C. Trade theory and natural resources

This section looks at key features of natural resources trade from a theoretical perspective. Does trade provide an efficient mechanism for ensuring access to natural resources? What is the impact of trade on finite or exhaustible resources, including under conditions of "open access" where there is a common ownership of – and access to – a natural resource? Is there a relationship between trade and its impact on the environment? Does trade reinforce or reduce problems associated with resource dominance in certain economies? And how does trade affect resource price volatility? These broad questions are addressed by surveying the relevant theoretical literature on the determinants and effects of trade in natural resources.

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1. Trade theory and resource distribution

Countries' differing natural resource endowments – and their uneven geographical distribution – play a critically important part in explaining international trade. Traditional trade theory emphasizes that differences in factor endowments prompt countries to specialize, and to export certain goods or services where they have a comparative advantage. This process allows for a more efficient allocation of resources, which in turn leads to an increase in global social welfare – the "gains from trade".

Relative differences in countries' resource endowments are key to the standard version of the Heckscher-Ohlin theory of international trade. This states that a country will export the good which requires the intensive use of the country's relatively abundant (and therefore cheap) factor for its production, and import the good which requires the intensive use of the country's relatively scarce (and therefore expensive) factor for its production. This includes cases in which the natural resource is directly exported (after a minimal amount of processing), rather than being used as an input in another good that is later sold in international markets.

Hence, endowments of immobile and scarce natural resources may form a source of comparative advantage that guides the pattern of international trade. Consistent with this theory, Leamer (1984) finds that the relative abundance of oil leads to net exports of crude oil and that coal and mineral abundance leads to net exports of raw materials. Trefler (1995) finds similar results with respect to trade in resource-intensive goods. While most of the report focuses on trade in natural resources, Box 4 provides an example of the static gains associated with trade in goods that embody a resource (water).

The Heckscher-Ohlin theory has been modified and extended by introducing other factors besides resource endowments, such as transportation costs, economies of scale and government policy,[1] that also influence comparative advantage. For example, distance from world markets can be a decisive factor when the natural resource in question is bulky, such as natural gas, and when transportation costs are high. Complementary inputs, such as technology, capital and skilled labour, are also significant when a natural resource sector is characterized by difficult or technically complex extraction processes.

Variables such as education, infrastructure and institutions have also been observed to affect sectoral patterns of natural resources trade (Lederman and Xu, 2007). Only when these other determinants of comparative advantage are in place will a resource-abundant country tend to export resources to countries with a relative abundance in capital and skilled labour and import capital-intensive goods in return (Davis, 2009). In short, natural resource endowments may represent a necessary but not sufficient condition for the production and export of resources or resource-intensive goods.

Box 4: **Virtual trade in water**

Trade can help to address problems related to the unequal geographical distribution of a natural resource when it is the goods embodying that resource that are exchanged rather than the resource itself – as is the case with trade in "virtual water".

Growing food where water is abundant and trading it with areas lacking in fresh water has the potential to save water and to minimize new investments in dams, canals, purification systems, desalination plants and other water infrastructure. Ricardo's theory of comparative advantage has been extended to explain the effect of water availability on international trade (Wichelns, 2004). This theory of "virtual water trade" suggests that the importation of a water-intensive commodity is attractive if the opportunity cost of producing that commodity is comparatively high due to scarce freshwater reserves or low water productivity. Similarly, exporting these commodities is attractive when freshwater reserves are abundant or productivity is high.

It follows that countries facing freshwater scarcity should import water-intensive products and export less water-intensive products. They can consequently save domestic fresh water and direct it towards producing water-intensive products with higher marginal benefit. Given that agriculture accounts for almost 90 per cent of total freshwater usage, international trade in agricultural commodities could play a major role in addressing the problem of water scarcity.

There is clear empirical evidence that trade in water-intensive products saves fresh water (Hoekstra, 2010). The most comprehensive study on this subject found that some 352 billion m^3 of water is already saved each year by trade in agricultural products (Chapagain et al., 2006). Table A shows the net water savings achieved through virtual water trade for a selection of countries. Japan, which was the largest net importer of water-intensive goods over the period 1997-2001, was able to save almost four and a half times its domestic use of water through trade in virtual water (Hoekstra, 2010).

