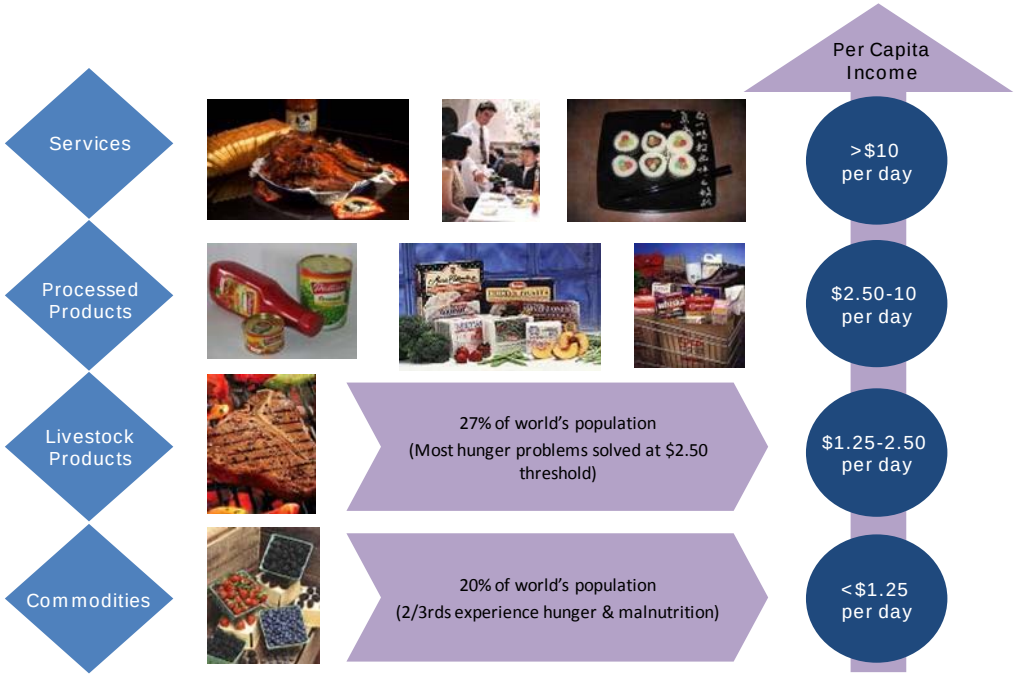
Chart 3: World GDP Growth by Region – 2008 to 2020



When you look at the number of consumers and where they are located, you look at the incomes and how fast they are going to be growing and where that's occurring in the world, that brings you to the dynamics of food demand and a little bit more of what that means for our business.

On the right-hand side of the following chart is the income ladder (Chart 4). You can see we have about half – 47 percent – of the world's population today of 6 billion people live on less than $2.50 a day. These were the people who were the most affected by this dynamic and widespread GDP growth we had in the first half of the decade. These are the people who were quickly moving up the income ladder, spending most of that additional income for food.

Chart 4: Dynamics of Food Demand



Source: World Bank, 2008

On the left-hand side of the chart, you can see what happens as incomes rise. People move away from staple foods, from basic commodities, and the first thing they want to add is more animal protein to their diets. As incomes continue to increase, they add more animal products and they add more services to the food products.

Again, when you look at population growth and income growth and where all of that is expected to occur, you are seeing this dynamic work itself out for our business as we look just 10 or 15 or 20 years ahead.

What are the implications of all this? As I indicated, we are in a multipolar economy now. We have engines of growth outside of the developed world. We've certainly seen that in this past

recession in the case of India and China. We no longer have the Third World. This "emerging market economy" label is now more appropriate than probably "developing countries."

The other thing these projections for population and income suggest is that by 2030 – just 20 years hence – we are going to have to produce 50 percent more agricultural products than we produce today. By 2050, we will perhaps have to double the amount of agricultural products we produce today. I say again, to 2030 is not a very long. To 2050 is not a very long time to essentially double the agricultural output.

In 2005, if you add up the volume by weight of all of the agricultural output, it was slightly more than 7 billion tons. By 2030, we are going to have to produce an additional 3 to 4 billion tons. Just imagine the investment required. It is not only the production of that amount, but it is the storage, the transportation, the processing, and the distribution of that amount. Think of the huge investment in transportation infrastructure, storage infrastructure, and all the other things required to do that.

Another implication of these population and income numbers is the increased role of trade. The world is becoming increasingly urban. In 2007, we passed the halfway point. More than 50 percent of the world's population now lives in urban areas. That is projected to be as much as 70 percent by 2050. We are increasingly in a situation where the population centers are in one part of the world, the surplus food production is another part of the world, and to meet the demands we have to increase trade, which highlights the importance of having more liberalized rules, cheaper transactions, and certainly a more robust rules-based trading system.

Very quickly, I want to say a couple words about the market characteristics. In the developing countries, the food markets are still concerned about price: the price of food first and foremost, then getting a sufficient number of calories, and improving and upgrading those diets. Once they pass that, it's a concern about basic food safety and then it's about reducing spoilage. Waste and spoilage are a big portion, because of the lack of infrastructure, so the focus is on trying to improve the infrastructure and reduce the wastage.

But in the developed countries, and certainly in the North American market, the concerns and pressures are much different. Production agriculture today in North America is being criticized from many vantage points. We are seeing already a big emphasis on trying to collectively change the national diet.

The U.S. Department of Agriculture issues new dietary guidelines every five years. A new set of guidelines is to be issued shortly. It is expected there will be a big shift away from animal products and into more fruits and vegetables and away from fats. There are new school feeding regulations for breakfast-lunch school programs.

The FDA is reexamining the role of salt in the diet. There are lots of state bans on trans fats, for instance. Sin taxes are coming into vogue again, where you tax sugar products or you tax sweetened sodas.

There is a lot of concern about obesity. It's no longer just a health concern. It's now a part of the food and agricultural policy issue. A lot of discussion is held about local foods, eating smart, home gardens. There are a lot of pressures. There are a lot of shifts characterizing the markets in the developed countries today.

The point is there is a lot of change likely coming. It's going to require adaptation all across the food system from changing production patterns for farmers to also changing patterns for processors, sellers, and for everyone in the system. That concludes the discussion of the principal demand drivers for our industry.

Now I want to say a little bit about the supply system, the condition we find it in today, and then the expectations for it. First, in the surplus food producing regions, we have seen a big investment in research and development over time. We have seen a lot of technological innovation. Producers have been quick to adopt these new techniques. As a result, we have seen tremendous productivity growth in the crop sector and in the livestock sector.

In the food-deficit regions, we see the opposite. There has been a long-term neglect for the agricultural and rural sectors in developing countries. There has been virtually no investment in research and development for three decades or more: no development of extension services, marketing services, very little investment in basic infrastructure such as farm-to-market roads or water containment, flood control, irrigation, or storage facilities. We also see very poor policies – both macro policies for countries and sectoral polices as they affect the agricultural sector. And, certainly in a lot of these countries, very little emphasis is placed on trade.

The result of this is that in the fall of 2006 we saw commodity prices worldwide start to move up and these prices peaked in the middle of 2008. We all remember $8 a bushel corn and $15 a bushel soybeans. Those prices prompted a reexamination of the global agricultural production system. The result is what I just described for you there.

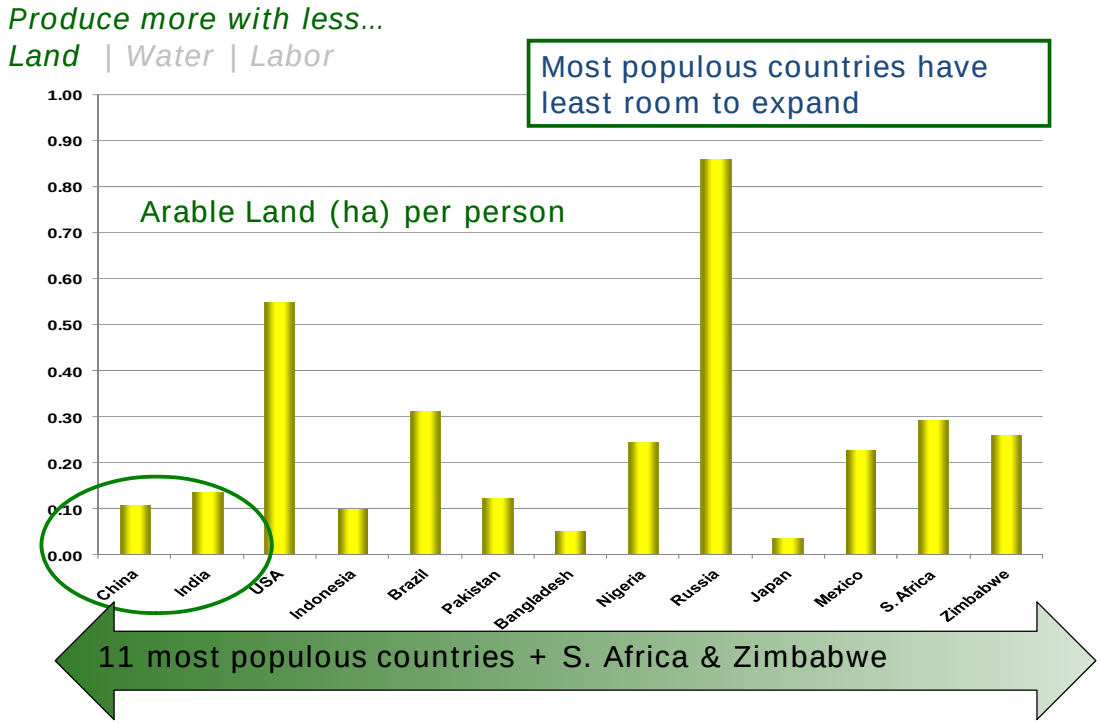
After the price increases beginning in 2006, farmers responded. They haven't repealed the laws of economics. Farmers responded by expanding area and increasing input intensity. By 2008, we saw a big increase in crops, just as the recession came along, which dampened demand. The result today is we have a much better balance in terms of supply and demand, commodity prices have moved down, and the carryover stocks are at more comfortable levels. This came about in large part because the recession gave us a breather.

The question is what do we do now? What happens to the supply side as we look forward 10 years, 15 years, and 20 years? I would suggest, as we try to meet these growing demand requirements, we are going to face some increasing constraints.

We all know about the land constraint. Most of the good farmland in the world today is already under cultivation. Any additional land you bring in is going to require increased capital investment, because it is not of the same quality as land we are already using. There is no consensus as to how much additional land might be available. The estimates vary, but they

generally gravitate toward something in the 10 to 12 to 15 percent range. Again, any expansion in the land base for farming purposes is going to be costly and is going to be controversial.

Chart 5: Growing Resource Constraints - Land

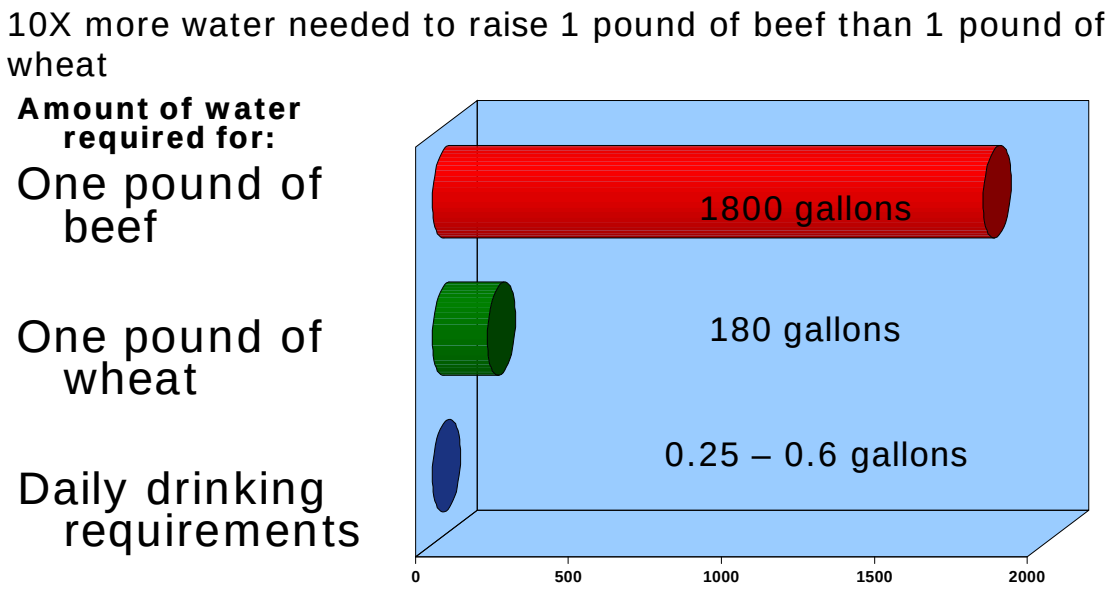


Source: FAO/FAOSTAT 2007/2008

We are all aware of environmental and other concerns. We are aware of the indirect land-use issue. So any additional expansion of area is going to be both costly and controversial. Chart 5 further illustrates that point, because it shows the 11 most populous countries in the world. It shows the arable area per hectare and it certainly reveals the most populous countries have little room for further expansion.

Water may be the more constraining resource – more so than land – as we look to the future. Agriculture is the big user of available fresh water today, using 70 percent or more worldwide (Chart 6). The competition is increasing from urban and industrial uses. We're already experiencing water-scarcity problems in many parts of the world. We certainly see that here in North America.

Chart 6: Growing Resource Constraints - Water



Source: UN-Water and FAO

As agriculture is called upon to produce more, the pressure is going to grow for increased irrigation, because that is one way you can boost yields on the land you are already farming. But we are also going to have to use the water more efficiently. That's going to call for more investment in new irrigation technologies and more capital investment in the adoption of those new technologies as they are developed. This chart, again, emphasizes the added pressure on water, as we see the dietary transformation around the world that includes more and more livestock products in the diet. So not only are we going to be required to irrigate more, but as we produce more animal products then more and more water is going to be required.

I want to mention labor. It seems a little strange to be talking about labor as a constraint if we are going from 6 billion people to 9 billion people, but it is already occurring. In fact, I've seen a spate of articles in the last few days about labor shortages in China. The world's most populous country is already having problems in finding available labor and labor with appropriate skills. That is certainly going to be the case in the agricultural industry and in some segments of food processing. So the big consideration is going to be, what does that do to the capital structure? What does that do to the cost structure of food production and processing as we go forward?

Despite all the recent controversy about climate change, there is still a large body of technical experts who believe climate change is going to affect the agricultural industry in the next 40 years and most of that effect is going to be adverse. There is further consensus that most of the adverse effects from climate change are going to be in the lower latitudes of the world in

the emerging market countries, where the production plants are the least able to adapt to climate change, which is also the part of the world where the diets are already the least adequate. We are going to have another emerging controversy, because it is the upper latitudes of the world that will be alleged to have caused the climate change. It's the lower latitudes that will be bearing the brunt of that climate change. We're probably in for another controversial issue there.

The point I'm making is, in addition to the other constraints I've just enumerated, climate change – if it is real and if we see the onset of it – is going to further constrain the ability to produce food and fiber.

The implication of having the production plan in the condition it is in today and having constraints is we have a very big challenge in front of us. We are going to have to feed more people, feed them better, and we're going to have to do it with about the same bundle of resources, or maybe even less, than we have today. And we're going to have to do it less intrusively by reducing the environmental footprint of the global agricultural plan. That is quite a challenge indeed.

All is not gloomy. There are a couple of positive things that have happened on the supply side I want to briefly mention. One is structural change that has occurred slowly, but has occurred nonetheless in U.S., European Union, Australian, and New Zealand farm policies. That is the reduction of artificial incentives to produce specific crops.

As you know in North America, for a long time farmers just continued to produce regardless of what the market signals were indicating. We produced huge surpluses that overhung the market and masked the price signals. Most of that is gone today, so we have a much more robust system. We have a just-in-time inventory system. We produce a crop in the Northern Hemisphere, and we start to consume it, just as we are producing a crop in the Southern Hemisphere. Then we start to consume that one. So we have a much more responsive and robust system today.

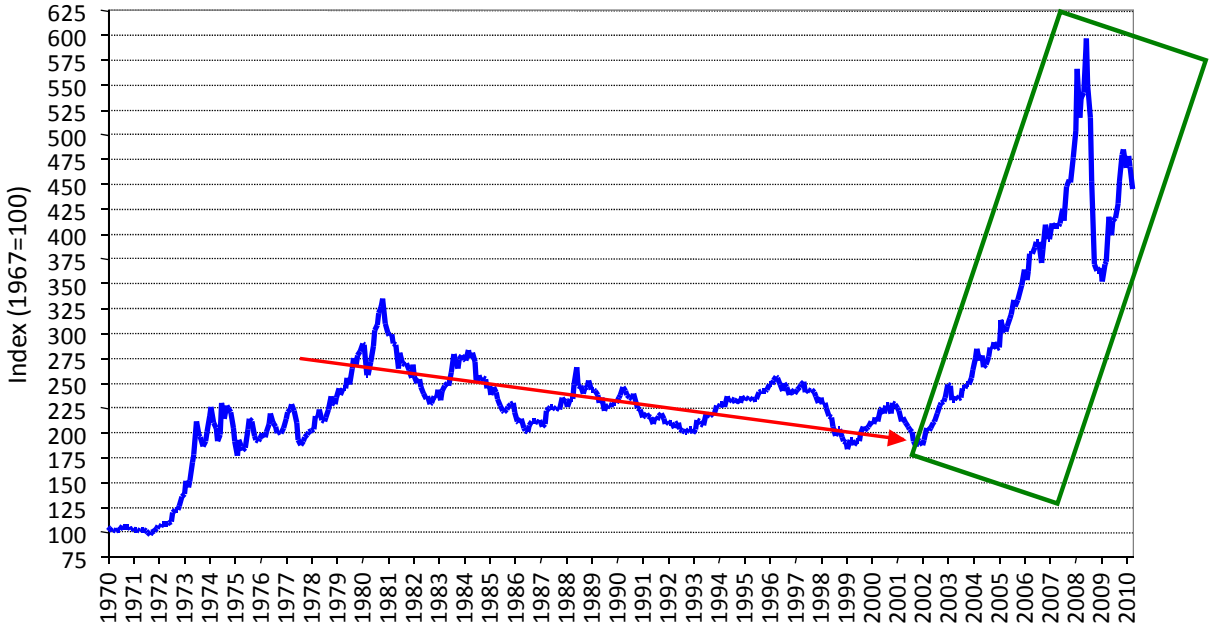
A second positive aspect is, following the price spikes in 2008 and the political turmoil following those spikes, we saw increased attention once again to the condition of the agricultural plan. There were a lot of multilateral initiatives, such as the G-20 pledge of $20 billion for agricultural development. The United States has a new initiative on food security with an additional $3 billion.

