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A Dynamic Factor Model for Commodity Prices

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Abstract

In this note, we present the Commodities Factor Model (CFM), a dynamic factor model for a large cross-section of energy and non-energy commodity prices. The model decomposes price changes in commodities into a common “global” component, a “block” component confined to subgroups of economically related commodities and an idiosyncratic price shock component. Unlike with ordinary factor models, these components have meaningful economic interpretations: the global component mostly relates to global commodity demand shocks, while the idiosyncratic component mostly relates to commodity-specific supply shocks. We give several examples to show that the CFM provides plausible historical decompositions.

Bank topics: Econometric and statistical methods; Recent economic and financial developments
JEL codes: C51, Q02

Résumé

Dans cette note, nous présentons le modèle factoriel des prix des produits de base, un modèle à facteurs dynamiques appliqué à un large échantillon de prix des produits de base énergétiques et non énergétiques. Le modèle décompose les variations des prix des produits de base en trois composantes : une composante « globale», une composante « par blocs », qui concerne les sous-groupes des produits de base liés d’un point de vue économique, et une composante idiosyncrasique qui rend compte des chocs de prix spécifiques. Contrairement aux composantes dérivées des modèles factoriels habituels, ces composantes proposent une lecture économique utile : la composante globale se rapporte principalement aux chocs de la demande mondiale de produits de base tandis que la composante idiosyncrasique est surtout associée aux chocs touchant l’offre de tel ou tel produit de base. Nous donnons quelques exemples pour montrer que ce modèle offre une décomposition plausible des facteurs historiques à l’origine des mouvements de prix.

Sujets : Méthodes économétriques et statistiques; Évolution économique et financière récente
Codes JEL : C51, Q02

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1. Why Would a Dynamic Factor Model Be Useful for Interpreting Commodity Price Movements?

There is a high degree of correlation across the price movements of most commodities. This suggests that the bulk of underlying price fluctuations can likely be represented by a few common "factors." Factors are latent, statistical objects designed to capture the variation of a large cross-section of variables with a few explanatory series. Delle Chiaie, Ferrara, Giannone (2017) have recently shown that by restricting certain factors to load on selected subgroups of commodities, commodity price series can be decomposed into a common "global" component, a local "block" component and a commodity-specific "idiosyncratic" component.

The Commodities Factor Model (CFM) is a dynamic factor model that includes 42 energy and non-energy commodities. We adapt the factor model proposed in Delle Chiaie, Ferrara, Giannone (2017) in two ways. First, from the commodity price series used in their paper, we discard those that contain frequent outliers or other irregularities. We complement the remaining series with selected price series from the Bank of Canada commodity price index[1] and the World Bank. Second, we propose a slightly different model structure to facilitate the economic interpretation of the factors and components.

The CFM has several advantages over commodity-specific structural models. Structural models typically rely on consumption and production data, but these are often difficult to obtain, are released with lags or do not exist for many commodities. In contrast, the CFM relies solely on readily available market price data. In addition, the CFM is easy to maintain and to modify (e.g., by adding additional commodity price series to the model or changing the groupings of commodities in its block structure).

2. The Structure of the CFM

Factor analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved latent variables, called factors. For example, it is possible that variations in, say, 10 commodity prices mainly reflect the variations in two unobserved, underlying factors. The CFM is able to identify these independent latent factors. The observed variables are modelled as linear combinations of the potential factors, plus "error" terms. In a sense, factors can be thought of as weighted averages of the various series that they are composed of, but are far less "noisy" (Delle Chiaie, Ferrara, and Giannone 2017).

[1] The Bank of Canada commodity price index (BCPI) is a chain Fisher price index of the spot or transaction prices in US dollars of 26 commodities produced in Canada and sold in world markets.