However, trade in virtual water can also have a negative impact on water conservation when the incentive structures are wrong. For instance, according to Hoekstra and Chapagain (2008a), Thailand experiences water shortages partly because too much water is used to irrigate rice crops for export. Similarly, Kenya depletes water resources around Lake Naivasha to grow flowers for export. In another study, Nascimento and Becker (2008) find that fruit exporters in the São Francisco River region in Brazil are prospering in part because of an artificially low pricing system for water. In short, trade in virtual water can exacerbate, rather than reduce, water scarcity problems unless exporting countries account fully for the opportunity costs of fresh water use and address any potential negative environmental impacts. A properly managed water sector is key to ensuring that virtual water trade maximizes the productivity of this scarce resource – a point which will be explored in detail in Sections C.3 and C.4.

Table A: **Examples of nations with net water saving as a result of international trade in agricultural products, 1997-2001**

Country	Total use of domestic water resources in the agricultural sector[1] (10^9 m^3/yr)	Water saving as a result of import of agricultural products[2] (10^9 m^3/yr)	Water loss as a result of export of agricultural products[2] (10^9 m^3/yr)	Net water saving due to trade in agricultural products[2] (10^9 m^3/yr)	Ratio of net water saving to use of domestic water (per cent)
China	733	79	23	56	8
Mexico	94	83	18	65	69
Morocco	37	29	1.6	27	73
Italy	60	87	28	59	98
Algeria	23	46	0.5	45	196
Japan	21	96	1.9	94	448

[1] *Source:* Hoekstra and Chapagain (2008a).
[2] *Source:* Chapagain et al. (2006). Agricultural products include both crop and livestock products.

2. Trade theory and resource exhaustibility: The problem of finite supplies

A defining feature of non-renewable natural resources is their finite availability – and the fact that extraction and consumption today irreversibly alters the extraction and consumption possibilities of future generations. The traditional model of trade discussed above does not directly address this problem of exhaustibility and the inter-temporal trade-offs involved. Understanding how trade impacts on the exploitation of non-renewable natural resources involves looking beyond the standard version of the Heckscher-Ohlin model, and adopting a dynamic approach that takes into account the change over time in the availability of a finite resource.

(a) Efficient resource extraction: The Hotelling rule

In his pioneering work on the economics of exhaustible resources, Hotelling (1931) developed a framework for predicting the behaviour of prices and extraction paths in light of inter-temporal trade-offs – or “depletion opportunity costs”.[2] In doing so, he addressed two key questions: how should a resource be extracted over time in order to maximize the welfare of current and future generations, and can economic competition sustain the social optimum level of extraction? Although he worked within a closed-economy model, his insights provide a benchmark for understanding how trade impacts on non-renewable resources in open economies.

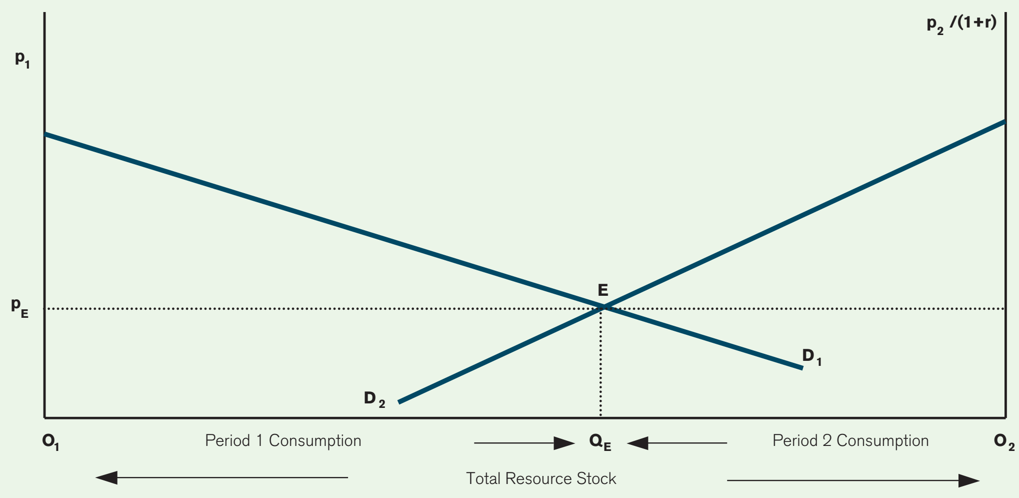
In response to the first question, consider the case of a social planner who chooses a resource extraction rate to maximize the welfare of current and future generations. The planner understands that, due to the fixed supply of the resource, any change in the rate of extraction in one period will trigger an opposite effect at some later period, with negative consequences for the welfare of later generations (i.e. an increase in consumption of the resource today may benefit the current generation, but it will reduce the consumption possibilities of a future generation). According to the Hotelling rule, the social optimum is achieved when the price of the resource net of extraction costs grows at a rate equal to the rate of interest. This, in turn, determines the efficient path of extraction of the natural resource. In essence, when the present value of one unit extracted is equal in all periods, there is no social gain from increasing or reducing the amount of the resource available in each period (Devarajan and Fisher, 1981).