Many emerging-market governments, especially in Africa, pledged 10 percent of their national budgets to be devoted to agricultural and rural sectors. In addition to all of the governmental activity, we have seen a lot of investor attention. The sovereign wealth funds and individual investors – hedge funds and others – are focused on obtaining access to agricultural resources and producing agricultural products. I was in Africa a couple weeks ago visiting some of the big investor projects involving 25,000 hectares and more. That is occurring and it is occurring much more widely than I had recognized.

The big question about these new sources of supply expansion in my view is, is it different this time? Will it continue? History tells us, as commodity prices go up, everybody focuses on agriculture. As commodity prices go down, attention soon wanes. These governments forget their pledges and these investment projects begin to shift their capital to places where returns are higher. The question of whether this time is really different or not is going to depend on what happens to commodity prices in the future.

This is a rather interesting chart (Chart 7). I'll leave it up to you to interpret as you wish. This is a 40-year sweep of commodity prices – all commodities, not just food and agriculture but all commodities that are traded on the futures exchange. Out of this index, food and agricultural commodities make up 41 percent and petroleum makes up 26 percent, which equal two-thirds. Metals and minerals make up the other third. This is all commodities.

Chart 7: CBS Futures Index



Source: Informa Economics, May 2010

You can see down to the turn of the century we had a decided downward trend. About the time of the turn of century, when we started experiencing this robust, widespread global economic growth, you can see what happened to commodity prices. They shot up.

Next, you can see what happened when the Great Recession came. Commodity prices fell. To me, the interesting thing in this is, despite having endured the greatest recession since the Great Depression, commodity prices have not returned to their pre-crisis levels. What accounts for that? That is where you can interpret it as you wish. I think it suggests there are structural changes that have occurred – the most important one probably being new sources of demand. We

have suddenly seen this vast growth, especially in the Asian region. We've seen the dietary transformation that has occurred in that part of the world. That is probably one.

The second one is this structural change in the farm programs, so that farmers can now respond. That is no longer masking the signals. We can see much more clearly what is happening.

Third, what this reveals is, after the price spike in 2008, we've unmasked the condition of the production sector. A lot of people now realize the condition of the global agricultural production plan in many parts of the developing world and the markets are taking that into account.

The final thing is probably the emergence of value investing. Virtually everybody now – the hedge funds and the others – want to have commodities as a part of their portfolio. That is a relatively new thing. Maybe that plays some role in what we're seeing here today.

After the review of the main demand drivers and the characteristics of the supply plan today and then the prices, I want to move on and say a quick word about policy drivers.

We have a whole host of policies that affect our business: immigration policy, financial regulatory reform policy, energy policy, climate change policy, macroeconomic policies, and monetary policy. A lot of these policies are pending in North America and a lot of these are going to be decided by the Congress before long. They will have an impact on our business.

I want to take a longer look at the things that could affect the outcome of the fundamentals I've just described. The first of these is the failure to liberalize the global trading system. I've already made the case, I hope, trade is going to be increasingly important because production is going to be in one part of the world and consumption in another. We're going to need to have a strong rules-based trading system and we're going to need to have the barriers reduced to a minimum. We're also going to need a strong dispute-resolution system. And sanitary and phyto-sanitary rules increasingly coming into the trade agenda are going to need to be dealt with.

The other issue is infrastructure investment in the emerging countries. I've talked about that and have said there is a lot of attention being given to that. There is a possibility we are getting a misinterpretation or we're getting a garbled message. A lot of those activities are focused on state-driven development with minimal involvement of the private sector, minimal harnessing of private-sector capital.

The one thing we have learned is central planning doesn't work. If the effort crowds out the private sector, if the private sector doesn't have a very big role in the investment in these agricultural systems, then we will waste a lot of money. We are going to see a lot of scarce capital invested into production systems that are not sustainable. I am concerned about that. As you look at the plans by a number of these governments, you can see it has much more of central-planning focus than it has of a market-driven focus.

Finally, in innovation we need improved policies certainly. We need investment certainly, but we also need research and development. I want to mention briefly the Global Harvest

Initiative. This is an organization created a couple years ago by Deere, DuPont, ADM, and Monsanto. The purpose of the organization is to highlight the situation just described and to focus on what we call the productivity gap. Over the last 50 years, global agriculture has experienced some increase in the rate of productivity of global agriculture.

But, if we are going from 7 billion tons of output to 10 or 11 billion tons to 14 billion tons, then the rate of productivity growth is going to be some multiple of what an extrapolation of the trend rate of productivity growth has been. We have a gap. We have one line going this way and one line going that way. We need to close that gap. The Global Harvest Initiative is focusing on the most meaningful ways to close that gap.

Of course, if we don't close the gap – if demand outruns the ability to supply it – then we will have expanded hunger and malnutrition, beyond what we have today. We will have trade disruptions and environmental degradation. We'll have a drag on global GDP growth and we've already seen global GDP growth is a big, big driver in our business.

Finally, we'll have what we all dread, which is political instability. We saw riots and fragile governments grapple with the food price increase in 2008, so you can imagine if this occurs on a more frequent basis what will happen to fragile governments. In some key parts of the world, that could result in regional hostilities, disruption of shipping, disruption of all kinds of economic activity, and we'd have a much more unstable world than we have today. That is not good for our business. That is not good for the world.

To make a couple of final key points: One is I think the fundamentals underpinning our business, looking ahead 10, 20, or 30 years, are quite strong. The basic fundamentals are really quite good.

There are some real challenges for the global food system. Trying to meet these demands with a smaller bundle of resources and with these additional constraints from society is indeed a daunting challenge, but it is one we can meet. There is no doubt we can certainly meet the challenge. The people who thrive, the people who do well, and who are profitable are the people who are flexible and adapt. The pace of change is only going to accelerate, so we are going to have to be very adept in adjusting to that change.

Overall, it is an absolutely fabulous time to be in agriculture. For much of my career, we have focused on saying we have the production capability, if we only had the demand. And we looked for new uses for agricultural products. Looking ahead, the situation may be just the opposite. We have the demand. Can you produce it? So I think it is an absolutely fantastic time to be in agriculture.

Financialization of Commodity Markets: Non-linear Consequences from Heterogeneous Agent Behavior

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During the two decades following the oil shocks of the seventies the issue of commodity prices lost prominence in academic and policy debates. However, in the last five years we saw that nominal peaks in many commodities were accumulating in an impressive row. Records were broken in almost every month from the last part of 2007 and to the first half of 2008 in main commodity markets such as oil, copper, nickel, soybean or rice just to mention a few. But the rising trend in prices was spread out all over commodity varieties. It is now crucial to understand the global causes and consequences of this sharp increase and its following violent reversion.

Policymakers and academics did neither forecast the intensity nor the speed of recent commodity price movements. Therefore, the ongoing research agenda includes two problems: to understand what elements explain price movements; and to review policy responses in the light of this new scenario. In this paper we cover the first issue of the agenda, although we will point out the main policy challenges at the end of the document.

In explaining the commodity price movements there are roughly speaking two stories not necessarily well connected, as Krugman (2008) has advocated. The first story is basically about fundamentals. It says that world income is growing at a pace that is not matched by the supply side of the commodity markets. China and emerging Asia are the main characters here because living standards are increasing more than proportionally precisely in countries that have high income commodity demand elasticity due to Engel law (IMF, 2006; Kaplinsky, 2006; OECD-FAO, 2008). There is also room in this view for big dollar movements. The influence of this variable over commodity prices has been discussed in other historical booms and busts cycles (Ridler and Yandle, 1972; Dornbusch, 1985; or Borensztein and Reinhart, 1994). Also loose monetary conditions and excess of international liquidity are critical elements of this view, since they add inflationary pressure which tends to be reflected rapidly and with more intensity in auction markets like commodity ones (Frankel, 2006; Lipsky, 2008).

Finally, if the focus is posited on food commodities it will be necessary to add biofuels as a new determinant of prices (UNCTAD, 2006; IMF, 2007). The second story points out speculation as the driving force of recent commodity price movements. It stresses the relevance of the so-called "financialization of commodities", a process according to which a number of non-conventional actors such as investment banks, hedge-funds or pension funds have been investing in commodity-linked instruments.

Of course it could be asserted, as we do in this paper, that both stories overlap and are connected and that a complete picture should take all the pieces together in a coherent way. We argue that the impact of financialization and speculative activity is reflected on short run price dynamics, but not in the long term equilibrium. Specifically, we propose that financialization generates a non-linear adjustment pattern of commodity prices to its fundamental value.

Thus, in the theoretical front, we develop a simple heterogeneous agent-based model in commodity markets that include chartists, fundamentalists and portfolio managers. An outcome of this framework is that price adjustment to equilibrium is reached in a non-linear way, being more intense as long as the past gap between the spot price and the equilibrium price increases.

Concerning this commodity price equilibrium, we assert it depends on determinants highlighted by previous literature: world demand, real exchange rate of the United States, real interest rates and the Prebisch-Singer hypothesis.

A novel characteristic of this paper is that it employs an empirical methodology that allows us to distinguish permanent and transitory movements in prices once the long run equilibrium is estimated. Thus, in modeling short run dynamics we make use of a smooth transition autoregressive model (STAR) which is suitable for testing the hypothesis derived from our heterogeneous agent based model in commodity markets The intuitive idea of the STAR model is that the discrepancy between current and fundamental prices plays a double role. On the one hand, it is the force that drives price changes in the required direction to fill the existing gap as in any traditional error correction model. On the other hand, the misalignment acts also as a transition variable, governing the state of the model – the larger the misalignment, the faster the speed of convergence.

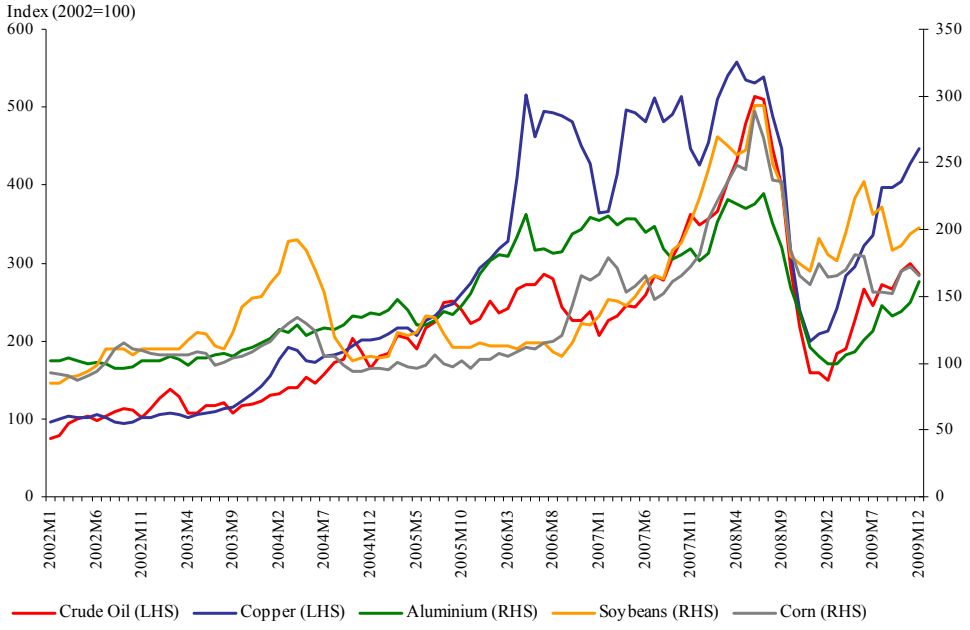
The organization of the paper is as follows. In the next section the past pattern of commodity markets is described. The analysis suggests there are significant differences in the commodity outlook depending on both the time window employed and whether real or nominal indexes are considered. After that, we review theoretical and empirical literature of long run commodity price determinants. The issue of financialization is discussed in the third section. We conclude from it there is some evidence that at least does not contradict our hypothesis that financialization is important in influencing short run price dynamics rather than equilibrium levels. Following this, we present a stylized model of heterogeneous agents in commodity markets that gives support to our hypothesis. In the next section, the econometric methodology is summarized. The empirical evidence is shown in the sixth part of the paper considering both long run and short run commodity behavior. Finally, the conclusions and policy challenges are presented.

1. Stylized facts of commodity prices

Up to the intensification of the financial slump during the second part of 2008, commodity prices grew in nominal terms at a strong pace for six consecutive years. However, the crisis has showed us again that commodity price flexibility is remarkable and those record values by

June-July, 2008 were cut at least by a 30% at the end of October. In Figure 1, we have drawn the evolution of some key commodity prices from 2002 to 2008.

Figure 1. Key Commodity Price Indexes



Contrary to the common belief that commodity prices have reached currently historical high levels, long-run perspective shows stagnant or decaying prices if we incorporate into the analysis the world inflation. In Figures 2 and 3, the long run trends of food, metals and oil in nominal and real terms are presented. The real series are deflated using US consumer price index (CPI).

Figure 2: Food and Metal Price Indices

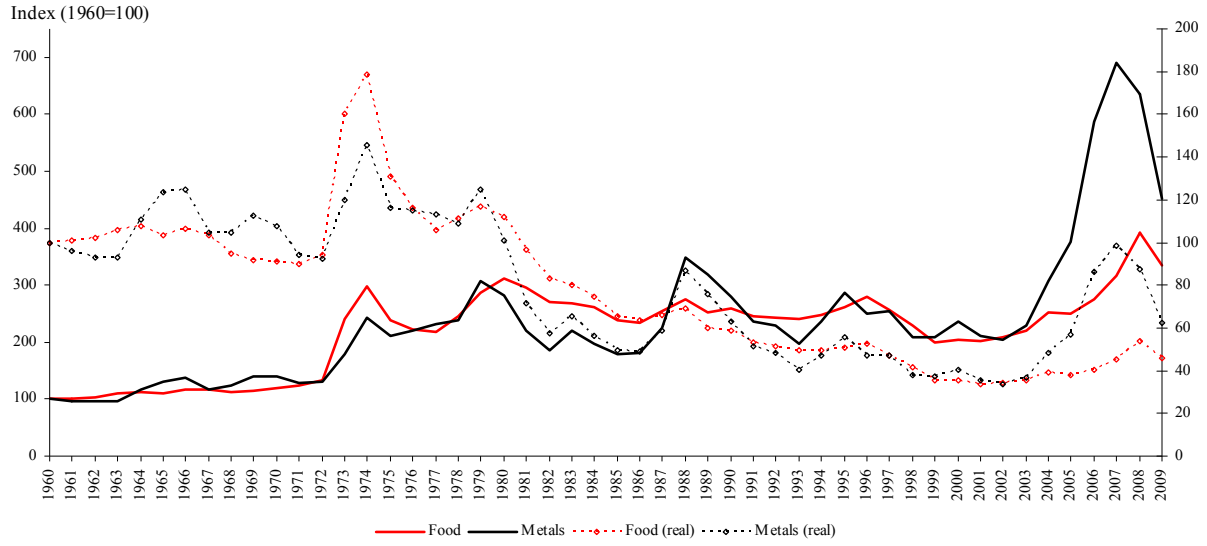
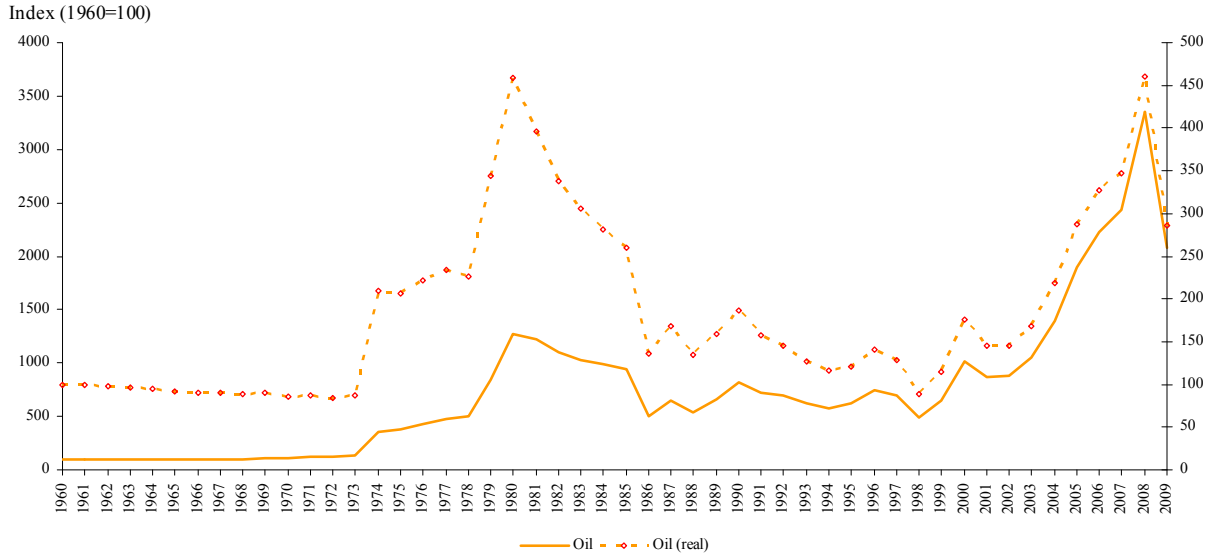


Figure 3: Oil Price Indices



When food and metals price indexes in real terms are analyzed, for example, we indeed verify between 2002 and 2008 an increase of 170% and 290%, respectively. Nevertheless, when the period 1960-2008 is considered, we observed that even after the last boom, real food prices are far below of their level in 1960 (-41.84%) and real metals prices have just recovered the levels exhibited in that year. The oil story is quite different. Real oil price have risen strongly in the last decade, being its current level five times the figures it presented in 1960.

Some authors have stated that, instead of long-run trends, the most remarkable feature of commodity price dynamics is short and medium term volatility. According to Deaton (1999)

"what commodity prices lack in trend, they make up for in variance." Cashin and McDermott (2002) find that commodity price volatility has increased notably since Bretton Woods breakdown at the beginning of the seventies. Figures 4 and 5 depict the real price volatility measured by the standard deviation of the monthly real price changes using a rolling window of 12 months.