Standard dynamic factor models often take the following form:

$$x_t = \Lambda F_t + e_t$$

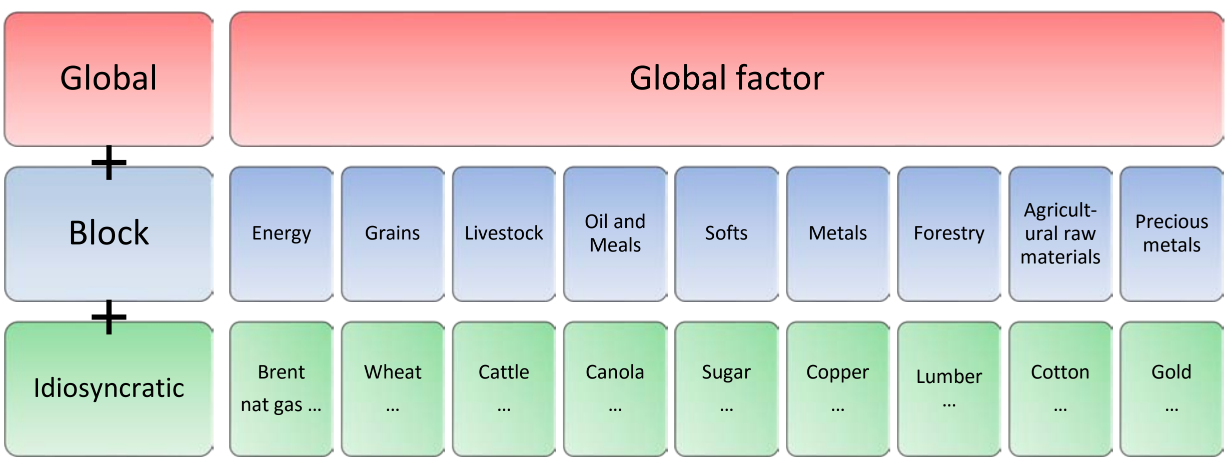
$$F_{jt} = \Phi_j F_{jt-1} + \omega_{jt}$$

$$e_{it} = \rho_{it} e_{it-1} + \varepsilon_{it},$$

where x_t is an $n{\times}1$ vector of commodity returns in month t; F_t is an $r\times1$ vector of factors; Λ is an $n{\times}r$ matrix of loadings; and e_t is an $n{\times}1$ vector of idiosyncratic error terms with $\omega_{jt} \sim i.i.d.N(0,1)$ and $\varepsilon_{it} \sim i.i.d.N(0,\sigma_i^2)$. The magnitude of the loadings in Λ determines how important each factor is for a given commodity return.

In contrast to a standard dynamic factor model, the CFM imposes a block structure on the factors. Standard factor models allow all commodity returns to be related to all factors. In the CFM, however, the factors contained in F_t are composed of one global factor extracted from the returns of all commodities and nine additional factors that are extracted only from specific subgroups, or blocks, of related commodities. The blocks are energy, grains, livestock, oils and meals, forestry, agricultural raw materials, other softs, metals, and precious metals. The model is estimated for monthly log returns from January 1981 to February 2017.

Figure 1: Model Block Structure



This factor structure decomposes the price movement of each commodity into a global, block or idiosyncratic component (Figure 1). While the "global" factor will load on each individual commodity, this is not the case for the block factors. For example, the "grains factor" will load only on grain commodities and is restricted to have no impact on all other commodities. The idiosyncratic component reflects commodity-specific shocks and can be thought of as the "residual" price movement that cannot be accounted for by the global and block factors.

The equation below presents these results algebraically where, as an example, the wheat return is given by

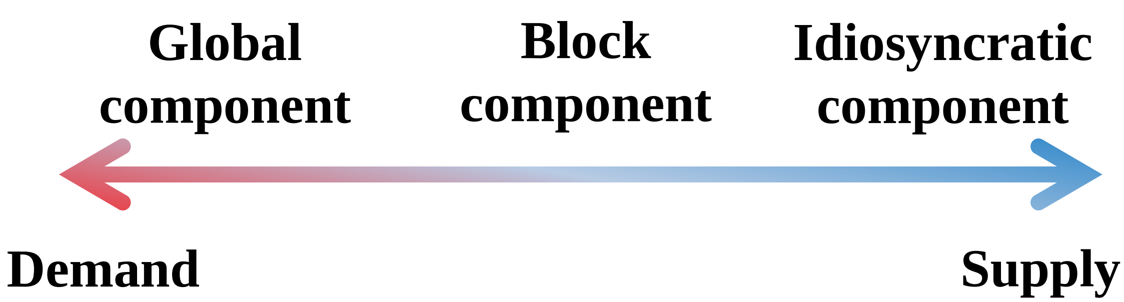
$$x_{wheat,t} = \underbrace{\lambda_{wheat}^{global} \times f_t^{global}}_{\text{Global component}} + \underbrace{\lambda_{wheat}^{grains} \times f_t^{grains}}_{\text{Block component}} + e_{wheat,t}\,.$$