The second question is, how does the extraction rate described above compare with that of a competitive, profit-seeking entrepreneur? In other words, should we assume that competition will lead to over-exploitation of non-renewable natural resources? To answer this question, imagine that the world lasts two periods: today and tomorrow. Assume that the marginal cost and the average cost of resource extraction are negligible, so that they can be set equal to zero. Under this scenario, the resource owner faces the dilemma of whether to extract all the resource today, tomorrow or to split the extraction between the two periods. His final decision will depend on the price of the resource in the two periods: the higher the price tomorrow, the higher the profits from future extraction and the lower the incentive to exploit the resource today.

Figure 12 captures the essence of the dilemma of when to extract resources. The horizontal axis is the total amount of the resource. Consumption in Period 1 is measured from left to right, while consumption in Period 2 is measured from right to left. The two vertical axes measure the price of the resource. On the left, there is the price in Period 1, while the right axis is the price of Period 2 discounted to the first period (i.e. the present value of the future price). Finally, the two lines are the demand curves of the resource in the two periods which, as usual, are downward sloping as the quantity demanded increases as the price of the resource falls.

The equilibrium is at point E, where the two demand curves intersect and where a producer is indifferent between selling an extra unit of the resource in the first or in the second period. The equilibrium price p_E is such that $p=p_2/(1+r)$ where r is the interest rate, while the equilibrium consumption (and extraction) of the two periods are given by the segments (O_1-Q_E) for Period 1 and (O_2-Q_E) for Period 2 respectively. It is instructive to understand why the competitive equilibrium is the one that corresponds to the Hotelling rule. If p_2 is greater than $(1+r)p_1$, it will be more profitable for the resource owner to extract tomorrow and not today, which will reduce the price of the resource tomorrow and increase the price of the resource today up to the point where the equality will be restored; while if p_2 is less than $(1+r)p_1$, it will be more convenient to increase the extraction of the resource today, with the opposite effect on prices.

Figure 12: **Perfect competition and the Hotelling rule**



In a competitive setting, price is usually equal to the marginal cost of production. But in this framework, the price is higher because the resource owner takes into account the depletion opportunity cost in addition to the marginal cost of production (i.e. the extraction cost). If he did not take the depletion opportunity cost into account, current profits would come at the expense of future profits, which is inconsistent with the profit-maximizing behaviour of competitive entrepreneurs. Since the depletion opportunity cost is taken into consideration by producers, the competitive outcome will be equal to the social optimum. In essence, Hotelling demonstrated that a competitive producer behaves like a social planner, taking into account the consequences of depleting resources by extracting less today.

However, in practice the Hotelling rule has not proved an accurate predictor of the evolution of observed price trends for non-renewable resources. According to his model, prices of non-renewable resources should have increased over time, whereas in fact they have moved erratically. This is largely because the Hotelling model does not take into account other important factors influencing price trends, such as the fact that the market structure of non-renewable resource sectors is better characterized as imperfect (such as monopoly or oligopolistic producers) rather than perfect competition, that on-going technological changes affect incentives to extract resources, that extraction costs tend to increase over time (e.g. digging deeper mines) (Hotelling, 1931; Peterson, 1975; Weinstein and Zeckhauser, 1975) and that uncertainty regarding future supply and demand affects decisions (Arrow and Chang, 1978; Hoel, 1978; Devarajan and Fisher, 1981; Weinstein and Zeckhauser, 1975).[3] Several of these specific points will be analysed below.