Figure 4. Food and Metal Real Price Volatility

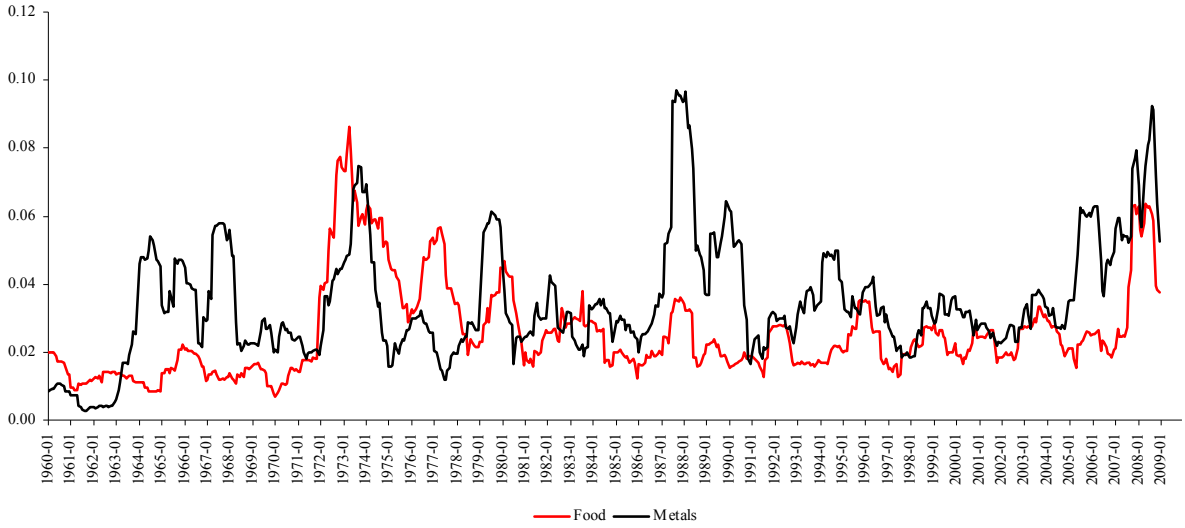
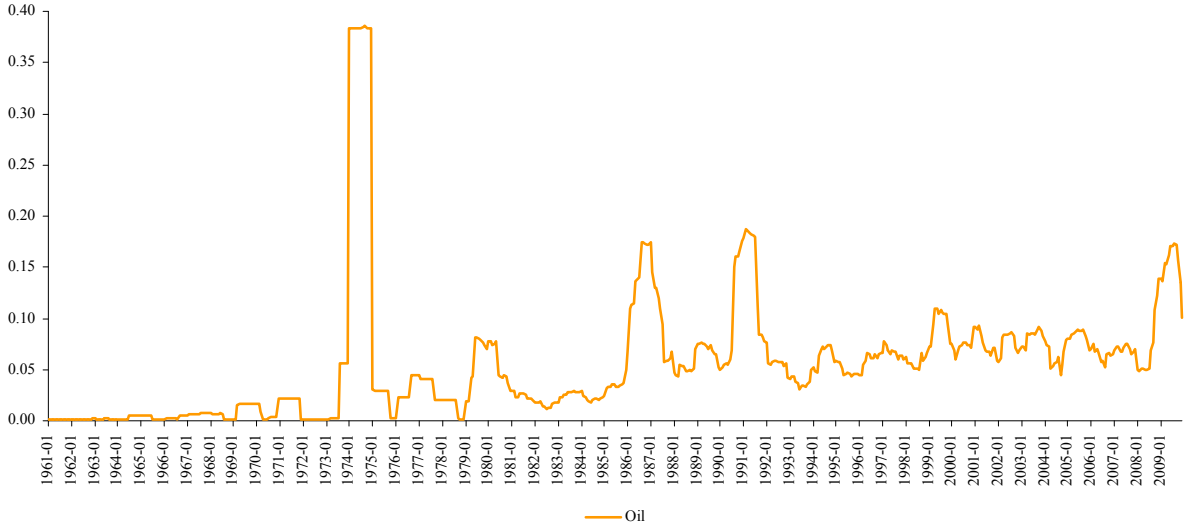


Figure 5. Oil Real Price Volatility



We found that, in fact, average volatility in post Bretton Woods era has doubled with respect to the 1960-1972 period in the case of food, while it has risen 40% when the metal price index is analyzed. Oil has exhibited a more abrupt price volatility increase. During the first phase the volatility measure averaged 0.0058 whereas in the second one that figure reached 0.069.

After summarizing stylized facts, we will disentangle the underlying factors that influence commodity prices in the long run – obtaining an "equilibrium" or "fundamental" price; and the mechanisms that generate, strengthen and eventually correct short run deviations with respect to that equilibrium after the Bretton Woods breakdown.

2. Long run drivers of commodity prices

In one of the most controversial thesis in the international economics field over the past century, Prebisch (1950) and Singer (1950) claimed that, contrary to the classical view, primary product prices would fall relatively to those of the industry. Prebisch (1950) asserted this tendency would be the outcome of a fundamental asymmetry in the international division of labor. Thus, while countries at the "center" had kept all the gains of their productivity increases, "the periphery" had conceded parts of the benefits of its own technological progress. The influence of this hypothesis over empirical research on commodity prices has been substantial and explains why the primary way of studying these prices has been through univariate methods such as unit root test or structural breaks tests.[1]

A different approach for studying commodity prices begins by asking which macroeconomic factors could have a clear connection or act as determinants of them. In this sense, the pioneering model of Ridler and Yandle (1972) uses comparative static analysis in a single-good model to demonstrate that an increase in the real value of the dollar (i.e. a real exchange rate appreciation) should result in a fall in dollar commodity prices. Dornbusch (1985) constructs a simple two country, supply-demand model to highlight this effect. In that paper, the elasticity of commodity prices to United States real exchange rate (RER) should conform to the following relationship:

$$\frac{\partial \ln\left(\frac{P}{CPI}\right)}{\partial \ln\left(\frac{CPI}{eCPI^{*}}\right)} = -\frac{\beta^{*}}{\left(\frac{\beta\eta}{\eta^{*}} + \beta^{*}\right)} \qquad (1)$$

where P is the price of a representative commodity basket; CPI and CPI^{*} are consumer price indexes in the United States and the rest of the world respectively; e is the multilateral nominal exchange rate (therefore $\frac{CPI}{eCPI^{*}}$ is the RER); η and η* are demand price elasticities of; and ß and ß* are market shares of each country in the world demand. According to this theoretical

[1] See for instance Grilli and Yang (1988), Cuddington and Urzúa (1989), Bleaney and Greenaway (1993), Cashing and McDermott (2002) or Ocampo and Parra (2003). The evidence that emerges from these papers is that negative growth rates tend to prevail when commodities are compared to industrial products considering the very long run. However, there is not a clear consensus about growth dynamics. While some authors have argued there is a decaying constant trend, other papers have stressed the importance of structural negative shifts that are not fully recovered during the upward phase of commodity prices cycles.

model, this elasticity should lie between 0 and -1. However, in empirical research it has usually been the case that it overshoots its theoretical value (i.e. is lower than -1).[2]

World demand is obviously another important driver of commodity prices. There is general consensus that Engel's law is an accurate framework to predict the impact of income on food commodities (Houthakker, 1987; Hamilton, 2001). Hence, aggregate food income-elasticity in each country would fall as long as the transit to development is completed. In the case of metals, it has been argued there is an inverse U-shape relationship between its use and income level. Thus, the consumption intensity of metals increases up to a point in which GDP per capita reaches approximately 15,000 or 20,000 purchasing power parity adjusted U.S. dollars (IMF, 2006) and then it starts to go down. In empirical models, indexes of world industrial production have been employed to measure world demand. Apart from real exchange rate and industrial production, a third variable has been suggested as a determinant of commodity prices – the real interest rate.

Explaining the excess of co-movement of commodity prices with respect to fundamentals, Pindyck and Rotemberg (1987) consider that these movements are the result of herd behavior in financial markets since its participants could believe that all commodities tend to move together. The authors claim that, as storable assets, commodities are affected by expectations. Interest rates might affect the harvest or production in a number of commodities, thereby changing its future supply and current prices. It could also affect expectations about future economic activity and then future commodity demands which, again, impact on spot prices.

Frankel (2006) remarks that rising interest rates are transmitted to commodity prices through three channels: i) by increasing the incentive for extraction (or production) today rather than tomorrow; ii) by decreasing the desire of firms to carry inventories; and iii) by encouraging speculators to shift out of commodity contracts into treasury bills. The three channels of transmission work to reduce spot prices. In fact, the author has argued that nominal records during 2006 in some commodities could be a signal that monetary policy has been too loose.

In our empirical non-linear model we will allow all these variables to play an explicit role determining the "equilibrium" or "fundamental" long run price of a selected commodity basket.

3. Financialization of commodity markets

The debate regarding the issue of financialization in commodity markets has been intense and positions are diverse in this point. Some authors have blamed financial markets as the only element responsible for violent price movements, while others have neglected their influence on prices. Hence, the key issue among financial market participants, academics and policymakers is trying to establish to what extent the financialization of commodities influence spot price levels and its stochastic properties.

[2] Dornbusch (1985), Gilbert (1989), De Gregorio et al. (2005).

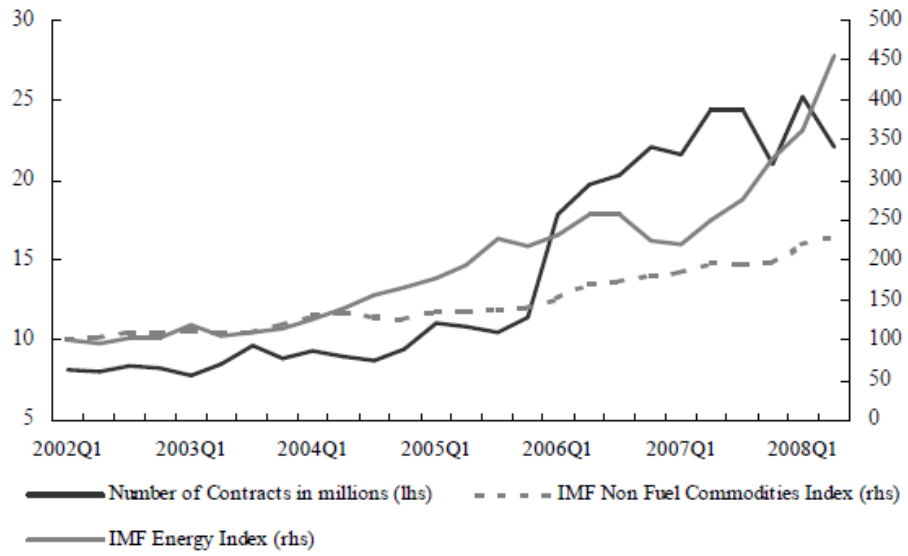
According to their characteristics, the market for each commodity is divided into two parts. On the one hand, it is the physical spot market in which the consumers demand these goods to the producer and the spot price is determined. On the other hand, it is the financial derivative market where long and short traders agree on a future settled price. Derivative markets can be further decomposed in two categories: exchange markets where standardized contracts are traded through a central clearing entity, and over-the-counter markets (OTC) in which tailored contracts are negotiated, usually by means of a market maker.

With the term "financialization" of commodities the literature usually makes reference to two different, though partially linked facts. The first fact is that derivative market activity has experienced an impressive growth in the last years. The second issue is the increase in the participation of financial investors in futures markets that occurred simultaneously.

Hence, one of the reasons to believe there is a close connection between price dynamics and speculative activity rests on the idea that we observed, during the past five years, a consistent rise in commodity prices in conjunction with a notable increase in turnover on commodity-linked instruments. In fact, trading volume in these instruments is several times higher than that of the physical production. Just to mention an example, Domanski and Healt (2007) have pointed out that contracts in derivative commodity markets tripled between 2002 and 2005; while in the same period the ratio of financial activity of crude oil and copper to their world productions increased from 3.2 to 3.9 and from 30.5 to 36.1, respectively.

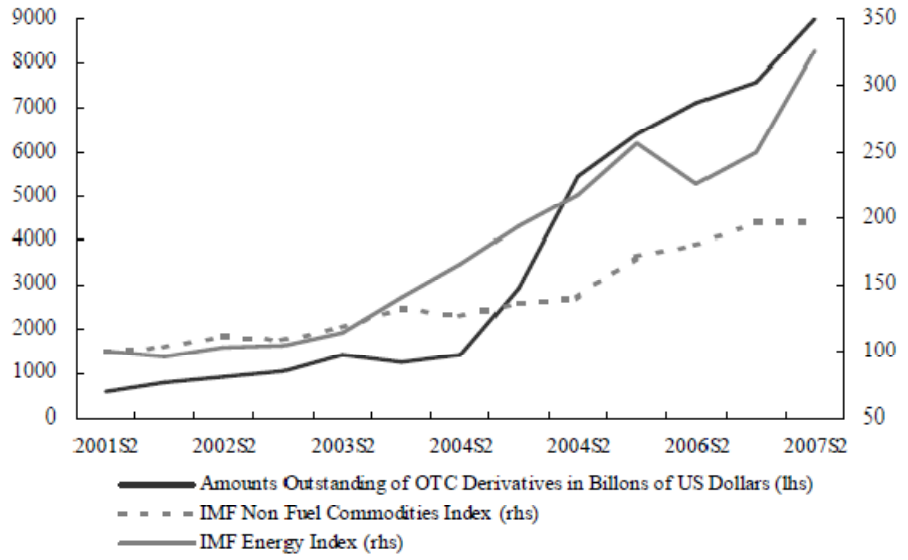
It is possible to illustrate this hypothesis comparing both the evolution of the number of outstanding commodity contracts and the amounts of USD outstanding OTC derivatives in conjunction with nominal commodity price movements. The exercise is presented in Figures 6 and 7 using the energy index and the non-fuel commodity index elaborated by the IMF.

Figure 6. Evolution of Derivative Commodity Contracts and Commodity Prices



Source: IMF International Financial Statistics and BIS Quarterly Review

Figure 7. Evolution OTC Derivatives and Commodity Prices



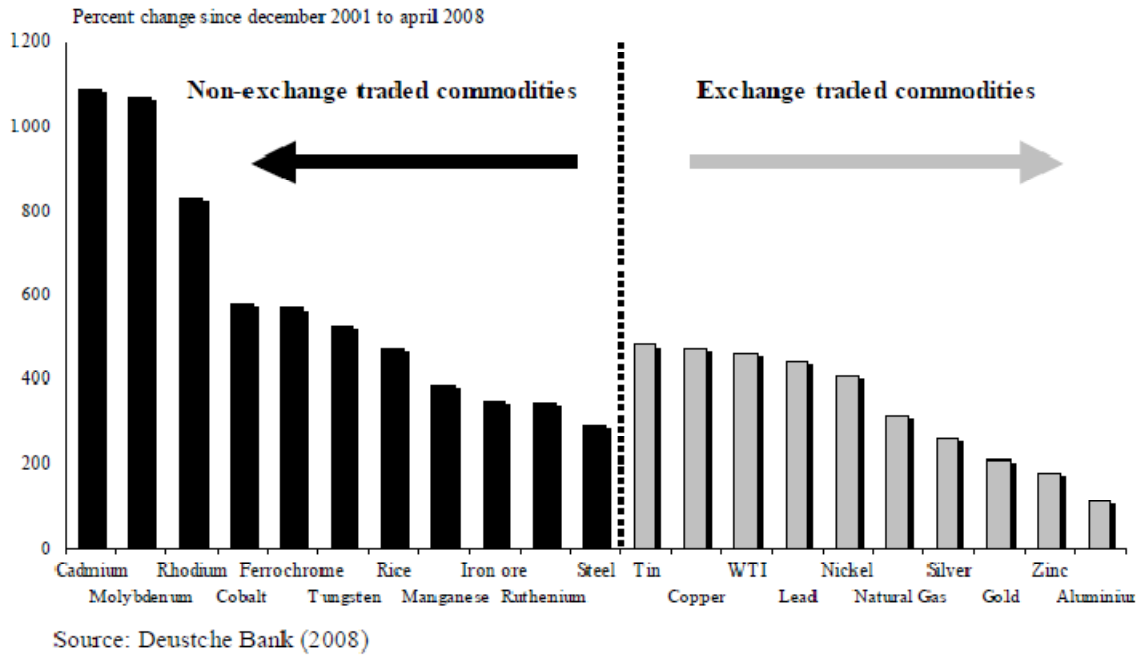
Source: IMF International Financial Statistics and BIS

As it was mentioned before, there is evidence of a considerable rise in derivative market activity when the so-called "boom" cycle of commodity prices from the beginning of 2002 to the second quarter of 2008 is observed. During this period, total commodity contracts grew by 170%; while energy and non-energy commodity prices increased by 350% and 120%

respectively. Moreover, the evolution of OTC derivatives in nominal US dollars was even more impressive (Figure 7). Thus, in the light of this evidence it results quite natural to associate this significant increase in financial commodity market deepening with soaring prices.

However, there is an important caveat in this line of reasoning. Specifically, if financialization has actually played a fundamental role in boosting commodity prices, we would expect lower growth rates for those commodities that lack derivative markets. Figures 8 and 9 reproduce the exercises carried out by Deutsche Bank (2008) and Viñals (2008) consisting in calculating price increases in both exchange and non-exchange trade commodities.

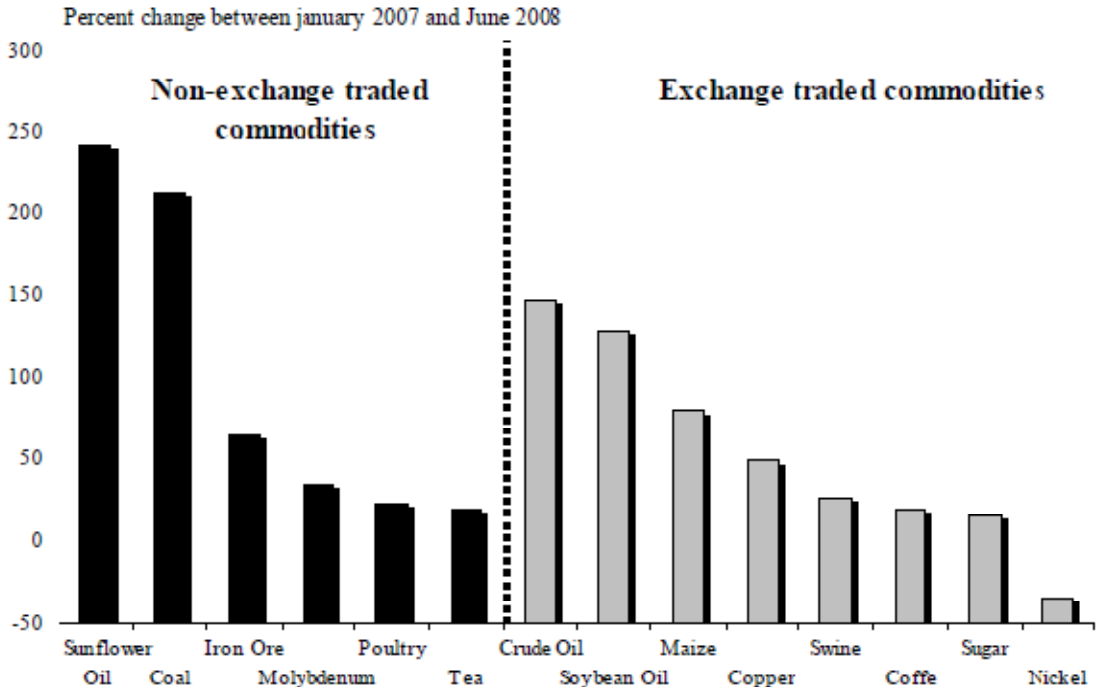
Figure 8. Price Changes in Selected Commodity Markets



Source: Deustche Bank (2008)

In Figure 8, we observe that prices of exchange traded commodities have appreciated by a similar, if not lower, amount to non-exchange traded commodities where financial activity is not possible. Viñals (2008) has performed a similar exercise considering just the final part of the commodity boom (Figure 9).