The commodity-specific loadings λ_{wheat}^{global} and λ_{wheat}^{grains} determine how sensitive wheat returns are to changes in the global and grain factors, respectively. The values of the loadings for the global and block factors for selected commodities are provided in **Appendix 1**. Note that the factors are independent by construction. This representation lends itself to decompositions that show how much each of the global factor, block factor and idiosyncratic component contribute to movements in the price of a specific commodity.

3. How Can We Interpret the Global Factor, Block Factor and Idiosyncratic Component?

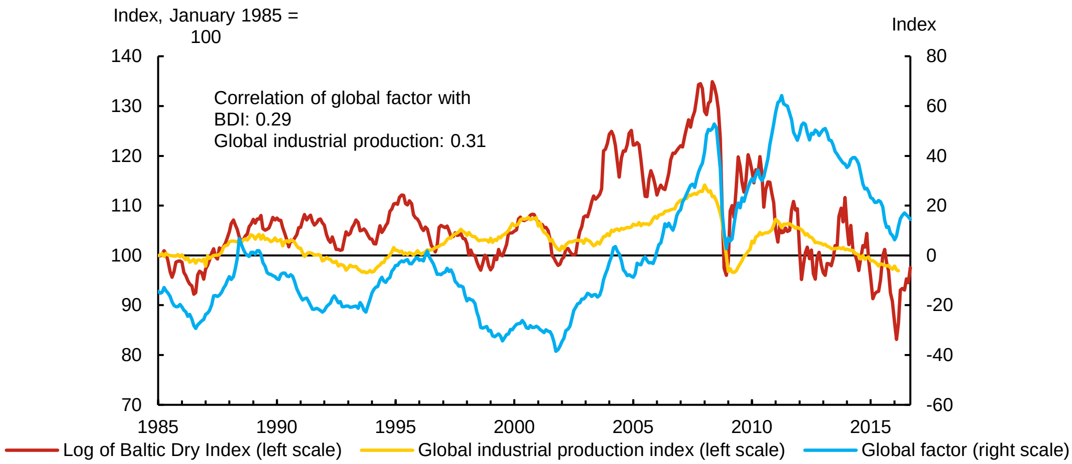
The decomposition of commodity price series into global, block and idiosyncratic components offers a tentative interpretation of commodity price movements. **Figure 2** shows the broad scheme of interpretation for the components, highlighting that the interpretation, which is along demand- and supply-side developments, might not always be clear-cut.

Figure 2: Interpretations of Components



The global factor captures price trends that are common to all included commodities, which are typically related to anticipated and realized **global commodity demand** (Alquist and Coibio 2014) particularly to the **global business cycle** (see, e.g., Baumeister and Kilian 2016). Indeed, there is a significant positive correlation between the global factor and other popular measures of global economic activity, such as the Baltic Dry Index and the global industrial production index (**Chart 1**).

Chart 1: The global factor captures global demand determinants



Sources: Haver Analytics, Baumeister and Hamilton (2015) and Bank of Canada

Last observation: industrial production, March 2016; others, September 2016

In contrast, the idiosyncratic component mainly captures supply shocks. Supply shocks tend to be more idiosyncratic and confined to one particular commodity or to a small group of related substitutes. We would therefore expect the idiosyncratic component to mainly reflect exogenous supply-side developments.