(b) Heckscher-Ohlin model in the context of natural resources

Do the main predictions of the Heckscher-Ohlin theory continue to hold when exhaustible natural resources are used as factors of production – including the situation where they are sold directly in international markets?

One study devised the following three scenarios to test the theory's validity (Kemp and Long, 1984). In the first scenario (defined as the *Anti*-Heckscher-Ohlin model), each final good is produced using only two exhaustible resources. In the second case (referred to as the *Hybrid* model), one of the two resources used in production is exhaustible (as in the first model), while the other is not (as in the traditional theory). The third scenario assumes that the production of final goods requires that two non-exhaustible resources are combined with an additional exhaustible resource (*Generalized* Heckscher-Ohlin model) (Kemp and Long, 1980; Kemp and Long, 1982).

What was found under each scenario[4] is that a country which is initially relatively well endowed with a non-renewable resource will specialize in that resource sector – and/or in the production of goods which are relatively intensive in the use of that resource. In other words, even when finite resources are involved, trade patterns (i.e. what countries export and import) are still explained by comparative advantage driven by differences in resource endowments.[5] Welfare gains from trade are still possible because specialization allows for the efficient allocation of limited resources.

Importantly, in this environment there is no over-exploitation of the natural resource as extraction is set (either by a social planner or by competitive producers) to maximize social welfare of present and future generations. This is not to say that trade never leads to over-exploitation of finite resources, but rather that over-exploitation is affected by trade opening only when market failures (such as imperfect competition or externalities) or political economy failures (such as rent-seeking or corruption) are involved.[6]

(c) Imperfectly competitive markets

So far the discussion has not departed from the traditional assumptions that markets are perfect, firms produce under constant returns to scale and that all stages of production occur in the same location. Under these assumptions, the economic literature shows that the predictions of standard trade theory hold true – namely, that under free trade, countries specialize according to their comparative advantage and exchange different goods.

However, several features of natural resource markets make them particularly prone to various forms of market power. First, the fact that natural resources are often concentrated in few countries increases the scope for collusion and limits the scope for the development of perfectly competitive markets. Second, the relatively scarce supply of many natural resources creates potential for extracting "scarcity rents" (see Box 5) which in turn encourages rent-seeking activities. Third, due to the high fixed costs of extraction, production and

Box 5: **What is a rent?**

In economics, the concept of economic rent is equivalent to that of (positive) economic profit – that is a return in excess of normal profit, where the latter is the return that an entrepreneur should earn to cover the opportunity cost of undertaking a certain activity rather than its best alternative. In other words, any revenue exceeding total costs including the opportunity cost (or normal profit) is economic rent (or economic profit) (McConnell and Brue, 2005).

Economists generally distinguish three types of rents:

1. Differential or Ricardian rent

The classical notion of differential rent is related to land. The idea is that greater rent accrues to land of higher productivity and better quality (e.g. greater fertility), with marginal land receiving no rent. More generally, differential or Ricardian rents arise when producing firms operate under different conditions – that is, at production sites with more or less favourable characteristics. For example, there may be deposits from which it is easier and cheaper to extract oil or mineral resources; as a consequence, some firms face lower or higher costs than others and earn more or less than others, respectively.

2. Scarcity rent

Scarcity rents arise when there are restrictions on the supply of a natural resource, so that demand exceeds supply. These restrictions can be natural or legal. Natural limitations exist because natural resources are generally available in finite amount, whereas legal limitations can derive from an export or a production restriction.

3. Quasi-rent

Quasi-rents are attributable to entrepreneurial skills and managerial efforts. Firms can adopt innovative practices and undertake strategic investments in advertising, training of employees and so on, thereby attaining higher prices (e.g. better reputation, higher productivity) or lower costs (e.g. better technology).