Figure 9. Price Changes in Selected Commodity Markets



Source: Viñals (2008)

Again, we cannot establish a clear cut line between exchange and non-exchange traded commodities in terms of price variations. In some sense, this refutes the claim that commodity price increases that took place until the first half of 2008 were driven largely by speculative activity.

A more careful analysis of the issue of financialization requires going deep into the microstructure of derivative markets. Among of these market participants, there is a first wide division between commercial hedgers and financial investors.

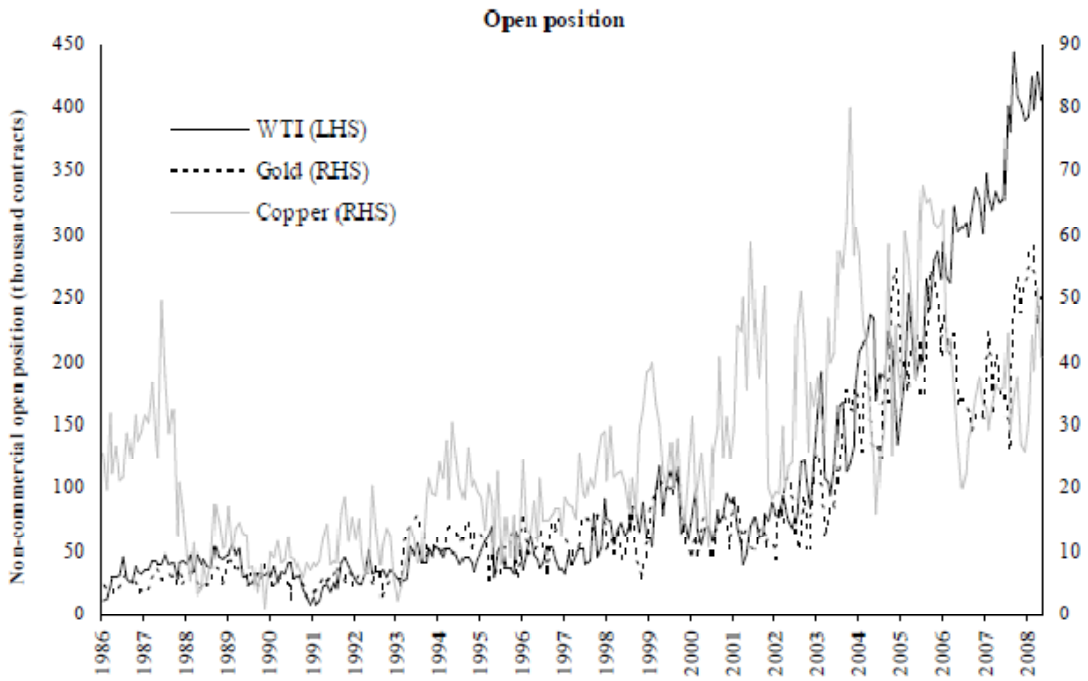
Commercial hedgers are buyer or sellers of the physical commodity who use derivatives to hedge against the risk of price fluctuations. In the end, this type of agent is interested in the evolution of future spot prices of the underlying commodity (IMF, 2006).

Financial participants have different incentives from commercial hedgers. We can distinguish two strategies among them. On the one hand, there are "buy and hold" investors who pursue fully collateralized long-only future strategies, i.e., acquiring a long position in futures and investing the same amount in treasury bills as collateral. This strategy is usual among pension and mutual funds and it has historically had excess returns similar to those of equities. Additional interesting properties of commodity futures as a buy and hold strategy is that their returns are negatively correlated with equity and bond returns, and they prove to be a good hedge against unexpected inflation (Gorton and Rouwenhorst, 2004; Erb and Harvey, 2005).

On the other hand, we have a broader group of investors pursuing more complex strategies. Hedge funds have recently played an active role. Their operations are characterized by freedom in using a wide range of instruments and the ability to short sell and high leverage (Stefanini, 2006). Also, retail investors are becoming increasingly important since they could participate in new instruments such as Exchange Trade Commodity Funds or Structured Commodity Notes (McNee, 2006; Bienkowski, 2007).

Although it could be argued that the action of financial investors has increased in the last years, this is not new. Figures 10 and 11 depict the number of open positions (long plus short) of financial participants in key future commodity markets since 1986. We observe a strong increase in the number of contracts opened by financial investors in the oil, gold and copper markets since the beginning of 2002; but the activity previous to that date was far from negligible.

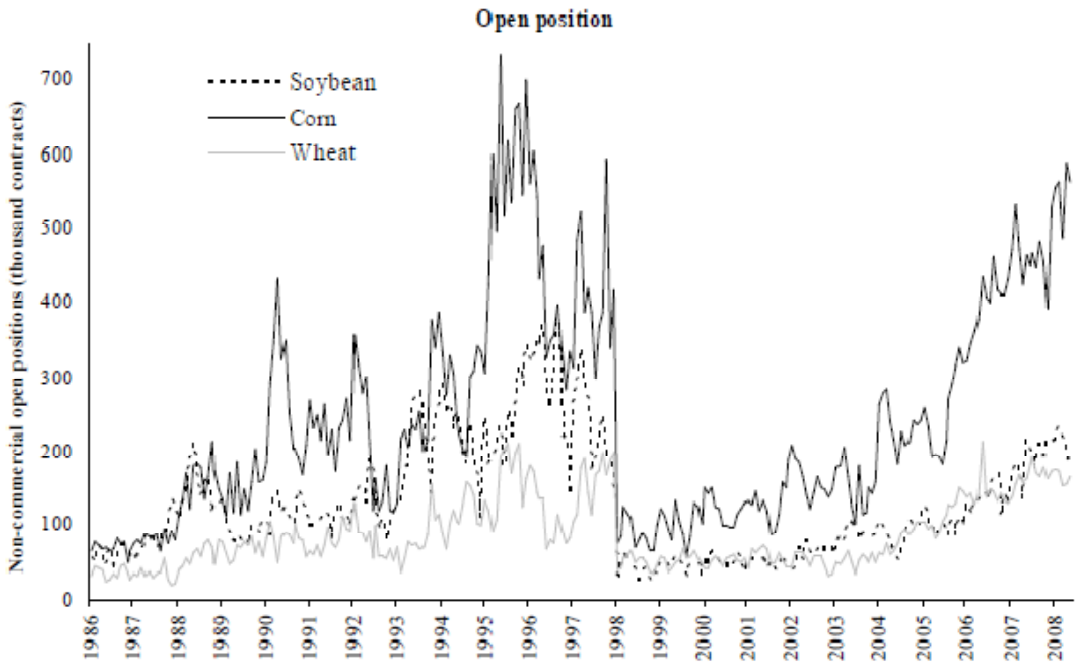
Figure 10. Non-Commercial Open Positions in Oil, Gold and Copper



Source: Calculations based on Deustche Bank data

The picture is quite different from soft agricultural commodity markets in which we observe a sharp drop in financial activity connected to the Asian crisis of 1998 (Figure 11). After that, the number of open contracts just recovered its previous levels. From this evidence we conclude that financial activity has intensified in the last five years but could not be viewed as a completely new fact.

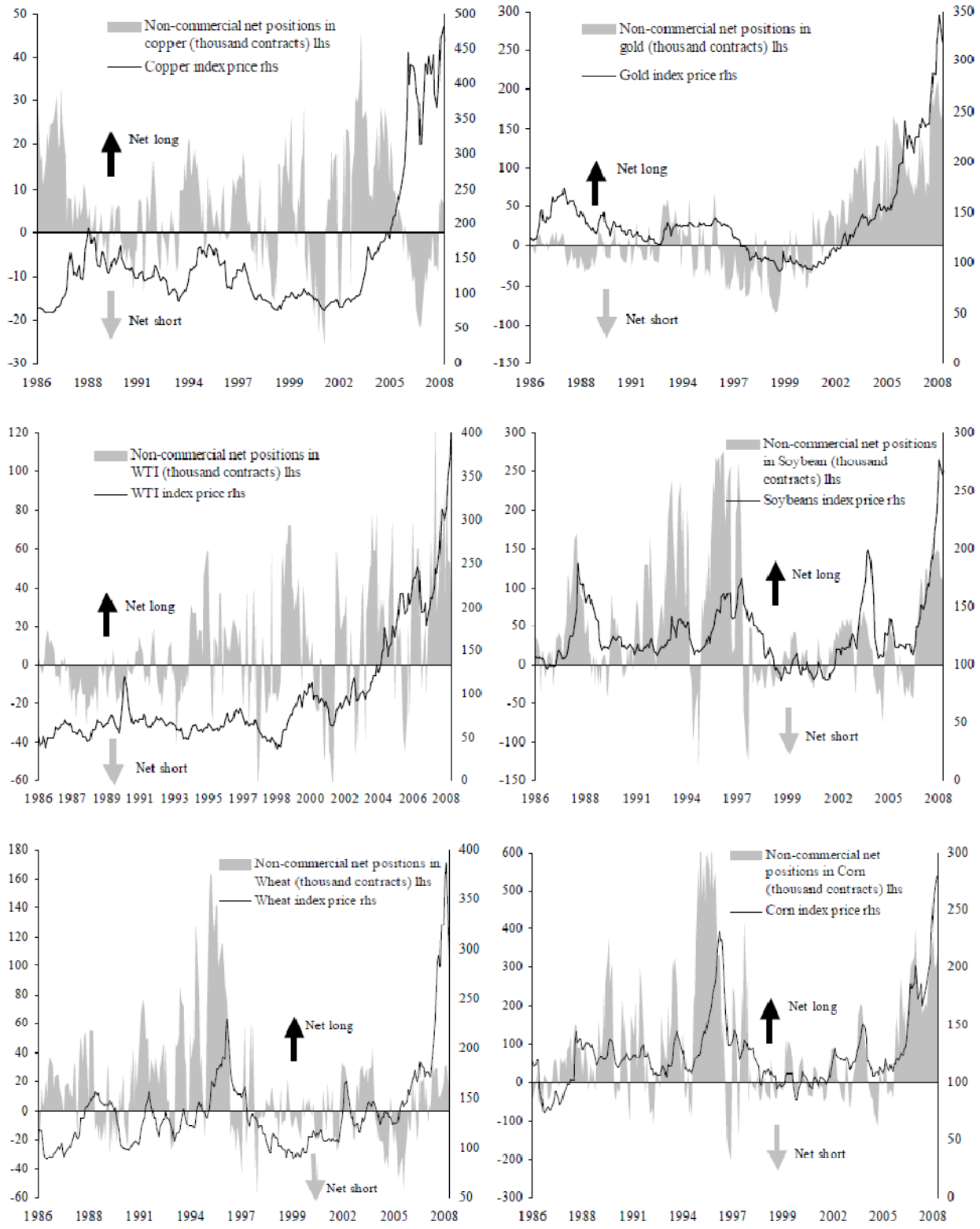
Figure 11. Non-Commercial Open Positions in Soybean, Corn and Wheat



Source: Authors calculations based on Deustche Bank data

Besides, the impact of speculative activity on prices could depend more on net positions (long minus short) rather than open positions. In Figure 12, we have drawn these net positions of financial participants in selected derivative markets and the corresponding spot price (expressed as an index).

Figure 12. Net Positions of Financial Investors in Selected Commodity Markets



Source: Authors calculations based on Deustche Bank and IMF data

There are several relevant points to highlight from this figure. Firstly, it seems that the mean position of financial investors throughout time tends to be a long one, but this fact could be partially explained by institutional investors going into long "buy and hold" strategies. There is a positive "long bias" among non-commercial participants.

In the second place, we can observe that net financial positions tend to be volatile which means that non-commercial investors could either act as a push or pull factor of influence over prices depending on specific circumstances.

In the third place, it seems there is a positive correlation between the net position and the spot commodity price which indicates that high price levels induce appreciation expectations of financial participants.

Finally, with the notable exception of copper, it was the case that the last phase of high prices from 2005 went along with short net non-commercial positions. However, it is important to note that apart from the most recent case of copper, there were other phases in the past in which net long positions coexisted with stagnant commodity prices. In wheat for instance, we observed a 200% increase in prices between 2005 and 2008 which coincides with a slight long position during the whole period. Moreover, we could also note from Figure 12 that price drops were not necessarily followed by aggressive net short positions. Explicitly, all this evidence means it is not necessary to have neither derivative markets nor aggressive financial investor participation to observe sharp price fluctuations.

In the financialization debate there is a last remark connected with the issue of causality. We think that a hypothesis that deserves some attention is that higher prices during the past five years could have caused an increased interest in commodity investment, and not the other way around as it is usually stated. To shed some light about this hypothesis we have calculated in Table 1 the correlation coefficient between net financial positions and the growth rates in various commodity prices using different time windows. We take the net financial positions at the end of the month and compute firstly the contemporaneous correlation with the price variation taking place between this date and the previous month. Then we consider both backward and forward price variation windows of up to three-months. In this way, the pairwise correlation between open positions and price changes at t + 3 considers the accumulated three month forward price variation. As a complementary exercise we have added the corresponding Granger causality test to establish if changes in financial positions anticipate spot price changes or if it is the other way around.

Table 1. Net Financial Positions and Commodity Prices, Correlations and Causality, 1986-2008

	COPPER	GOLD	SILVER	WTI	SUGAR	SOYA	MAIZE	WHEAT
T vs T-3	0.35	0.64	0.53	0.39	0.09	0.52	0.58	0.34
T vs T-2	0.37	0.59	0.50	0.39	0.07	0.51	0.56	0.37
T vs T-1	0.38	0.50	0.46	0.40	0.05	0.47	0.50	0.39
T vs T	0.39	0.42	0.44	0.41	0.02	0.40	0.42	0.37
T vs T+1	0.22	0.27	0.17	0.16	0.07	0.20	0.26	0.21
T vs T+2	0.19	0.29	0.13	0.11	0.15	0.15	0.24	0.20
T vs T+3	0.20	0.34	0.14	0.12	0.18	0.12	0.21	0.17
Granger Causality Test								
Price Variantions do not Granger Cause Changes in Net Financial Positions	1.77820**	0.67559	0.86989	0.80581	0.30402	0.98956	1.57599*	0.82225
Changes in Net Financial Positions do not Granger Cause Price Variantions	0.76235	2.785***	1.05728	1.29875	0.80934	2.09115**	1.21476	1.56979*

Source: Authors calculations based on Deustche Bank and IMF data

It is clear that in all the cases there is a strong positive correlation of past price variation at time (t - 1 , t - 2 , t - 3) that tend to lower in subsequent periods. This fact could indicate that financial speculators take long positions when they observe price increases in the recent past with the expectation of further increases in the future. In the next section, we will refer to this type of behavior as driven by simple "rules of thumb" or "chartist analysis." The evidence of Granger causality tests, however, does not reveal any clear causality pattern. This means the issue of causality remains open and further research would be needed.

Taking together, we interpret this preliminary evidence as an indication that financial participants could induce price fluctuations or excess volatility in some markets, but do not have a long-lasting impact on equilibrium prices which are ultimately determined by fundamental supply-demand factors. In the next section, we develop a simple model to stress a potential mechanism in which financialization alters the dynamic adjustment of prices to equilibrium. We will test then how actual commodity data fits with this hypothesis.

4. Heterogeneous agents in commodity markets

The model assumes that the change of the commodity price in the next period is determined by the interaction of three different agents[3] called fundamentalists (F), chartists (C) and portfolio managers (PM) in accordance to the following expression:

$$\Delta P_{t+1} = a_1 E(\Delta P_{t+1}^{C}) + a_2 E(\Delta P_{t+1}^{F}) + a_3 E(\Delta P_{t+1}^{PM}) \qquad (2)$$

[3] Pioneering work on heterogeneous agents literature corresponds to Frankel and Froot (1987a,b and 1990), DeLong et al. (1990a,b), and Shleifer and Summers (1990).

where $E(\Delta P_{t+1}^{C}), E(\Delta P_{t+1}^{F})$, and $E(\Delta P_{t+1}^{PM})$ are the price change expectations of each agent and a_1, a_2, a_3 are fixed weights that measure the relative importance of each group.

The expectations of the fundamentalists are based on the notion of commodity price reversion towards its long run equilibrium. The particular specification is:

$$E(\Delta P_{t+1}^{F}) = -\propto (P_t - F_t(X_t)) \qquad \propto > 0 \tag{3}$$

where F_t is the fundamental price of the commodity (or the relevant commodity price index) in time t. This price is a function of a vector of variables (X_t) stressed by empirical literature such as world demand for commodities, the real exchange rate of the United States and the real interest rate.

According to equation (3), fundamentalists expect decaying (increasing) prices when current prices are higher (lower) than fundamental prices. Thus, they are prone to sell or buy the commodity in a counter-cyclical fashion. It is not necessary to assume that fundamentalists know exactly which the long term value of the commodity is. We can think instead they can obtain a consistent estimation of this equilibrium. For instance, it could be assumed that these agents have an imperfect knowledge about the real model because there exists uncertainty regarding the true value of the parameters, but they build their expectations based on an econometric regression without making systematic errors (Bray and Savin, 1986 and Fourgeaud et al., 1986).

Chartists, on the contrary, employ technical analysis and follow the current trends in prices. One way to formalize this type of strategy is:

$$E(\Delta P_{t+1}^{C}) = \delta(P_t - P_{t-1}) \qquad \delta > 0 \tag{4}$$

Every time prices increase, these agents will take a long position in commodities because they expect that this trend will continue in the future. From the correlation analysis of the third section we know this is compatible with the actions of financial participants.

The key factor of this simple model is the inclusion of portfolio managers who are assumed to have an information advantage, in the sense they know the way the other market players form expectations. In order to take advantage of their knowledge, PM agents adjust their expectations employing a weighted average of expressions (3) and (4):

$$E(\Delta P_{t+1}^{PM}) = (1 - w_t)E(\Delta P_{t+1}^{C}) + w_t E(\Delta P_{t+1}^{F}) \qquad 0 \leq w_t \leq 1 \tag{5}$$

It is crucial here to note the role of the variable w_t which governs the weight given to each type of expectation in time t. We assume that w_t adjusts endogenously in response to the size of past misalignment. Thus, the w_t variable is the source of non-linearity into the model. We propose, in particular, the following exponential function:

$$w_t = 1 - exp\left(-\gamma\left(P_{t-d} - F_{t-d}(X_{t-d})\right)^2\right) \qquad \gamma > 0, d \geq 0 \tag{6}$$

The intuition behind the specification of equation (6) is that the gap between actual and fundamental prices (lagged by d periods) is the element that determines the weights assigned to the expectations of F and C agents by the portfolio managers. When $F_{t-d} \equiv P_{t-d}$, then w_t will show

a very small value encouraging portfolio managers to follow the behavior of chartists. In the limit, when $F_{t-d} = P_{t-d}$, ($w_t = 0$), the price change will be given by:

$$\Delta P_{t+1} = (a_1 + a_3)E(\Delta P_{t+1}^{C}) = (a_1 + a_3)\delta(\Delta P_t \ ) \tag{7}$$

If we are interested in empirically studying commodity price dynamics, expression (7) suggests employing a purely autoregressive econometric specification.