The block factors capture both supply and demand elements. They could reflect both changes in demand for a particular group of commodities (say, base metals), as well as supply shocks that spread to related commodities through substitution effects (say, livestock).

Despite the theoretical and empirical evidence supporting these interpretations, some potential pitfalls and limitations need to be taken into account:

- The global factor might also reflect other common influences, such as higher energy prices, that feed through to other commodity prices (Alquist and Coibion 2014). Empirically, however, the factor loadings of the oil series are not exceptionally high compared with those of other commodities, indicating that this effect is unlikely to be a major driver of the global factor (**Appendix 1**).[2]
- While demand shocks are unlikely to be confined to a particular commodity, they sometimes might be. For example, regulations can target particular commodities (such as lead), and technologies can reduce demand for specific goods (such as newsprint). In these cases, demand shocks would show up largely in the idiosyncratic component.

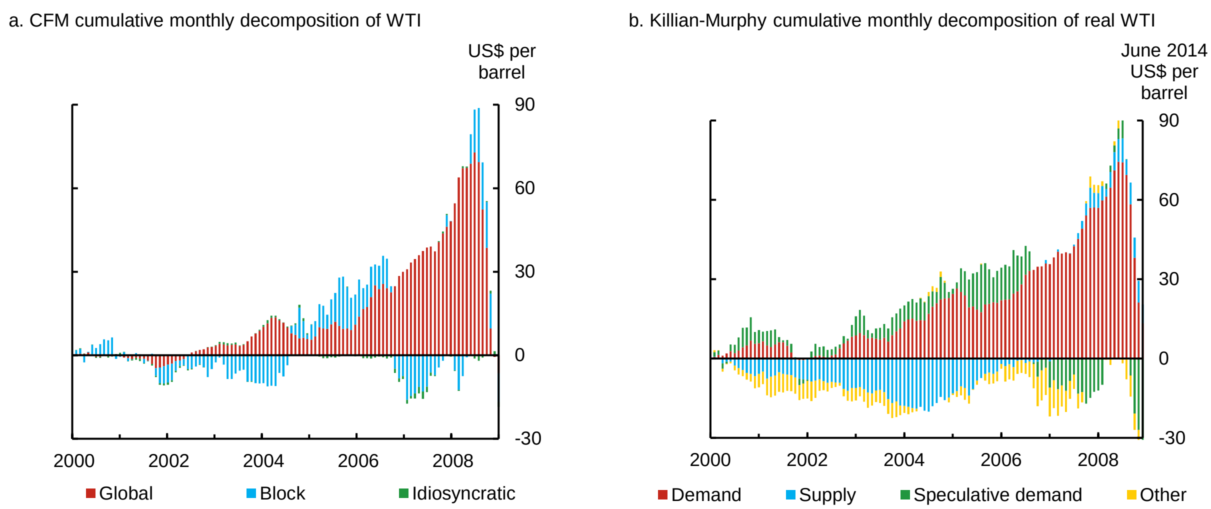
[2] Note that excluding energy commodities from the CFM would not help to resolve this problem.

4. Applications to Oil, Zinc and Corn Prices

Example 1: Situations where the global factor reflects global economic growth

The CFM would suggest that strong global demand drove the run-up in oil prices in the mid-2000s. This is consistent with the narrative that the rise of China and other emerging-market economies led to a series of positive demand shocks in the global oil market. The relative contributions of demand and supply from the CFM are broadly consistent with the structural decomposition provided by other models, such as that of Kilian and Murphy (2014) (**Chart 2**).