In general, the resource rent is the total of the differential rent and the scarcity rent. Quasi-rents can also be resource rents when they accrue to natural resources. The fundamental difference is that while differential rents and scarcity rents exist even in markets characterized by free entry and perfect competition (as they relate to the innate characteristics of natural resources), quasi-rents are driven to zero as competitors adopt profitable strategies as well (Van Kooten and Bulte, 2000).

transportation that many resource-based companies face, natural resource sectors tend to exhibit increasing returns to scale[7] – which can in turn lead to imperfect competition. Finally, some natural resource markets have a monopsonistic structure – that is, they are characterized by a dominant buyer – representing another departure from perfect competition.

The following discussion looks at the optimal extraction path for finite natural resources under imperfect competition, and then explains the implications for trade in these kinds of commodities. Since the literature on natural resources trade under imperfect competition is fragmentary, the question of how trade impacts on resource sustainability can only be answered for specific circumstances.

(i) Market structure and optimal extraction of exhaustible natural resources

Cartels provide the simplest case of imperfect competition that can be analysed in an inter-temporal economic model – the model which, as noted above, best reflects the exhaustible nature of non-renewable natural resources. Because other forms of imperfect competition, such as duopolies or oligopolies, involve strategic interactions among agents, they introduce a number of analytical complexities which limit the model's applicability and relevance.[8]

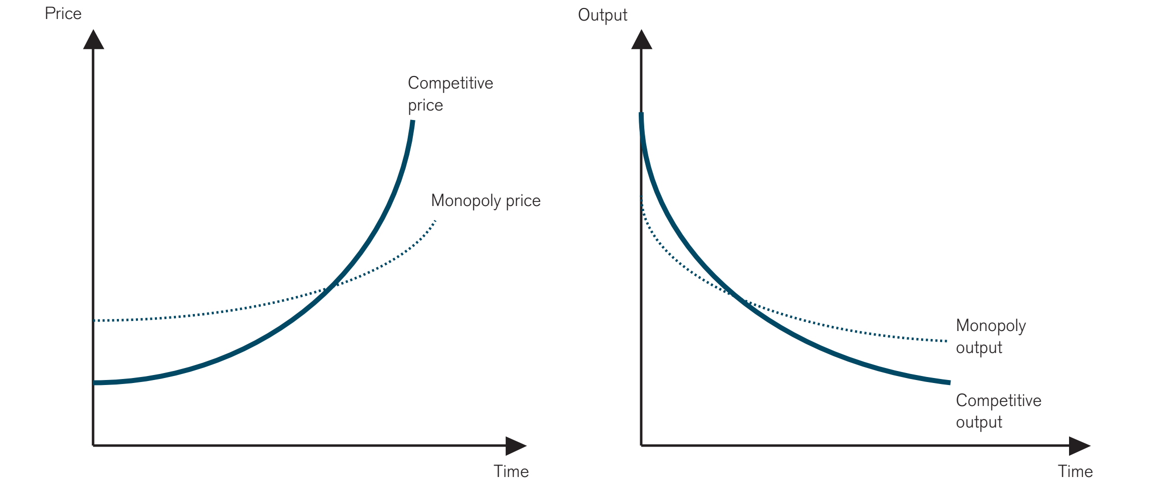
In general, economic theory suggests that an imperfect market structure will generate a dynamically inefficient outcome with a bias towards the initial conservation of non-renewable resources – a result that holds true for monopolies, core-fringe market structures, oligopolies and monopsonies.[9] In the case of a fully cartelized market, the intuition is as follows: when a natural resources cartel includes all producers, it will behave as a full monopoly. Given world demand for the cartelized commodity, the monopolist will at each moment in time set prices at the point on the demand curve corresponding to the quantity where marginal cost equals marginal revenue. In other words, the monopolist at each moment in time will set prices at a level above marginal cost.[10]

Therefore, as with the static theory of cartels, non-renewable natural resource cartels will restrict output relative to the output of a perfectly competitive (or oligopolistic) industry, in order to raise prices and profits. Over time, the optimal price and extraction path for a resources cartel will be described by a modified Hotelling arbitrage condition, whereby the marginal revenue, rather than the price, will grow at the rate of interest. This is because when extraction costs are negligible,[11] the value for the monopolist of extracting a unit of the commodity some time in the future must be the same as the money the monopolist would get if they extracted it now and kept the money in a bank.

