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The fossil episode

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ABSTRACT

Agriculture sector output (biocarbon) is a good substitute for oil in energy production but oil cannot be used as food. This one-way substitutability is analyzed in a dynamic general equilibrium model. It features three endogenous phases: a pure fossil, a mixed fossil and biocarbon and an absorbing biocarbon fuel only phase. In the latter two, the demand for biocarbon as fuel leads to increasing food prices. Depending on how easily capital and labor can reallocate, food prices increase by between 40% and 240%. The model is also used to analyze climate consequences of biocarbon fuel polices and of the shale revolution.

1. Introduction

The average price of a barrel of oil over the year 2013 was US$109. Using an energy content of 1699 kWh/barrel, this implies an energy price of 6.4 cents/kWh. Over the same year, the average market price of corn was US$259 per ton. Using an energy content of 4389 kWh per ton, the energy price of corn was quite close at 5.9 cents/kWh.[1] This closeness is not a unique coincidence. Over the period 2005–2015, the average energy prices of oil and corn were 4.9 and 4.5 cents/kWh, respectively. However, the prices of energy in these two forms have not always been close. Fig. 1 depicts yearly prices of oil and corn in a long historic perspective, both expressed per unit of energy content. The price of oil has converged slowly to the price of corn from below, reaching it in the last decade and coinciding with it rather closely since 2005.

After oil and corn prices first were equal, they have been tracking each other in a way that did not occur before. This is easier to see in Fig. 2, which depicts the same data as Fig. 1 but for the period of 1981–2015. The recent change in the dynamic relation between corn and oil prices has been more formally documented by Avolos (2014). He finds evidence of a structural break in 2006 making the corn price co-integrated with the oil price while no such relation existed before.

Fig. 2 also depicts the energy price of sugar, another agricultural staple good with a well-defined energy content. The figure shows that the sugar price per unit of energy is much higher than that of corn and oil for the whole period. Furthermore, there is no tendency that the oil price and the sugar price have become more correlated. A tentative interpretation of the increased correlation between oil and corn prices is that the degree of substitutability between oil and corn

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[1] Price data from the World Bank Commodity Markets Outlook, January 2014. The energy content of corn is taken from Penn State College of Agricultural Sciences (2012) as the energy content of shelled corn taking into account a water content of 15%. The energy content of oil is from EIA http://www.eia.gov/energyexplained Units and Calculators.

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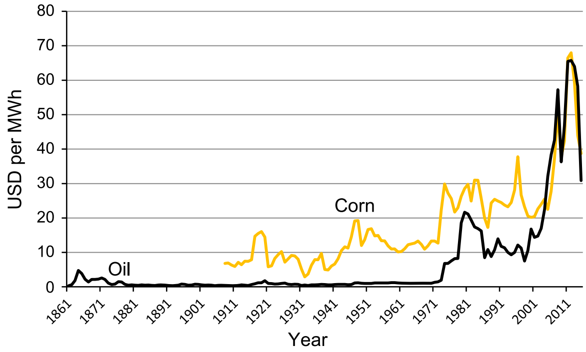

Fig. 1. Prices in current USD per unit of energy for corn and crude oil. *Source*: Ifo Institute calculations.

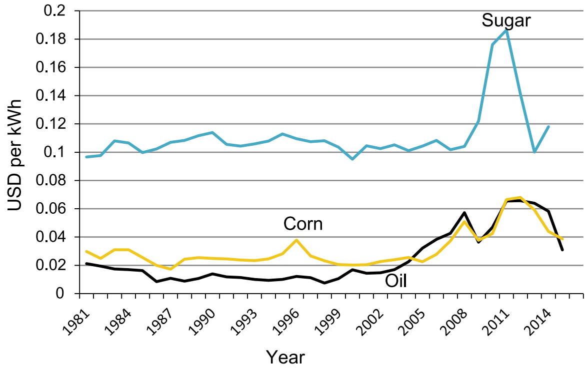

Fig. 2. Prices in current USD per unit of energy for corn, crude oil and sugar. *Source*: Ifo Institute calculations.

(but not oil and sugar) increased quite suddenly. With a higher degree of substitutability, any factor affecting the price of one good is more likely to also drive the prices of good substitutes in the same direction.

Over the last decades, the price of oil has been quite volatile. Our paper does not attempt to explain this volatility. Our focus is instead on providing an explanation for a sudden increase in the substitutability between biocarbon in the form of corn and fossil carbon in the form of oil. We then analyze the consequences of this for long-run global growth patterns. Our explanation will be based on a well documented feature of oil and corn – namely a unidirectional substitutability. For many uses, corn is an almost perfect substitute for fossil carbon. Corn can easily be used as fuel in heat production, both industrially and in owner-occupied housing. It can also be used in the transportation sector. In fact, in 2007, 8% of US agricultural land, or 30% of US total corn output, was used for the production of bioethanol (von Braun, 2008). However, fossil carbon is not a good substitute for most uses of biocarbon – we cannot eat fossil oil. All attempts to chemically convert the hydrocarbon in fossil fuel into edible substances have failed.

The unidirectional substitutability implies that the substitutability becomes operational only when the price of fossil carbon has reached the price of biocarbon, both measured per unit of energy. As argued above, this happened for corn in the middle of the previous decade but has not (yet) happened for sugar. When the price of fossil carbon is lower than that of biocarbon, the substitutability is non-operational and prices can move independently. When the price of fossil carbon has reached that of biocarbon two interesting mechanisms arise. On the one hand, increasing fuel prices can pull food prices with them. In particular, a trendwise increasing fuel price can cause a similar trend in food prices. On the other hand, the fact that biocarbon is a substitute for fossil carbon has an impact on fossil fuel prices. In particular, biocarbon may endogenously become a backstop technology for fossil fuel that can cap or limit future fuel prices.

To analyze the mechanisms described above, a dynamic general equilibrium model is required. A natural starting point is the seminal work by Dasgupta and Heal (1974). Like in their paper, our model has a production sector that uses labor, capital and energy to produce an output that can be consumed as well as used for capital investments. One source of energy is oil, and like in Dasgupta and Heal (1974), a secular positive trend in energy scarcity results in an upward trend in the relative price of energy. Our model also includes a second production sector, producing biocarbon from capital, labor and fixed factor called land. In line with the discussion above, biocarbon can be consumed directly as well as used as energy input in the first production sector.

Our model has a number of qualitative predictions. With just one unforeseen shock, the appearance of a technical device to exploit the fossil fuel reservoirs, namely steam and combustion engines (the Industrial Revolution), we can endogenously derive a development path with four stages: (1) A pre-industrial stage where food and fodder rival for land, and bioenergy is the only form of energy available. (2) A fossil phase where land is exclusively used for the production of food while energy is