As long as the gap between F_{t-d} and P_{t-d} increases, portfolio managers start to bet against this misalignment. That is, the larger the misalignment, the larger the weight they give to F expectations. Again, in the extreme case, $exp\left(-\gamma\left(P_{t-d} - F_{t-d}(X_{t-d})\right)^2\right) \to 0$, and consequently $w_t = 1$ and $E(\Delta P_{t+1}^{PM}) = E(\Delta P_{t+1}^{F})$. After some substitutions, the law of motion for the price dynamics will be given by:

$$\Delta P_{t+1} = a\delta(P_t) - (a_2 + a_3)\alpha(M_t) \tag{8}$$

where we have defined $M_t = P_t - F(X_t)$.

The parameter γ is also relevant in this scheme, governing the speed in which portfolio managers adjust their expectations through the w_t variable. If γ is quite high, for instance, even a small misalignment will induce *PM* agents to form expectations as the fundamentalists.

The general expression of commodity price changes can be obtained by replacing (3), (4), (5) and (6) into (2) and rearranging terms:

$$\begin{aligned}\Delta P_{t+1} = {} & (a_1 + a_3)\delta\Delta P_t - a_2\alpha M_t - a_3\delta[1 - exp(-\gamma M_{t-d}^2)]\Delta P_t \\ & -a_3\alpha[1 - exp(-\gamma M_{t-d}^2)]M_t\end{aligned} \tag{9}$$

Thus, price dynamics depends on several factors. The first two terms are based on a standard error correction model: a purely autoregressive term and a linear error correction factor. The remaining terms are those which generate the non-linear adjustment pattern. In the empirical analysis the emphasis will be placed on the non-linear adjustment coefficient of the price deviation from the long-run equilibrium.

Summarizing, we have developed a theoretical model in which fundamentals continue to be the only real force that drives long run prices. However, heterogeneity in expectations among market participants is important in determining the adjustment properties to equilibrium.

It will be shown in the methodological section that a specific type of smooth transition autoregressive model (STAR) tracks the commodity price dynamics derived from the model and described by the equation (9). With this econometric specification it will be feasible to study both the fundamental equilibrium and the potentially non-linear adjustment properties of the implied misalignment.

5. Econometric methodology

In recent decades there has been a growing interest in the use of non-linear econometric techniques. Among them, models with switching regimes turn out to be particularly attractive because they incorporate a law of motion that governs the shift from one state to another. This law could be deterministic or stochastic. In the first case, the regime is determined by past values of observable variables, and it is known with certainty by all economic agents. In contrast, the state is stochastic if the regime is known only with some probability at every moment of time.

The simplest autoregressive model with deterministic regimes corresponds to the case of sudden changes and was developed by Tong (1978, 1990), Tsay (1989). In brief, it compares the transition variable (TV_t) with a threshold (c) in order to split up the linear model into two sub-models. If an autoregressive specification without explanatory variables is assumed, then the threshold model will be:

$$y_t = \begin{matrix} (\emptyset_{1,0}+\emptyset_{1,1}y_{t-1}+\ldots+\emptyset_{1,p}y_{1,p})+\varepsilon_t & \forall y_t \leq c \\ (\emptyset_{2,0}+\emptyset_{2,1}y_{t-1}+\ldots+\emptyset_{2,p}y_{1,p})+\varepsilon_t & \forall y_t > c \end{matrix} \tag{10}$$

In equation (10), the switch between states is determined by the comparison between the transition variable (y_t) and the threshold (c), and it occurs abruptly. The idea that the transition can be done gradually represents an important progress in this literature. It theoretically corresponds to the notion that economic agents do not react simultaneously when new information is spread or when a shock hits the economy. This empirical strategy is also valid if the effects of structural changes materialize slowly.

Moreover, whenever economic intuition or theory suggests that a relationship among variables is valid under certain circumstances but is no longer true if these circumstances change, then a smooth transition autoregressive (STAR) model will be suitable for its empirical test. Chan and Tong (1986); Granger and Teräsvirta (1993); Teräsvirta (1994), or Franses and van Dijk (2000) are pioneering references of this approach.

The representation of a smooth transition autoregressive model of p order or STAR(p) is as follows:

$$y_t = (\emptyset_{1,0} + \emptyset_{1,1}y_{t-1} + \ldots + \emptyset_{1,p}y_{t-p})(1 - F(TV_{t-d};\gamma,c)) + (\emptyset_{2,0} + \emptyset_{2,1}y_{t-1} + \ldots + \emptyset_{2,p}y_{2-p})F(TV_{t-d};\gamma,c) + \varepsilon_t \tag{11}$$

Alternatively:

$$y_t = (\emptyset_{1,0} + \emptyset_{1,1}y_{t-1} + \ldots + \emptyset_{1,p}y_{t-p}) + (\lambda_{2,0} + \lambda_{2,1}y_{t-1} + \ldots + \lambda_{2,p}y_{2-p})F(TV_{t-d};\gamma,c) + \varepsilon_t \tag{12}$$

where the following conditions are satisfied:

$$\lambda_{2,0} = \emptyset_{2,0} - \emptyset_{1,0}, \lambda_{2,1} = \emptyset_{2,1} - \emptyset_{1,1}, \ldots, \lambda_{2,p} = \emptyset_{2,p} - \emptyset_{1,p} \tag{13}$$

$$E(\epsilon_t \Omega_{t-1}) = 0 \tag{14}$$

$$E(\varepsilon_t^2 | \Omega_{t-1}) = \sigma^2 \tag{15}$$

$$\Omega_{t-1} = (y_{t-1} \dots y_{t-p}) \tag{16}$$

In equations (11) and (12), the expression $F(TV_{t-d}\ ;\ \gamma, c)$ is known as the transition function. It is a continuous function whose image is the interval [0, 1].[4] The γ parameter measures how fast the adjustment between regimes is, while the parameter c , establishes the limit point after which the switching between regimes start to take place. Finally, TV_{t-d} refers to the transition variable with d lags. There are very few technical restrictions on the sort of variable(s) that could be TV_{t-d}. Usual options include lags of endogenous variables, exogenous variables, functions of endogenous and/or exogenous variables or a time trend (van Dijk et al., 2002).

On some occasions, however, a theoretical hypothesis suggests which variable can be regarded as a determinant of the transition. This is precisely the case of commodity prices and their possible pattern of non-linear equilibrium correction. From the heterogeneous agent model we obtain a specific theoretical restriction establishing that past misalignment between the current price and the fundamental value not only acts as a determinant of price changes but also as the variable that governs the transition between regimes.

Usual TV_{t-d} functions are either logistic or exponential:

$$F(TV_{t-d}; \gamma, c) = \frac{1}{1+\exp\left(-\gamma(TV_{t-d}-c)\right)}, \gamma > 0 \tag{17}$$

$$F(TV_{t-d}; \gamma, c) = 1 + \exp\left(-\gamma(TV_{t-d} - c)^2\right), \gamma > 0 \tag{18}$$

The logistic function[5] allows us to distinguish between two regimes or states, named high and low regimes, respectively. The high state arises from positive and large values of (TV_{t-d} - c), since $\exp\left(-\gamma(TV_{t-d} - c)^2\right)$ tends to zero, and hence the expression (17) tends to 1. By contrast, the regime is low when (TV_{t-d} - c) takes low values and so $\exp\left(-\gamma(TV_{t-d} - c)^2\right) \to \infty$ and $F(TV_{t-d}; \gamma, c) \to 0$.[6] The logistic specification is valid when it is believed that the transition takes place in a monotonic way.

On the contrary, the exponential function is useful if the value of absolute deviation of the transition variable with respect to parameter c is the important feature. This specification is known as ESTAR model (exponential smooth transition autoregressive model) and restricts the dynamics of the equation to be the same alongside the extreme values of $F(TV_{t-d}; \gamma, c)$. Thus, in

[4] Both properties differentiate a smooth transition autoregressive model from a threshold model, because in the latter the transition function is direct, taking only two values: 0 or 1.

[5] A logistic smooth transition autoregressive (LSTAR) model is obtained when function (17) is applied.

[6] Since the transition function can take any continuous values between zero and one, characterization of a STAR model with only two regimes may look quite arbitrary, particularly in those cases in which the smoothing parameter is low and, therefore, there are many intermediate values of the transition function. In this sense, van Dick et al. (2002) argue that the STAR model can be thought of as a methodology that allows a "continuous" set of regimes.

an ESTAR model the asymmetries between regimes are given by the absolute magnitude of the differences rather than by their sign.

Some well-known applications of STAR models could be found in papers studying misalignment of the real exchange rate regarding its fundamental value given by the purchasing power parity (Michael et al., 1997; Taylor et al., 2001, or Chen and Wu, 2000); in the literature of non-linear adjustment of deviations from uncovered interest rate parity (Sarno et al., 2006); or in those works that test non-linear mean reversion in stock futures (Monoyios and Sarno, 2002). The extensions of STAR models to multivariate contexts (VAR models or systems of equations) have been studied, among others, by Weise (1999), van Dijk (2001), Camacho (2004) and Mendoza (2004). The general structure of a non-linear equilibrium correction model is:

$$\Delta Y_t = \Pi_{1,0} + \Gamma \mathrm{D}_t + \alpha_1 M_{t-1} + \sum_{j=1}^{p} \Pi_{1,j} \Delta Y_{t-j} + \left(\Pi_{2,0} + \alpha_2 M_{t-1} + \sum_{j=1}^{p} \Pi_{2,j} \Delta Y_{t-j}\right) F(TV_{t-d}; \gamma, c) + \varepsilon_t \quad (19)$$

where ΔY_t is a (nx1) vector, $(\Delta y_1, \Delta y_2, \dots, \Delta y_n)$, D_t is a (mx1) vector of dummies which control for outliers and Γ (mxn) is the respective matrix of coefficients. Also, $\Pi_{1,0}$ and $\Pi_{2,0}$ are (nx1) vectors containing the constants of the linear and non-linear part in each case. The $\Pi_{1,j}$ and $\Pi_{2,j}$ are (nxn) matrices for $j:1,\dots, p$ that correspond to the autoregressive coefficients. The equilibrium correction term is denoted by $M_t = \beta' X_t$, where β is the (nxr) matrix of coefficients of the long-term relationship and X_t is a (nx1) vector which stands for the variables in levels. Finally, α_1 and α_2 are (nxr) matrices formed by the adjustment coefficients of deviations from long-term relationships, where r indicates the number of cointegration equations. These coefficients play a fundamental role in the model since they capture the linear and non-linear adjustment pattern.

Concerning the operational steps needed to implement a STAR model, Teräsvirta (1994) proposes a procedure for the univariate case, whereas Granger and Teräsvirta (1993) examine the multivariate case and Camacho (2004), among others, extends it to a multi-equational approach. In all cases, the process encompasses basically four stages: i) estimating a linear model ii) testing non-linearity; iii) estimating the non-linear model, and iv) computing non-linear impulse-response analysis.

The first step is to estimate a linear model that will serve as a benchmark to contrast the non-linearity hypothesis. The estimation sequence follows common techniques of time series analysis. In this point, it is important to control for outliers and to check the behavior of the residuals regarding autocorrelation and heteroscedasticity.

The second stage consists of a linearity test. If the alternative hypothesis to the linearity is the smooth transition exponential model (STAR)[7], Teräsvirta (1994) suggests using a first order Taylor expansion (T_1^e) to obtain an auxiliary regression which may serve as a base to contrast the

[7] The auxiliary regression is modified when the specification is done throughout a logistic function. There is also evidence that expression (20) is appropriate when there is no knowledge (or no prior intuition) whether the relevant alternative is the expression (17) or (18). In this regard, see Luukkonen et al. (1998).

null hypothesis. To this end, one should take equation (18) and calculate T_1^e in $\gamma = 0$. After some simplifications, the following auxiliary regression will be achieved (vector notation):

$$Y_t = \beta_0' X_t + \beta_1' X_t TV_{t-d} + \beta_2' X_t TV_{t-d}^2 + w_t \tag{20}$$

where $X_t = [1, y_{t-1}, y_{t-2}, \ldots, y_{t-d}]$; $\beta_0 = [\beta_{0,0}, \beta_{0,1}, \ldots, \beta_{0,p}]$; $\beta_1 = [\beta_{1,0}, \beta_{1,1}, \ldots, \beta_{1,p}]$; and $\beta_2 = [\beta_{2,0}, \beta_{2,1}, \ldots, \beta_{2,p}]$. In (20), testing the linearity hypothesis is equivalent to prove that $\beta_1 = 0$ and $\beta_2 = 0$.

According to Teräsvirta (1994), the recommended procedure consists of an *F*-test with the following sequence: i) estimate the model under the assumption of linearity and compute the residual sum square (RSS_0); ii) estimate the auxiliary regression (20) to obtain RSS_1; and iii) compute the critical value of the LM statistics:

$$LM = \frac{(RSS_0 - RSS_1)/l_1}{RSS_0/l_2} \tag{21}$$

The l_1 degrees of freedom are calculated as the difference between the number of parameters in the unrestricted and restricted models, whereas l_2 is calculated as the number of observations minus the unrestricted model parameters. If the linearity test is performed on a list of possible transition variables, it will be necessary to define which variables will be considered. In such a case the highest *LM* statistics is employed to select the transition variable.

The third step is the estimation of the STAR model, which can be done by any conventional non-linear method. This will require the definition of initial conditions. An appropriate selection of these conditions will increase the probability of reaching a maximum in the likelihood function.

The usual practice to find initial conditions is conducting a two dimensional grid search on parameters γ and c. It is important to note in this regard that once the values of both parameters are fixed, the function $F(TV_{t-d}; \gamma, c)$ will lie in the interval [0, 1] in each observation, being equation (11) linear in all its arguments. The grid search iterates different values of γ and c taken at intervals that are relevant in accordance with their respective scales of variability. The conditional estimation can be done by a linear method as OLS or SUR. The configuration of (γ,c) which generates the restricted model with the maximum likelihood will be selected. Then, its parameters are used as initial conditions to estimate the unrestricted STAR model.

Theory could also provide some conditions for the smoothing parameter (γ) or the threshold (c). In those models where the misalignment is the state variable ($TV_{t-d} = M_{t-d}$), the condition $c = 0$ is often imposed because of the symmetry in the economic concept of misalignment itself. Thus, when the differences between actual and fundamental prices are very small, then $F(TV_{t-d}; \gamma, c = 0) = 1 - \exp(-\gamma (M_{t-d})^2) \rightarrow 0$, and so we will observe the system operating in one of the extreme regimes. In papers about purchasing power parity, transaction and transportation costs limit arbitrage and thus small mismatches are interpreted as a state variable, where PPP do not hold. The corollary is that the exchange rate behaves like a random walk if M_{t-d} is low.

Finally, a useful tool in a STAR model applied only to systems of equations is the computation of generalized impulse-response functions. A methodological description of these impulse-response functions is beyond the scope of this paper. However, the intuitive idea is that in a STAR model the effects of shocks depend on the history, size and sign of disturbances. For instance, the effect of a shock will not be necessarily the same if the shock occurs when there is a small misalignment with respect to the case of a high initial gap between current and equilibrium commodity prices. Also the size of shock could be relevant since it could involve different future dynamic trajectories of the endogenous variables. These characteristics are not incorporated by traditional impulse response functions estimation methods. We follow the bootstrapping methodology of Koop et al. (1996) to compute the generalized non-linear impulse response functions. We suggest reviewing this reference for a complete discussion of technical details.

6. Non-linearity in the adjustment of commodity prices: empirical results

With the aim of organizing the presentation of the empirical model, this section has been divided into four parts. In the first part, the variables and the data sources are described. Subsequently, we discuss the estimates of the long-run equilibrium equation of commodity prices and show the time path of the implied misalignment. In the third sub-section we present the non-linearity tests results, the interpretation of the transition function and its regimes, and the estimation of the non-linear system. Finally, impulse response analysis is performed to investigate the short-term reaction of commodity prices to shocks in fundamentals under both high and low misalignment regimes.

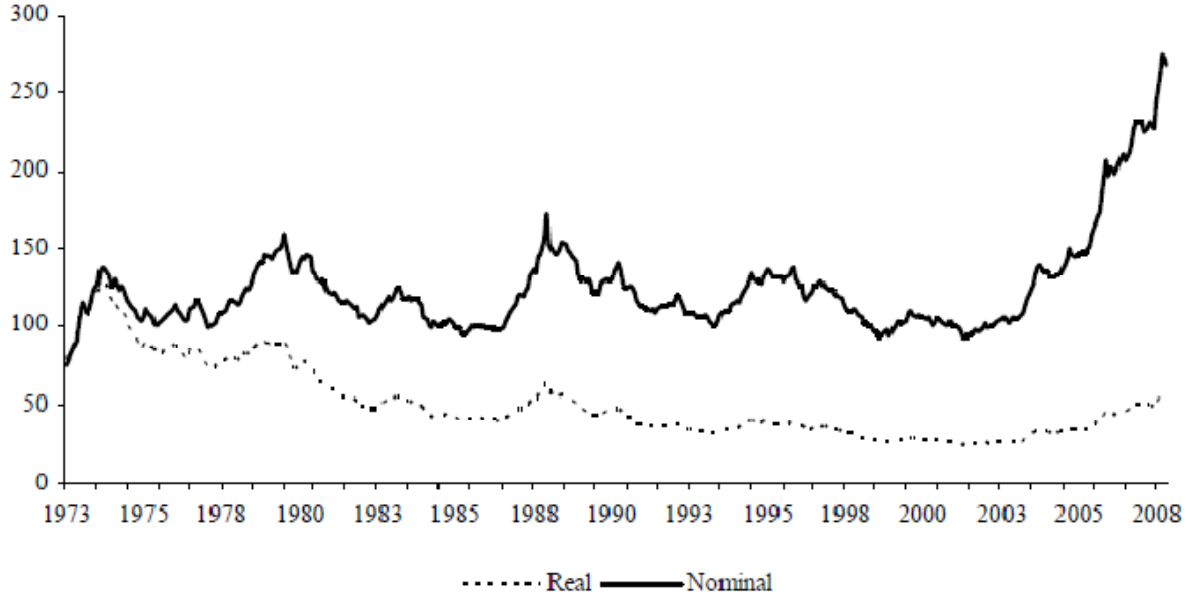
6.1 The variables of the empirical model

Our empirical analysis is based on monthly data belonging to the post Bretton Woods era, from January 1973 to May 2008.