What this means is that prices – and thus depletion – will increase faster or slower than under perfect competition depending on the changes over time in demand responsiveness to price changes (elasticity of demand). In particular, economic theory suggests that a monopoly will slow resource depletion when the elasticity of demand increases with price or over time, and will accelerate resource depletion when the elasticity of demand decreases. In short, it will deplete resources at exactly the same rate as a perfectly competitive industry when the elasticity of demand is constant (Dasgupta and Heal, 1979; Stiglitz, 1976; Lewis, 1976).

Figure 13 represents the price and output path when the responsiveness of demand to price changes (i.e. the elasticity) increases over time. This is generally thought to be the more realistic case because as the price increases over time, a substitute for the resource may become available – and consumers will more readily shift away from the consumption of the initial commodity (Devarajan and Fisher, 1981; Teece et al., 1993). In this case, a monopoly cartel will deplete resources more slowly than a perfectly competitive industry (see Box 6 for a discussion on why natural resources are prone to cartelization). The intuition is that, knowing that demand elasticity will grow over time, a monopolist will take advantage of the chance of extracting higher rents today when the elasticity is low by limiting extraction and charging high prices, thus preserving resources longer.

Figure 13: **Output and price paths in perfect competition and monopoly**



Box 6: Why are natural resources prone to cartelization?

The general case

A producer cartel is about monopolistic coordination aimed at jointly cutting supply or raising price, thus leading to increased revenue for the group. The conditions for cartel formation and cartel duration are not well understood, but economic theory can provide some useful insights. There is a clear incentive to form a cartel when the gains of setting a monopoly price exceed the costs of implementing and enforcing the cartel agreement. This is more likely to happen when the cartel's share of global supply is high and when the world demand as well as the outsiders' supply of the cartelized commodity is not too sensitive to price changes (Radetzki, 2008).

There are three major problems that a cartel must overcome if it is to be successful. First, there is the problem of determining the optimal level of output and the rules governing the allocation of that output among cartel members. This is an issue suppliers are likely to disagree upon, as they differ in technology, discount rates and forecasts of future demand. Similarly, when a cartel is formed among countries, the differing interests pursued by their governments, as well as the differing social and political contexts in which they operate, may reduce the likelihood of striking a deal.

Second, once output decisions have been taken, cartel members have an incentive to renege on the agreement and sell additional output, thus reaping additional profits. The temptation to depart from the agreement is positively affected by the elasticity of demand: a higher responsiveness of demand to whatever price discount is offered by the producer is associated with a stronger temptation to defect. In addition, defection depends upon the probability of detection and punishment: the easier it is to detect deviations from commitments undertaken under the cartel, the less likely it is that members will defect.

Third, a cartel has to be able to prevent entry by new firms. High profits will, in fact, provide an incentive for other firms to enter the market, and this would disrupt the cartel's original production and price targets.

The case of natural resources

In the case of depletable natural resources, different forecasts about the amount of reserves and the strategic value of such reserves make it particularly difficult to reach an agreement on output and price levels as well as on terms of revenue sharing.

There are, however, characteristics typical of natural resources that make the markets for these commodities particularly prone to cartelization. First, natural resources tend to be concentrated in few countries, hence few producers generally account for a large proportion of world supply. This reduces negotiation and enforcement costs among cartel members as the number of members required to cover a large share of world supply will be small.

Second, natural resources tend to exhibit high fixed costs of extraction. These costs reduce the risk of dissolution of a cartel due to entry by new firms, as they make it difficult for outside producers to equip themselves with the production capacity necessary to enter the market.

Third, natural resources tend to be relatively homogeneous. This increases the incentive for firms to defect, as a higher responsiveness to price changes is associated with less differentiated goods. However, deviations from a cartel agreement are easier to detect when products are similar than when they are differentiated (in the latter case it is easier to circumvent the agreement by varying quality, for example).