Chart 2: Price movement decomposition of WTI since January 2000



Note: The sum of the factors does not equal the total due to the conversion from estimates in logarithms to levels. WTI represents West Texas Intermediate crude oil prices.
Source: Bank of Canada

Last observation: December 2008

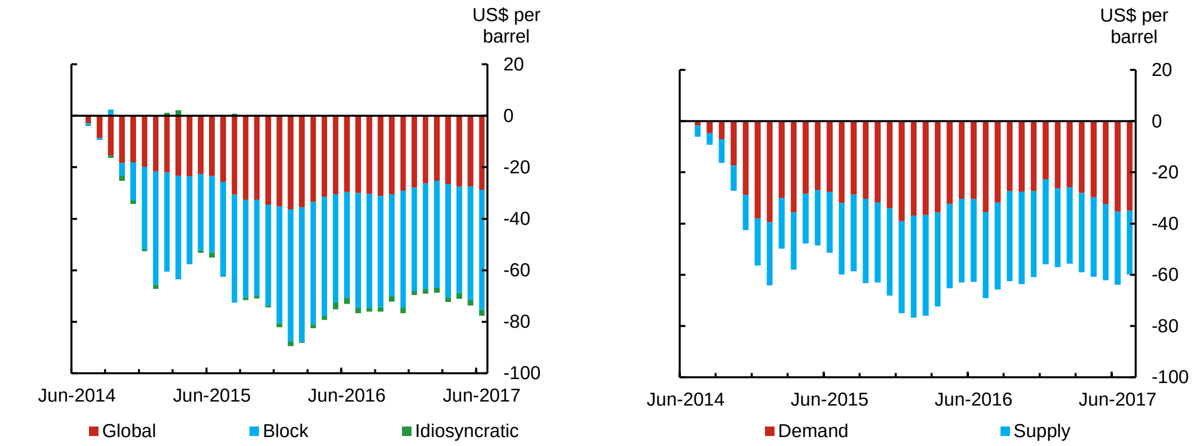
Global GDP growth in 2014 and 2015 was weaker than expected, contributing to a decline in oil prices after mid-2014. Decreases in the global factor account for about one-third of the decline in the price of Brent crude oil since June 2014 (**Chart 3**). Again, the relative contributions of demand and supply suggested by the CFM model are quantitatively similar to those provided by other models.[3]

[3] To construct the average supply-demand split, we average the relative contributions of demand and supply shocks to oil price movements from the models described in Beidas-Strom and Buitron (2015), Bernanke (2016) and Perez-Segura and Vigfusson (2016).

Chart 3: **Brent price movement decomposition since June 2014**

a. CFM cumulative monthly decomposition for Brent

b. Model average cumulative monthly decomposition for Brent



Note: The sum of the factors does not equal the total due to the conversion of estimates in logarithms to levels.
Source: Bank of Canada Last observation: June 2017

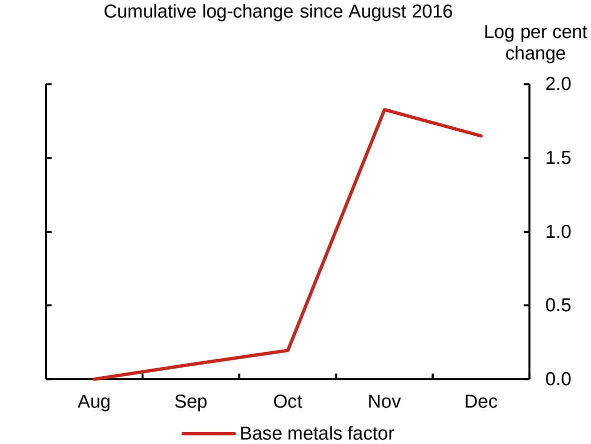
Source: Bank of Canada Last observation: July 2017

Example 2: A situation where the block factor reflects a shock to expected future demand that is related to a specific group of commodities

The rise in base metals prices in the aftermath of the 2016 US presidential election is reflected in an increase in the metals factor. The base metals factor increased in November 2016 following rising expectations of infrastructure spending after the US election (**Chart 4a**). Specifically, the decomposition of zinc prices shows that most of the price increase in that month is attributed to the metals block factor (**Chart 4b**).