After defining the period of analysis, we have to choose the commodities whose prices will be explained. Given that our theoretical framework is general enough and holds for a broad set of assets, we opt for studying an aggregated index. Particularly, the Food Index and the Metals Index from the International Finance Statistics (IFS) were averaged out to construct the All-Comm Index. To deflate the series, US CPI from the same source was used.[8] Figure 13 shows the evolution of the index in both nominal and real terms.[9]

[8] It is worth mentioning that oil was not considered because several authors such as Beenstock (1988) or, more recently, Cheung and Morin (2007) have stressed it has its own dynamic with low connection to other commodities.
[9] A clarification related to the issue of commodities as financial assets is needed. Price indexes we use are elaborated with data from spot prices and not from futures or other similar derivative instruments, which are in strict financial terms the real investment vehicles. However, the argument is that spot prices are very good indicators of the financial returns of commodities. In this sense, Gorton and Rouwenhorst (2004) show that the return on a future position and the current price has a correlation close to one.

Figure 13. Commodity Price Index



As highlighted in section one, the outlook for commodities dramatically changes whether nominal or real indexes are considered. Both series have exhibited an important growth since 2002; while the former has increased 166.3% up to 2008 from then, the latter has risen 124.3% in the same time interval. However, the overall performance has been very different: whereas in the first semester of 2008 the nominal index averaged a value 2.6 times higher than the figure of 1973, current real prices are roughly a half of the value observed at the beginning of the sample.

Regarding price fundamentals definition, we have the US real exchange rate (*RER*) in the first place. The broad multilateral version published by the Federal Reserve Bank of New York is employed. The variable is defined in such a way that it rises when the dollar is appreciating against the currencies of main trading partners. The real international interest rate (*IR*) is the one-year Treasury constant maturity rate from the Board of Governors of the Federal Reserve System. Again, US CPI is the deflator.

The price fundamental whose measurement presents serious difficulties is the commodity world demand proxy, especially because a series in monthly basis is required. Industrial Production of the developed countries is the alternative usually employed in studies on this topic. However, Asian emerging countries have become crucial players in commodity markets and they should be incorporated into the analysis. Therefore, we consider an Industrial Production Index (*PRO*) which also takes into account the industrial output of Korea, India, Malaysia and China. All the indexes come from the IFS, except from China whose series is built using the Industrial Value Added provided on an annual basis by the IMF World Economic Outlook and linearly extrapolating to become monthly. We use the share of each country in the industrial added value

(IVA) as a weighting factor.[10] The seasonally unadjusted series is corrected applying the X-12 ARIMA method.

In addition to the price determinants reviewed in the first section, the Dow Jones index deflated by US CPI (*DOW*) is also included. Our aim is to control for the return of alternative assets and to investigate if conditional covariance indicates substitution or complementary effects between these asset classes. As it was mentioned before, authors like Gorton and Rouwenhorst (2004) or Deutsche Bank (2005) have studied this link and they have found that the non-conditional correlation between returns of commodities and other assets (bonds and equities) is negative and very significant in the long term. In Domanski and Healt (2007) the ratio of net long contracts for non-commercial agents is negatively correlated, though slightly, with stock indexes.

6.2 The structure of the model, equilibrium estimation and the misalignment

The structure of the model to be estimated is similar to a VECM but includes non-linear terms in the commodity price equation. In this sense, we move away from the seminal work of Weize (1999) that specifies a symmetrical smooth transition VAR; which means all the equations present non-linear terms. Our decision is based on the fact we only have a theoretical rationale for non-linear adjustment in the price dynamics. An alternative empirical strategy could have been using a single-equation STAR.[11]11 However, that option would have implied abandoning the possibility of studying the short-term commodity price response to shocks in fundamentals and we would not be able to study interactive effects.

In particular, we take (19) as a benchmark and work with the following system:

$$\Delta P_t = \beta_{11} + \alpha_{11}(M_{t-1}) + \sum_{j=1}^{p} \Pi_{l1,j} \Delta X_{t-p} \tag{22}$$

$$+\left(\beta_{12} + \alpha_{12}(M_{t-1}) + \sum_{j=1}^{p} \Pi_{l2,j} \Delta X_{t-p}\right)(1 - \exp\left(-\gamma TV_{t-d}^2\right)) + \varepsilon_t^P$$

$$\Delta RER_t = \beta_2 + \alpha_2(M_{t-1}) + \sum_{j=1}^{p} \Pi_{2,j} \Delta X_{t-p} + \varepsilon_t^{RER} \tag{23}$$

$$\Delta IR_t = \beta_3 + \alpha_3(M_{t-1}) + \sum_{j=1}^{p} \Pi_{3,j} \Delta X_{t-p} + \varepsilon_t^{IR} \tag{24}$$

$$\Delta PRO_t = \beta_4 + \alpha_4(M_{t-1}) + \sum_{j=1}^{p} \Pi_{4,j} \Delta X_{t-p} + \varepsilon_t^{PRO} \tag{25}$$

[10] The weights we obtained by this criterion were increased by 50% in the case of emerging countries for two reasons. The first one is that emerging economies are underrepresented in the sample. The second reason is that these countries have a greater intensity of commodity consumption per unit of output. Capturing a specific amount of increase of this coefficient is beyond the scope of this study, but increasing it seems a better alternative than to ignore the two above-mentioned effects.

[11] This is the strategy adopted by Westerhoff and Reitz (2005) to explain mean reversion in corn prices. Other difference of that model in comparison to our empirical framework is these authors do not use an exponential specification for the transition function.

$$\Delta DOW_t = \beta_5 + \alpha_5(M_{t-1}) + \sum_{j=1}^{p} \Pi_{5,j} \Delta X_{t-p} + \varepsilon_t^{DOW} \quad (26)$$

where $X = [P, RER, IR, PRO, DOW]$ and the threshold coefficient c is set equal to zero because of theoretical reasons discussed in Section 5. As before, $M_t = P_t - F(X_t)$ and TV_{t-d} is the transition variable.

The main focus of the empirical analysis is centered on the expression (22) as it contains the price dynamics which is similar to that derived from the theoretical model (equation (9)). Particular interest should be given to the estimates of α_{11} and α_{12} which represent the price adjustment coefficients to the deviations from the long-term equilibrium.

The econometric strategy adopted is in line with the Engle and Granger proposal. In essence, we estimate in a first stage the long run equation for commodity prices and test for cointegration. Then, if a cointegration relationship is found, the whole error correction system will be estimated using $M_t = P_t - F(X_t)$ as a regressor.

To carry out the first stage requires coping with non stationary series.[12] As it is well known, if I(1) variables are cointegrated the OLS estimator of the coefficients of the long run relationship will be consistent. However, it will have a non-normal distribution, and inferences based on t-statistics will be misleading. Several econometrics techniques have been developed to overcome this problem. We apply the Dynamic OLS (DOLS) estimator developed by Stock and Watson (1993) which adds leads and lags of the changes in the right hand regressors in the standard long run equation. That is,

$$P_t = \beta_1 + \beta_2 X_t + \sum_{j=-p}^{p} \beta_3 \Delta X_{t-p} + \beta_4 t + \varepsilon_t \quad (27)$$

where X_t stands for the price determinants and p represents the number of leads and lags considered. DOLS estimator of β_2 results from OLS estimation of equation (27).

If the variables are cointegrated, the DOLS estimator is consistent and efficient in large samples. The methodology deals with potential simultaneity and small sample bias among the regressors by the inclusion of leads and lags. Besides, Monte Carlo experiments show that DOLS performs better, particularly in small samples, compared to alternative estimators of long-run parameters as those proposed by Engle and Granger (1987), Johansen (1988), and Phillips and Hansen (1990).[13]13 Finally, standard statistical inference remains valid when heteroskedastic and autocorrelation consistent (HAC) standard errors are employed. We apply this methodology to obtain the coefficients of the long run equation of commodity prices (Table 2). We use six leads and lags but the estimation was robust to changes in the value of p.

[12] The usual unit root tests were implemented confirming all the series are non stationary. Results are available upon request to the authors.

[13] See Stock and Watson (1993) or Montalvo (1995) It is worth mentioning that DOLS estimator is asymptotically equivalent to the Johansen estimator (Stock and Watson, 1993).

Table 2. DOLS Estimates of long run equation

Variable	OLS	DOLS	
	Coefficient	Coefficient	p-value
Industrial Production Index	3.6124	4.1368	0.0000
US Real Exchange Rate	0.7270	0.5994	0.0000
Real International Interest Rate	-1.0907	-1.5452	0.0138
Real Dow Jones Index	-0.1299	-0.1086	0.0163
Time Trend	-0.0097	-0.0111	0.0000
Constant	-4.1659	-6.9366	0.0000

Before analyzing these results it is necessary to perform a cointegration test. If there exists no cointegration among variables, it is not possible to evaluate the estimates because of the spurious regression problem. As it is remarked by Choi et al. (2008), DOLS is employed in many applications but few cointegration tests have been developed for it. These authors propose a Hausman-type test but it does not allow for regressions with time trends as is the case of our model. Therefore, we use the test proposed by Shin (1994) which admits all kind of deterministic components. An interesting common feature of both tests is that their null hypothesis is the presence of cointegration, in contrast to the no cointegration null hypothesis of standard ADF-type tests. Shin (1994) and Ogaki and Park (1998) argue that cointegration is the desirable null hypothesis in several applications. The Shin cointegration test statistic takes the following expression when a constant and time trend are present in the long run equation,

$$C_\tau = T^{-2} \sum_{t=1}^{T} S_t^2 / s_\tau^2(l) \tag{28}$$

where $S_t = \sum_{j=1}^{t} \varepsilon_j$, ε_j are the DOLS residuals from equation (27), and T stands for the sample size. Finally, $s_\tau^2(l)$ is the semiparametric consistent estimator of the long run variance of ε_j. We find a value of 0.07796 for $C_\tau$which is lower than the 2.5% critical value (0.088).[14] Thus, there is evidence of cointegration among commodity prices and their determinants.[15] Then, we can analyze the results showed in Table 2.

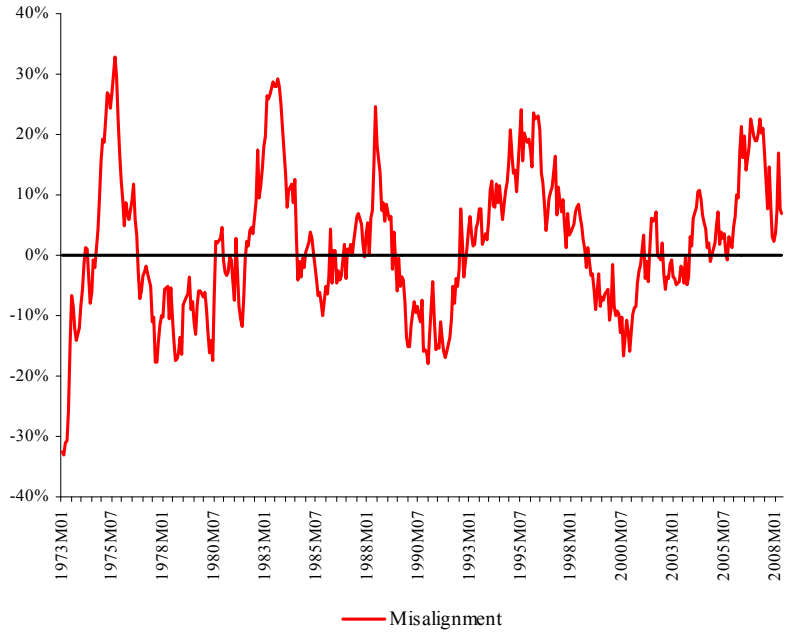
First, it is remarkable that all the variables are statistically significant and their signs are in line with the theoretical predictions. Next, regarding the value of the coefficients, we observe that a real devaluation (fall) of the dollar by 1% implies a 0.60% increase in commodity prices. This elasticity is lower than one in absolute value as suggested by the Ridle and Yandle (1972) model. It is also relevant to highlight the high elasticity of commodity prices to industrial production (4.13%). Stock market performance impacts negatively on the price of commodities. Along the findings by Domanski and Healt (2007), the substitution effect between the two asset

[14] Shin (1994) provides the critical values for his cointegration test statistics.
[15] For robustness check, we carried out the standard ADF non-cointegration test based on OLS residuals and we rejected the null hypothesis of unit root residuals.

classes tends to predominate. As for the coefficient of the real interest rate, it is slightly bigger than -1 in absolute value (-1.09). Finally, the negative sign of the time trend supports the Prebisch-Singer hypothesis. This result corroborates the first sight intuition suggested by Figure 13, where declining real prices were observed. In Figure 14, actual and "equilibrium" price series are depicted while implied misalignment is portrayed in Figure 15.

Figure 14. Commodity price index: actual values and equilibrium (logarithmic scale)

Figure 15. Commodity prices: estimated misalignment



From both figures we emphasize the fact that the magnitude of the misalignments observed during 2006-2007 are similar to those observed in the previous years to the 1980s debt crisis and both Asian and Russian Crisis (roughly 20-25%). In the next section we will see how misalignment plays a dual role: as an adjustment variable of short term deviations, and as a potential determinant of the state.

6.3 The short-term model and nonlinear equilibrium adjustment

As it was stated in Section 5, testing the nonlinear equilibrium adjustment hypothesis requires estimating a linear model which acts as benchmark. To this end, we specify a linear symmetrical vector error correction model (VECM) using the previously calculated misalignment. The Akaike Information Criterion (AIC) suggests using five lags for the changes in the variables. In addition, under this specification the residuals do not present autocorrelation.[16]

The adjustment coefficient (α_{11} in equation (22)) takes a value of -0.01921 and is statistically significant at 10% when Newey-West HAC standard errors are considered. Thus, there is evidence that, at least in average, correcting forces emerge when commodity prices are in disequilibrium. However, as our theoretical model of section 4 predicts, it is really possible that there exist some states where misalignments are high and so correcting forces operate, while in other states characterized by low misalignments the gaps remain. This is the intuition behind the non-linear equilibrium adjustment hypothesis.

Once we have estimated the benchmark linear model, we carry out the linearity F-test on the commodity price equation as it was described in the methodological section. The auxiliary regression takes the specific following form:

$$\Delta P_t = \beta'_{0,p}\Delta X_{t-p} + v_1 M_{t-1} + \beta'_{1,p}\Delta X_{t-p} TV_{t-d} + v_2 M_{t-1} TV_{t-d} + \beta'_{2,p}\Delta X_{t-p} TD^2_{t-d} + v_3 M_{t-1} TD^2_{t-d} + \varpi_t \quad (29)$$

where $\Delta X = [l, \Delta P_{t-p}, \Delta RER_{t-p}, \Delta IR_{t-p}, \Delta PRO_{t-p}, \Delta DOW_{t-p},]$, TV_{t-d} stands for the transition variable, and $p;1,...,5$. Note the first two terms in equation (29) correspond to the linear specification of the commodity price equation (22) in the VECM model described above. As we have already stressed, our theoretical model suggests the regimes are governed by the size of misalignment. Thus, we propose as potentially transition variables five ones. One of them is simply the misalignment (M_{t-d}) and the others result from averaging out the current misalignment and those of the previous j periods (AV_{jt-d}), where j ranges from 1 to 4. Besides, we consider d =

[16] We performed the Serial Correlation LM test with 12 lags and we failed to reject the null hypothesis of no autocorrelation at 5% statistical significance.

1,...,12 lags for each of them.[17] Table 3 shows the test results for the ten variables which exhibit the lowest p-values.[18]

Table 3. Linearity F-test results

Transition Variable	Lag	LM Statistic	p-value
AV1	1	1.38647	0.04912
AV4	12	1.38309	0.05040
AV3	12	1.21178	0.16396
AV4	11	1.19485	0.18166
AV1	6	1.15964	0.22287
AV2	1	1.15512	0.22859
AV2	12	1.12511	0.26910
AV2	6	1.12423	0.27036
AV4	4	1.12396	0.27074
AV3	5	1.12106	0.27490

Remember that the null hypothesis is a linear adjustment in the commodity price equation (22). We find evidence of non-linearity in equation (22) at 5% statically significance when the variable AVlt-1 is considered. That is, the regime in each moment *t* would be defined by the average value of the misalignments registered in *t - 1* and *t - 2*. Therefore, we will estimate the non-linear system (22)-(26) considering AVl_{t-1} as transition variable. In Section 5, we have anticipated that it is necessary for this to provide proper initial conditions for all the coefficients of the system. Those conditions can be found by estimating the linear system which is obtained after fixing the value of the parameter γ in equation (22). Instead of carrying out a grid search, we select a value of γ such that the transition function averages 0.5 in the whole sample. Intuitively, this means that portfolio managers assign the same weight to both fundamentalist and chartist agent expectations in average. Consequently, the initial value of γ approximately should satisfy the following expression:

$$W_t = \frac{1}{T}\sum_{t=1}^{T}\{1 - exp(-\gamma AVl_{t-1}^2)\} \cong \frac{1}{2} \qquad (30)$$

We find that γ= 133.77 numerically solves (30) for the January 1973 to May 2008 period. Then, after setting γ at this value, the system (22)-(26) is estimated by SUR and initials conditions for all the coefficients are obtained. Once we have these conditions, we proceed estimating the unrestricted non-linear system also by SUR.[19] In order to evaluate our hypothesis, analysis is centered in the adjustment coefficients of the commodity price equation, namely α_{11} and α_{12}. The linear error correction coefficient α_{11} appears not statistically significant

[17] We do not test $TV_{t-1} = M_{t-1}$ because of perfect multicolinearity problem when system (22)-(26) is estimated.
[18] This test was programmed on E-views. The code is available upon request.
[19] The E-Views code used in this section is also available upon request to the authors.

(p-value=0.2914) and takes a positive value of 0.035. Contrary, the non-linear adjustment coefficient α_{12} is significant at 5% (p-value=0.0418) and is equal to -0.109. Moreover, the γ parameter reaches a magnitude of 55.22 with a p-value equal to 0.0292.

These estimations support our non-linear adjustment hypothesis due to heterogeneous agents in commodity markets.[20] To see this, we define the Global Equilibrium Correction Factor (GEC) as the two terms of the price equation (22) containing the price deviation from its long run equilibrium (M_{t-1}).

$$GEC = (0.035)M_{t-1} + (-0.109)M_{t-1} * w_t = \{(0.035) + (-0.109)w_t\}M_{t-1} \quad (31)$$

When misalignment is low enough (low regime), w_t tends to zero and the second term of (31) vanishes. In this case, portfolio managers mimic chartist investors and initial misalignment is widened at a 3.5% monthly rate. Under these circumstances, there is no equilibrium correction.

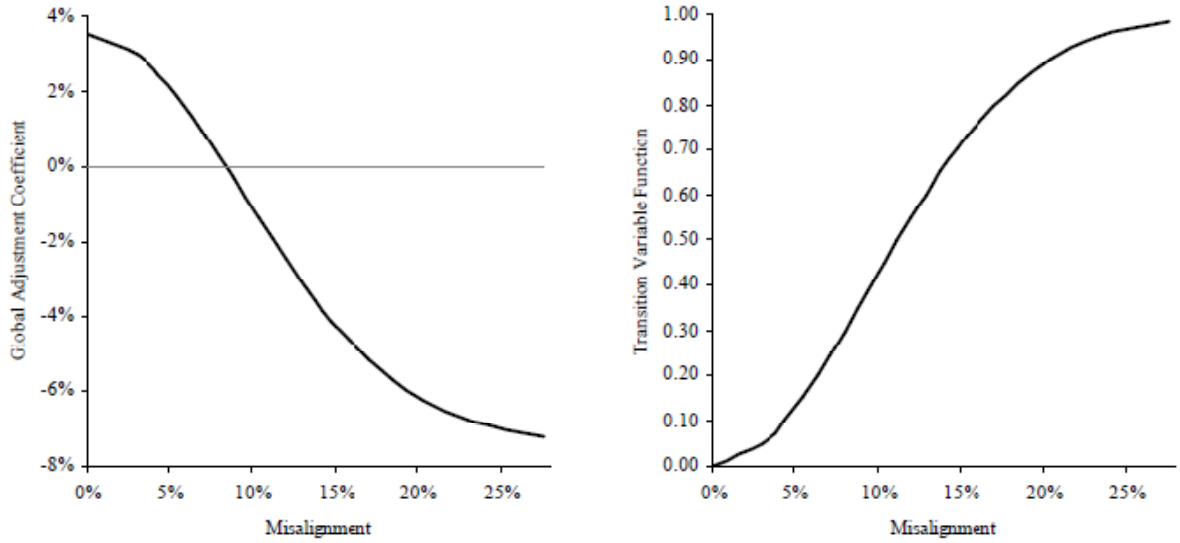
However, when the gap between actual and equilibrium prices reach a sizable value (high regime), w_t tends to one and the GEC adjustment coefficient attains a maximum of -0.074 (= α_{11} + α_{12}). Intuitively, portfolio managers assign a larger weight to fundamentalist investor expectations when misalignment is high and therefore we will observe price reversion toward the equilibrium.[21]

A key question is to determine what high and low commodity price misalignment means in our model. Figure 16 provides information to answer it. The LHS panel of Figure 16 reveals that price correction forces prevail in the market only when gap is larger than 8.5%. Considering the transition variable function (RHS panel), adjustment to equilibrium predominates when TVF (and w_t) exceeds 0.32. Furthermore, both panels show that non-linearity implies bigger adjustment coefficients, the higher the misalignment is. Maximum reversion speed (-7.4% monthly) is attained when spread between actual and fundamental commodity prices surpasses 25%.

[20] Most of the arguments will be stated considering positive misalignments, but the same applies for negative gaps because of the symmetry of exponential function.

[21] Given that non-linear adjustment coefficient (α_{12}) is negative and larger than a in absolute terms, the overall stability of the price equation is guaranteed.

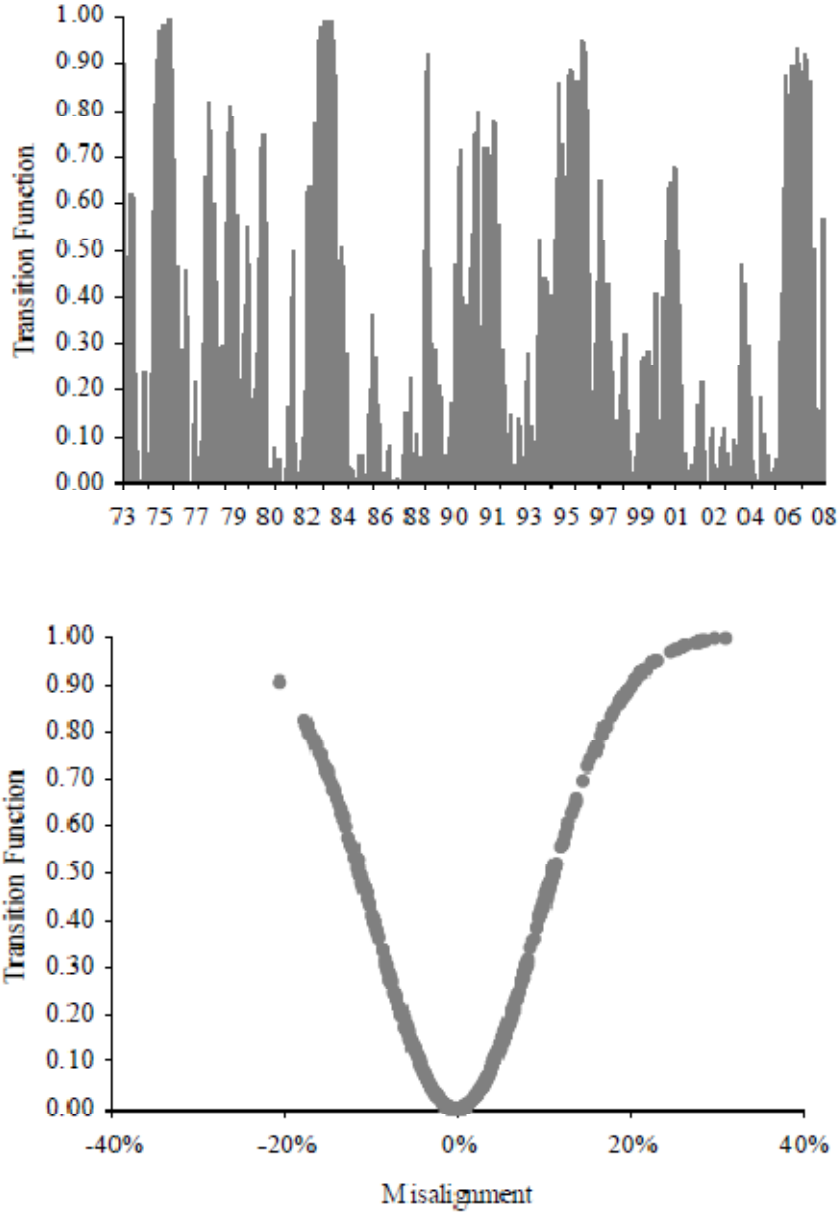
Figure 16. Misalignment, Transition Function And Global Adjustment Coefficient



The corollary is that higher misalignments in the past (measured by AVI_{t-1}) involve higher values of the transition function and this will indicate stronger future trend reversals. Finally, Figure 17 depicts the transition function in the period considered. In order to analyze the distribution of the states, we will assign observations to low regime if transition function takes values lower than 0.30 whereas we will consider they belong to high regime every time transition function exceeds 0.70.[22] The remaining observations form the "transition regime". Given this criterion, we find 56% of the time the market is dominated by chartists while fundamentalists only prevail about 18.85%. The rest of the time (25%) corresponds to transition periods.

[22] These figures imply that global adjustment coefficient is positive in the low state and larger in absolute value than -4% in the high state.

Figure 17. Transition Function Over The 1973-2008 Sample



Transition function averages out to be 0.34 in the whole sample. Therefore, mean price change expected by portfolio managers is as follows

$$E(\Delta P_{t+1}^{PM}) = (1 - \overline{w_t})E(\Delta P_{t+1}^{C}) + \overline{w_t}E(\Delta P_{t+1}^{F}) = 0.66E(\Delta P_{t+1}^{C}) + 0.34E(\Delta P_{t+1}^{F}) \quad (32)$$

The GEC coefficient associated to this figure is just -0.18%.

Summarizing, results support the hypothesis that high discrepancies between actual and equilibrium prices tend to be corrected relatively fast, while small misalignments tend to persist

over time without any endogenous correcting force taking place. In the next section we perform impulse-response analysis following the theoretical guidelines exposed in the fifth section.

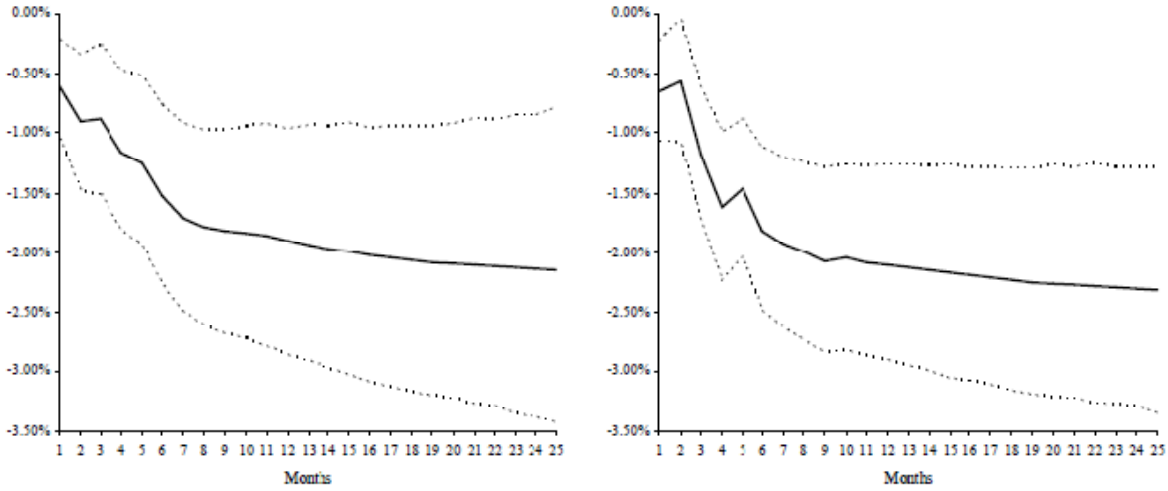
6.4 Non-Linear Impulse Response Analysis

As it was stressed in the methodological section, in an exponential STAR model the effects of shocks depend on the history and size of disturbances.[23] These properties are not incorporated in traditional impulse response analysis. Before presenting the results we will indicate just two technical issues. In the first place, to carry out the generalized impulse response function of Koop et al. (1996) requires assigning each observation to different regimes. We do this adopting the same allocation criterion stated in the previous section. Then, sampling of shocks is performed.

Secondly, initial state is defined by the analyst but after shock takes place, it could endogenously change as consequence of the system dynamics. Figures 18 to 21 show the accumulated change of commodity prices to one-standard deviation shock in the fundamentals for both high and low initial misalignment states. In the Appendix the effects of three-standard deviation shocks are depicted. The dashed lines are the 10% confidence bands.

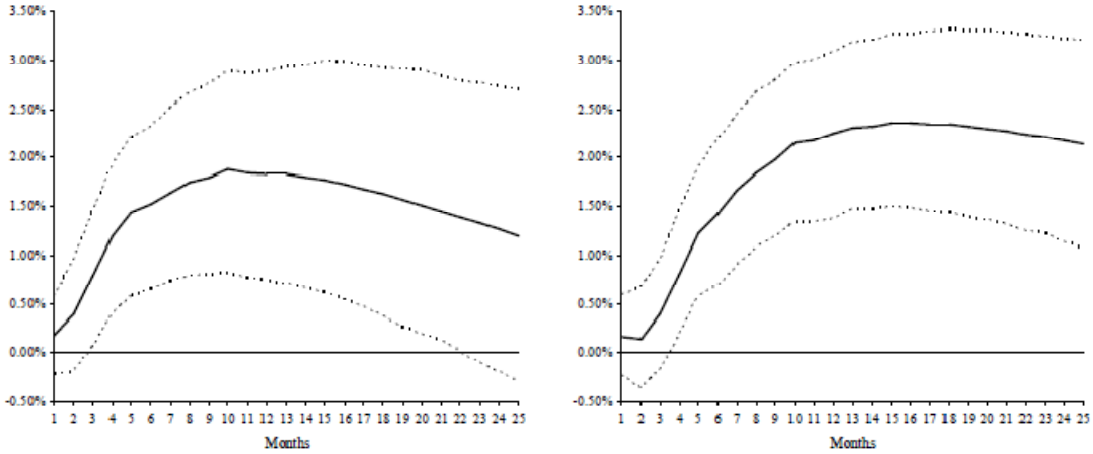
[23] This is the case when the transition function is an exponential function. If we had selected a logistic specification, the sign of the shock would also matter.

Figure 18. U.S. Effective Real Exchange Rate Shock



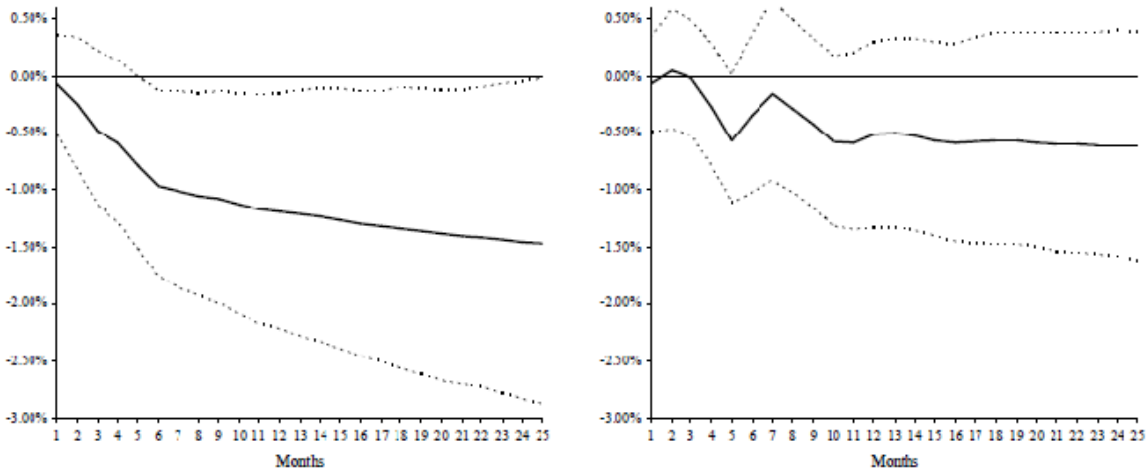
a) Low misalignment state b) High misalignment state

Figure 19. Industrial Production Shock



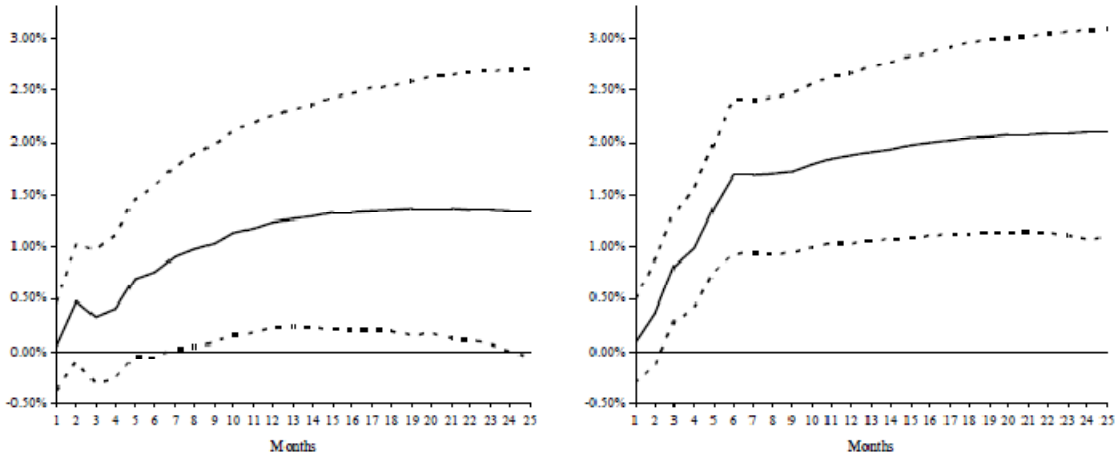
a) Low misalignment state b) High misalignment state

Figure 20. U.S. Real Interest Rate Shock



a) Low misalignment state b) High misalignment state

Figure 21. Real Dow Jones Index



a) Low misalignment state b) High misalignment state

The main conclusion we could draw from the figures is that, in general, the responses obtained are in line with both the theoretical predictions and the long-run relationship estimation. The only exception is that we find a positive impact of the Dow Jones index in the short run. Furthermore, it is noteworthy that price dynamics responses do not exhibit significant differences either the initial state is low or high. The effect of real interest rate shock differs from this general picture. If the shock occurs in the high regime, the commodity price reaction is minor and statistically non significant.

The same remarks apply when we study the consequences of bigger shocks (three-standard deviation). There are not important discrepancies when the effects of small and big shocks are compared, except for the interest rate shock response which becomes statistically significant whatever the initial regime is.

7. Conclusions and policy implications

From the policymaker perspective, the distinction between permanent and transitory movements in macroeconomic variables is one of the main challenges in order to make proper economic decisions. An important objective of applied economic models and empirical estimations is trying to give a consistent framework to rationalize those decisions. With this aim, we have proposed employing a non-linear multivariate STAR methodology to reach a better understanding of underlying causes for commodity price movements, once an explicit role for the financialization issue is incorporated.

It is appealing to think financialization is an amplifying factor of commodity price cycles. We develop a framework in which fundamentals and financialization interact each with other, treating speculative activity as an element that mainly affects short run price dynamics, but not the long run equilibrium.

This hypothesis appears satisfactory after summarizing the discussion regarding the financialization issue and showing evidence that it is not necessary to have neither commodity derivative markets nor strong net long positions of financial participants to experience a commodity price boom or a bust.

Thus, in our theoretical model, commodity fundamentals continue to be the only real force to forecast long run prices. However, heterogeneity in expectations among commodity market participants is important in determining the characteristics of the equilibrium adjustment.

Regarding fundamentals we have empirically confirmed some standard roles for macroeconomic variables, namely the real US exchange rate, aggregated industrial production as a proxy of world demand, and real international interest rates. We also verify a negative conditional correlation between our real commodity price index and the real return of stock markets. The short run dynamics shows the most remarkable results. Our findings support the idea that commodity prices tend to correct toward equilibrium, but this correction only takes place if past misalignment is sufficiently high. Thus, in the low misalignment regime, correcting forces do not prevail and prices can move in any direction, possibly depending on market sentiments.

Finally, regarding policy implications, we want to point out that for commodity-dependent developing countries, commodity price misalignments should be carefully monitored: price reversions tend to be abrupt when the gap between actual and fundamental price is higher than 20-25%. We cannot forget that commodities shape almost every macroeconomic policy stance in

these countries: from output growth and inflation to income distribution, national savings or fiscal revenues.

It is also important to note that factors affecting commodity prices (like real international interest rates and the real US exchange rate) are similar to those that influence capital flows. This explains why it is hard for developing countries to cushion terms of trade shocks with external finance. The same fundamentals that worsen terms of trade affect negatively the access to international credit markets. An appropriate policy mix should include in this case structural actions to smooth external cycles and alleviate commodity dependence when prices are at high levels.