Chart 4a: Base metals factor

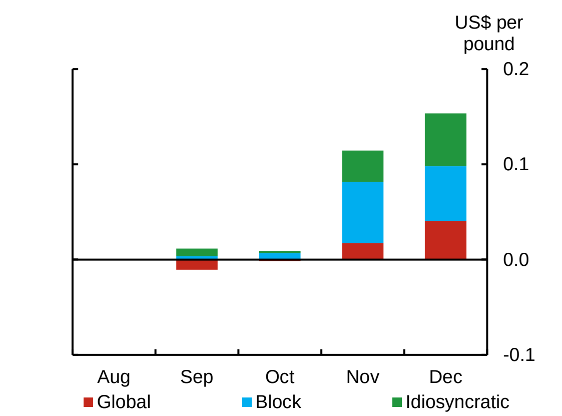
Cumulative log-change since August 2016



Source: Bank of Canada Last observation: December 2016

Chart 4b: Zinc CFM decomposition

Cumulative decomposition since August 2016

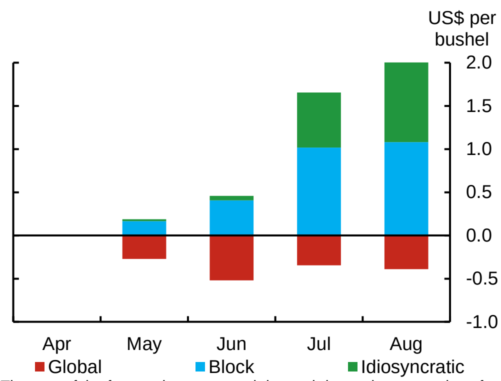


Note: The sum of the factors does not equal the total due to the conversion of estimates in logarithms to levels.
Source: Bank of Canada Last observation: December 2016

Example 3: A situation where the idiosyncratic component reflects a commodity-specific shock

The rise in corn prices following extreme weather conditions in the United States during the summer of 2012 is reflected in an increase in the idiosyncratic component (Chart 5). The 2012 drought in the United States devastated corn yields. Although yields of other agricultural products suffered as well, the geographical extent and timing of the drought led to particularly large losses in the corn harvest. Accordingly, the large increase in corn prices over the summer of 2012 is mainly reflected in the idiosyncratic component and, to a lesser extent, in the block component.

Chart 5: Corn CFM decomposition
Cumulative decomposition since April 2012



Note: The sum of the factors does not equal the total due to the conversion of estimates in logarithms to levels.
Source: Bank of Canada Last observation: August 2012

5. Conclusion and Extensions

The CFM provides a rough-and-ready interpretation of commodity price movements. In particular, the CFM can help corroborate existing interpretations of commodity price movements and identify less-conspicuous factors driving price movements that are difficult to spot from individual series alone.

Extensions to the CFM could be centred on refining the block structure and improving its forecasting performance:

- **The different block factors are, by construction, uncorrelated.** In practice, this may not be a good model feature. For example, higher energy prices could feed through to other commodities. In principle, such effects can be modelled within a dynamic factor model framework, although doing so would significantly increase the complexity of the existing structure.
- **Due to the dynamic structure of the factors and the idiosyncratic component, the CFM can also be used for forecasting.** Empirically, however, forecasting gains using the model's autoregressive structure seem to be limited to a horizon of less than one year for most commodities. Preliminary results indicate that conditioning the trajectory of factors on projections of global macroeconomic variables can improve long-term forecasts.

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Appendix 1: Factor Loadings for Selected Commodities in the BCPI

	Global loading	Block loading
Energy		
WTI	0.19	0.51
Brent	0.19	0.51
WCS	0.18	0.49
Natural gas	0.04	0.07
Metals		
Copper	0.22	0.45
Aluminum	0.19	0.46
Nickel	0.17	0.52
Zinc	0.17	0.51
Gold	0.13	0.64
Silver	0.17	0.58

	Global loading	Block loading
Agriculture		
Spring wheat	0.15	0.33
Winter wheat	0.18	0.36
Corn	0.19	0.40
Barley	0.17	0.23
Canola	0.25	0.35
Fertilizer	0.08	0.83
Cattle	0.07	0.66
Lean hogs	0.04	0.40
Forestry		
Lumber	0.05	-0.09
Hard logs	0.04	0.63
Plywood	0.02	0.52
Sawnwood	0.07	0.53
Newsprint	0.00	0.20
Pulp	0.06	0.01