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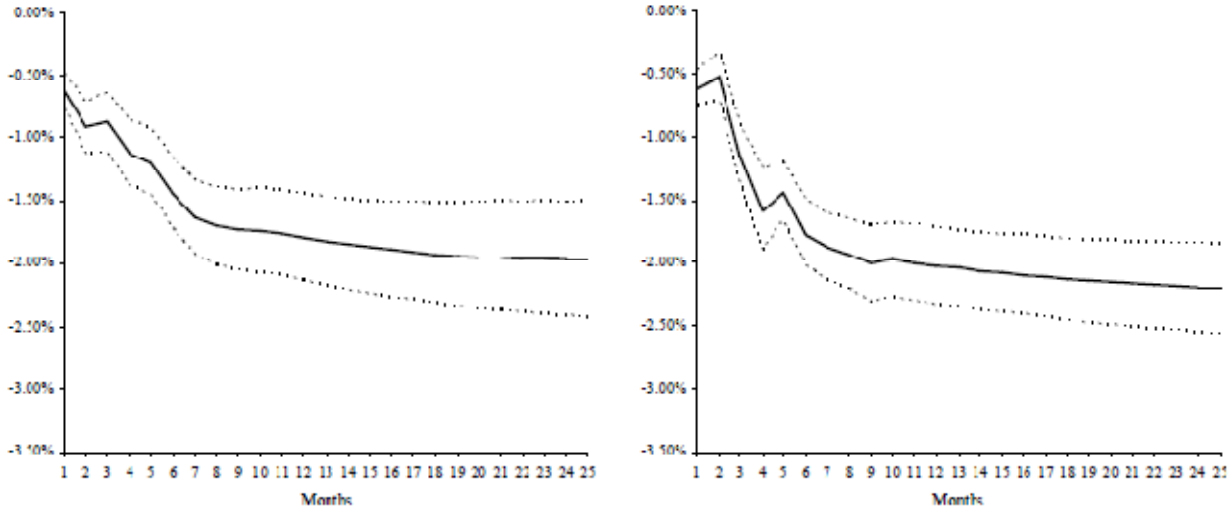
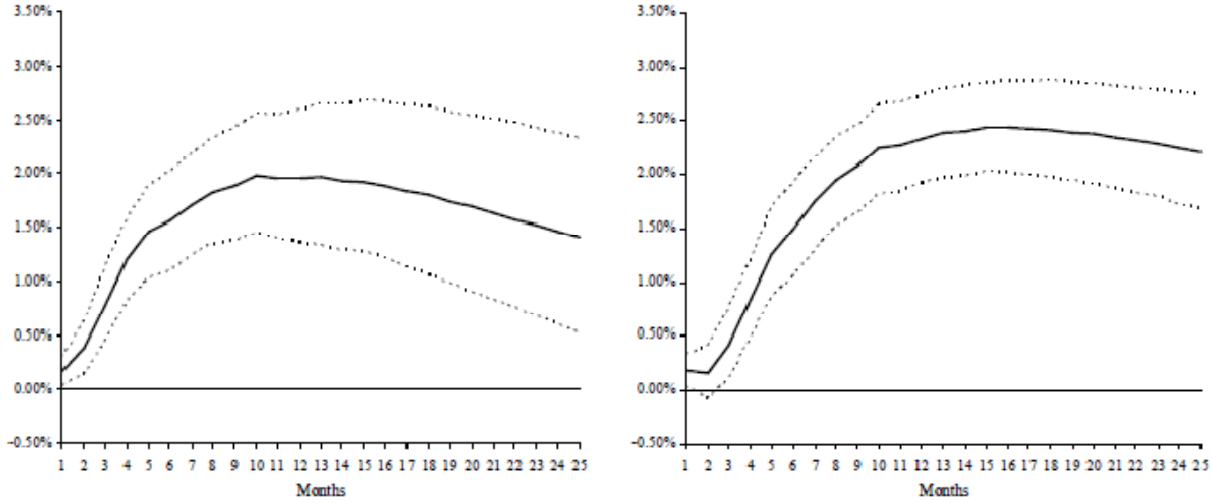
Appendix. Impulse-Response Analysis (Three Standard Deviation Shocks)

Figure A1. U.S. Effective Real Exchange Rate Shock



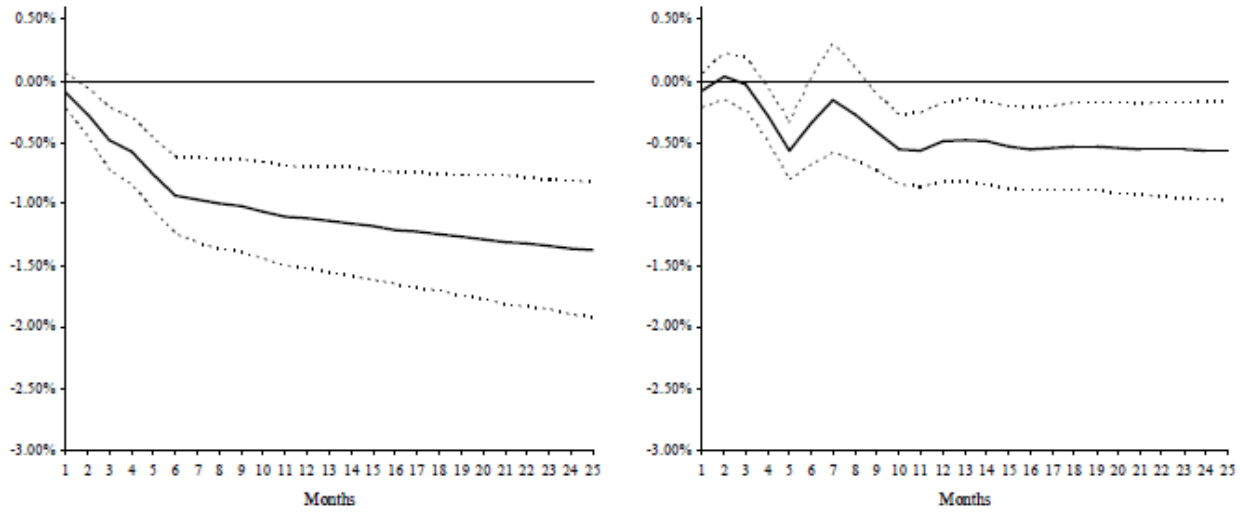
a) Low misalignment state b) High misalignment state

Figure A2. Industrial Production Shock



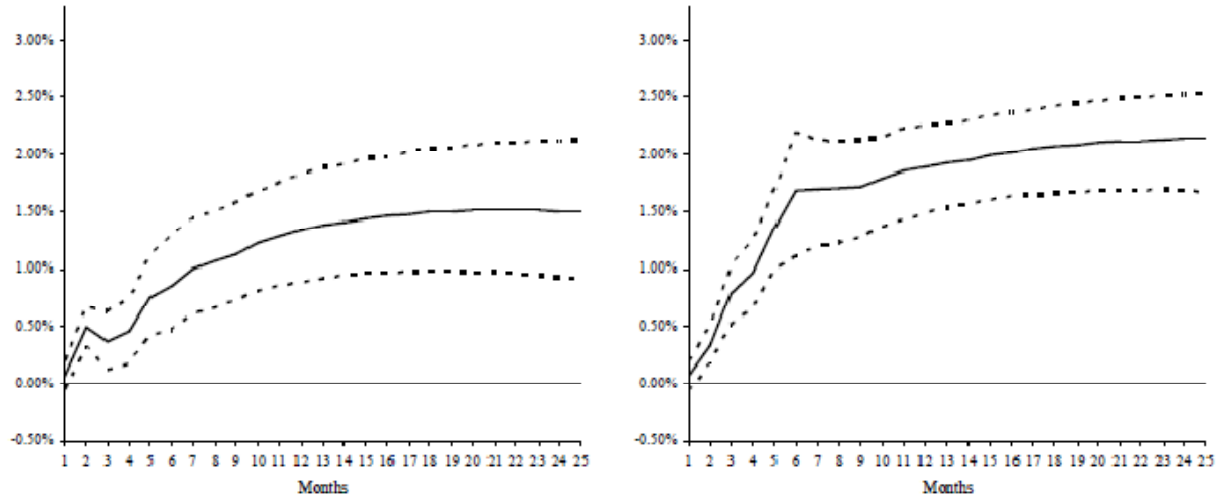
a) Low misalignment state b) High misalignment state

Figure A3. U.S. Real Interest Rate Shock



a) Low misalignment state b) High misalignment state

Figure A4. Real Dow Jones Index Shock



a) Low misalignment state b) High misalignment state

General Discussion

Agricultural Profitability in the 21st Century

Jason Henderson, Moderator
Vice President and Omaha Branch Executive
Federal Reserve Bank of Kansas City

Mr. Henderson: Why don't we talk about China and its growth in a long time period? What are some of the risks if China's growth doesn't materialize as we expect it?

Mr. Penn: That's a good question, Jason. What I tried to do in my presentation, as I said, is to rise to 30,000 feet and look at the fundamentals and I hope that is what I have done.

Lots of things can occur that will cause one to alter the outlook. There are things on the positive side that could occur – breakthroughs in technology and things of that nature. There are also things on the negative side. China is a big driver, as my numbers indicate, and there is concern about the pace of growth of the Chinese economy. It has been growing at near double digits for the past two decades. It grew about 12 percent in the first quarter of this year, the last reporting quarter. There are a lot of people who are very much concerned about an asset bubble. There are people who are concerned about the basic model of the Chinese economy. It's focused on the external sector for growth, but it needs to shift focus to the internal sector. Its currency may or may not be overvalued, depending upon who you listen to.

Any way you look at it, the ability of the Chinese economy, the ability of the authorities to manage that economy, is going to be a really key factor going ahead. Now I wouldn't bet against them. They have had a good track record. Look at how well they have done. Look at how well they did with the stimulus package. They are not a democracy, so they don't have to deal with a pesky Congress, 535 members who have their own agendas. So when they decide to do something, they can do it. If it is the right thing, then usually they are successful. So China is a big unknown. It is a big uncertainty. It is a big item to watch in the unfolding of the business environment for our industry.

Mr. Lortscher, Bern, Kansas: Gary Lortscher, former owner of a small ag business in a little town of Bern, Kansas. I am glad our lender was here to hear your positive future in the ag industry. I'm glad he was here to hear that. I have a couple of questions. [Question on African agriculture]

Mr. Penn: That too is a very interesting question and we could have a whole seminar on Africa.

First of all, we talk about Africa as one huge continent. As we all know, it is composed of many countries and the situation is very diverse. At Deere, we look at it as North Africa – Mediterranean-type agriculture – and that is assigned to Europe. Then we have Sub-Saharan

Africa, down to South Africa. We tend to look at that as a group. Then South Africa we look at as a separate entity.

You make a really good point in that I didn't say in my presentation, but of a lot of this new investment in Africa, some of it is by national governments. The Chinese have a lot of projects there, for instance. Some of it is by investor groups out of the Middle East. Some of it is by investor groups out of Brazil and a lot of other countries. Some of these projects focus on producing staple foods for the local market. Some of these others focus on producing cash crops for export markets. Others focus on producing food crops that go back to the home country of the investors.

When we have another crunch, it is going to be highly controversial. If you have a continent suffering from a shortage of food and you load boats and ship it somewhere else, it seems to me that is going to be very problematic. To the extent these investment projects are there and they are creating jobs and providing foodstuffs at reasonable prices to local markets – vegetable oil and things of that nature – then that is going to be a big plus.

There is a lot of question about stability in the Sub-Saharan African countries and in all the African countries. My sense now is that we have a perception of Africa as being a place in great turmoil. If you look at Africa as a continent, it is striving to be another one of these poles of growth. And Africa has been growing at 5 or 6 percent across the continent for the past several years. It slowed during the downturn for sure, but it is picking up again. There is more democracy, when you look at all the countries in Africa, than in a lot of the Asian regions. We hear a lot about famine and we hear a lot about the hostilities in a few particular places. But, again, Africa is a very big place. There is a lot of stability there and a number of those countries have turned around.

It is too important a potential market, if you are in the food and agricultural business, not to be there today. It may be a 15, 20, or 25-year play, but I don't think you can afford not to be there. If you aren't there, the Chinese are going to be there. It seems to me it is a country you have to pay a lot of attention to.

As to land titling, you are absolutely right. One of the biggest constraints on the continent is there is no secure system of land titling. We all know land is the asset used as collateral. It enables lending systems to thrive. So that is a big problem and it is being addressed a little bit but not nearly to the extent nor at the pace it needs to be to really spur agricultural development. Thank you.

Mr. Gabriel: Steve Gabriel at the Farm Credit Administration. I wonder if you could provide your views on the outlook in the future for the biofuels industry.

Mr. Penn: Steve, this is a Midwestern conference. Guys from the East Coast are not supposed to come here and ask questions. I'm surprised the organizers didn't tell you that. You have Bill Lapp and others who follow that far more closely than I do. As you know, that's a very complicated and controversial area. Today we have about a third of the corn crop being used for

corn ethanol. The EPA is considering increasing the allowable blend level, so we have that. We have a duty on this. We have a blenders' credit. We have a biodiesel credit that has lapsed. You know all of the complexities that are there. We have to see how the political situation shapes up. This is much more a political issue than it is an economics issue or than it is a markets issue. If you are going to forecast what happens to that industry, you have to be a political forecaster rather than a market forecaster or a market analyst, I think. There are people who are much better positioned to address this than I am, Steve. So I am going to let them handle that one for you.

Mr. Henderson: Dr. Penn, I'm Lynn Henderson, Publisher of Agri Marketing Magazine. How does a company like Deere view its future, given the diversity around the world? What product offerings and services do you expect to be involved with over the next five to ten years in this marketplace?

Mr. Penn: Thanks, Lynn. That is a question I can go on for some time about. Given the time constraints, I won't. We're in the farm equipment business. As you know, we are in the construction-equipment business, we are in the forestry-equipment business, we have a credit operation, and we are also very big in precision irrigation. It's all of those things we focus on as we look to the future. We've been around now for 174 years. Most of the people take that longevity as a pretty heavy burden. The senior leadership certainly wants to make sure the company continues in good health on their watch. So we are naturally focused on where the farming activity will be around the world in the future, over the next 10, 20, 30, and 40 years. Where will construction activity be, a lot of it infrastructure construction and things that relate directly to agriculture like farm-to-market roads and storage facilities that need construction equipment?

This also ties in directly with forestry equipment. That is why, as you may have heard, we have opened a new facility in Russia. Russia has more forestry sources than any other country on earth. So forestry goes right along with construction, housing, and development of infrastructure. Of course, you need to be able to finance all of that. That is our credit operation.

Where you are going to see farming activity, construction activity, and irrigation activity around the world, that's where we have to be looking as a multinational company.

Mr. Andrew: Dr. Penn, Jim Andrew, an Iowa corn and soybean farmer. I've spent a great deal of my life promoting those crops around the world and wondered if you have any idea as to how soon we can expect fortress Europe in the EU to approve biotech crops. The influence of that on starving countries and their ability or desire to import those crops to feed hungry mouths, in my sense, is morally irresponsible. What can we look forward to? I see some thawing, but what do you see?

Mr. Penn: I can certainly opine on that and will, but I also see Jim Borel from DuPont has finally made it. He follows this much more closely than I do. So you'll want to get him with the same question here a little later in the afternoon.

My sense is the same as yours. First, we have seen some thawing. We have seen some movement on acceptance of biotech by the governmental structures in the European Union. I don't know that the consumers are changing their mind a lot, but the governmental structures are moving in that direction.

Second, we are seeing the fundamentals I showed in my presentation, which certainly underscores the need for productivity enhancements, new technologies, and innovation. You can't deny biotechnology holds more promise than many other things we've seen.

Third, we've talked a lot about Africa. The per capita food production in Africa has actually been declining. In some part, it is because of the reluctance to accept GMOs in Africa. They are reluctant because they sell primarily to the European Union and the European Union says, "We don't want it."

So they discourage them from accepting it. I see that beginning to thaw, as well. There are a lot of activities on the African continent with AGRA, the new green revolution for Africa that involves Gates, Rockefeller, and others. So, at the ground-roots level, there is a lot of activity working on the science and on acceptance. Like you, I am optimistic. I can't predict a time certain, but my sense is that we'll get there.

Mr. Andrew: Is it possible that, in Europe, Greenpeace holds the moral high ground, but they really don't deserve it and over time it will erode, as we make the case for biotech being the helper of the world in feeding all the hungry?

Mr. Penn: My sense is that Greenpeace's stock went down a bit in 2008, when we had high food prices. When you get to the point of being very much concerned about food security, availability, and price of food, then this argument by Greenpeace and others begins to have a lot less appeal. It is one thing if you're talking about the rich EU where consumers can have a choice and can afford to pay for different kinds of products, than it is if you're spending 75 percent or more of your income for food and the price is rising. My sense is there is some movement there, as well. Thank you.

Mr. Henderson: One more question. We'll take one more question right now and then J.B. will be back with us after the next speaker to field more questions.

Mr. Gottschalk: My name is Andy Gottschalk, Denver, Colorado. If you could please, put the chart back up on the CRB Index. I noted with interest in the 1970s the CRB Index went from 100 to 325. We've just experienced a similar move percentagewise from 200 to 600. If we look at commodity prices historically over centuries, we see similar patterns, where prices spiked to new levels and then follow a pattern very similar to what we saw in the 1970s where we moved sideways for a lengthy period. What makes this time different than what we've seen before?

Mr. Penn: I said I knew there are many different interpretations of what's going on on that chart. So remember I said everybody gets to interpret it for themselves. Your interpretation is as good as the next person's. I suggested four things that have occurred, as I mentioned. It is new sources of demand we haven't had before. It is also the structural changes that have come about

quite slowly in the European Union, the United States, Australia, and New Zealand farm programs, for instance. It's the entrance of new money, hedge funds, and others into the agricultural and other commodity markets that probably wasn't there before.

Also, it is the markets taking a longer view of agricultural commodities than they used to take. For instance, we used to produce a corn crop in the fall and then the markets focused mostly on how we were going to use that crop over the course of the next few months until the next crop.

Today, you notice the futures markets look out a lot farther than they used to and they are more concerned about this just-in-time inventory situation about the crop status in North America and then it shifts to focus on the crop status in South America. So I think the markets are taking a longer view. That makes people look at these price trends different than they used to and maybe alters their investment behavior.

Those were my suggestions as to why this is occurring. You've had structural changes – the demand one being the biggest of course. But you are right. Oil is 26 percent of this. Back in

the 1970s you'll remember we had another little difficult period with petroleum at some point. That can have an impact on this.

Mr. Henderson: We just heard a presentation, where Jorge talked about how portfolio managers are switching between futurists and chartists and have the short-term fluctuations. Here in the United States we are undertaking financial reform. A big topic of that are derivatives. What are your thoughts on the regulation of derivatives and how does this impact agriculture?

Mr. Carrera: I was following also into the G-20 as a representative of the Central Bank of Argentina this discussion about the relative participation of nonfinancial investors. The role of futures markets is important in order to have a good setup for investment in the long run. Markets are very good in order to discover, as J.B. Penn said, and to introduce a lot of information into the decision of the producer.

It is clear, for example, naked short selling could be damaging for the stability of the market. Into the political decision of the G-20 and the Financial Stability Board, these two boards are trying to find a compromise between some European countries, like Germany and France that are highly against short selling and more importantly against the participation of noncommercial traders in this market. The position of England – the United Kingdom – is to maintain things more or less like this now. In some cases it is important to regulate and to put some limits on the act of short selling.