It is important to emphasize the limitations of economic theory in describing something as strategically complex as decisions about exhaustible resource extraction under imperfect competition. In an inter-temporal framework, decisions are made on the basis of expectations, especially about the actions of other agents. Assumptions about the way expectations are formulated are therefore crucial to determining the outcome. One common assumption is that future prices will be "announced" at the initial date and that agents do not deviate from the announced path. That is, producers set their extraction paths and consumers their demand path given each other's strategic choice at the beginning of the period. This is equivalent to assuming the existence of well-functioning future markets. In their absence, commitments to a certain price path will, in general, not be credible, as at some later stage the best choice of one of the parties, assuming that all others continue to behave as predicted, may differ from the one envisaged at the initial date (Newbery, 1981; Ulph, 1982).[12]

(ii) Imperfect competition and trade in natural resources

The effects of trade opening on exhaustible natural resources under imperfect competition remain largely unexplored in the economic literature. This is because the exhaustibility of natural resources and imperfect competition introduce dynamic and strategic considerations that significantly complicate welfare comparisons. The existing literature does, however, help to reveal some broad patterns.

To the extent that natural resources are geographically concentrated in one country or controlled by a cartel, it is clear that that country or cartel has a comparative (as well as an absolute) advantage in producing the resource and will export it. Furthermore, in the absence of barriers to trade, the extraction path chosen by the monopolist will depend only on how the inter-temporal world (foreign plus domestic) demand for the resource will change over time. Therefore, the expectation that imperfect competition will deliver a more conservative exploitation path than perfect competition continues to hold true (Bergstrom, 1982).

As far as patterns of trade under imperfect competition are concerned, economic theory suggests that the prediction of the standard Heckscher-Ohlin theorem – i.e. that countries will export goods using the factor with which they are relatively better endowed – also holds true (Lahiri and Ono, 1995; Shimomura, 1998). This explains why mineral-rich countries tend to export mineral products and import manufacturing-intensive products from capital-rich countries. It is worth noting, however, that in the case of fully cartelized commodities, the amount each country exports will depend on the production quotas agreed by the cartel's members. Considerations other than comparative advantage may affect decisions on quota allocation among cartel members, and thus trade patterns may depart from comparative advantage under these circumstances.

Furthermore, imperfect competition may also help to explain two-way trade (or intra-trade) in the same natural resource.[13] According to evidence based on the Grubel-Loyd index, this is relatively common for some resources (see Section B). The standard explanation for such two-way trade in a given market is that countries are trading different varieties of the same good (Krugman, 1979).[14] This cannot be easily applied to trade in natural resources given the similar nature of these products. There are simply not that many variations of iron ore or copper, for example. Nor can trade in natural resources within an industry be explained fully in terms of differentiated products – i.e. the two-way exchange of a resource at different stages of the production process to exploit countries' comparative advantages or increasing returns of scale. This is because the cost of transporting bulk commodities limits the scope for creating geographically fragmented production chains. Indeed, many natural resources are not even saleable until a certain amount of processing has been undertaken.

Instead, an important explanation for intra-industry trade in natural resource sectors may be the prevalence of imperfect competition in these markets and the phenomenon of reciprocal dumping. When markets are sufficiently segmented, firms can successfully price discriminate between foreign and domestic markets, allowing them to charge a low price for exports in order to make additional sales (Brander and Krugman, 1983). The rationale is the following: suppose that the same natural resource is produced by a monopolist in each of two identical countries. If the monopolist firm in each country charges the same price, no international trade will take place. However, if the foreign and domestic market can be segmented, domestic residents cannot easily buy goods designated for export and each monopolist can price-discriminate – i.e. set a lower price abroad than at home.[15]

By selling into the foreign market, each firm makes additional sales and profits (even if the foreign price is lower than the domestic price) and trade within an industry results. One study by Vasquez Cordano (2006) explains intra-industry trade in liquefied petroleum gas (LPG) in Peru by the presence of a dominant group of refiners that face international competition and a fringe of LPG importers. If the dominant group of refiners also controls the supply of LPG in the country, and if it is able to charge higher prices at home than abroad, then the competitive fringe will have to import LPG to be able to produce the refined product at a competitive price.

(d) Sustainability, technology and trade

Can an excessive use of exhaustible resources by current generations affect the potential for future economic growth? Will open trade facilitate or hinder sustainable growth? The Brundtland Report on the Environment and Development (United Nations, 1987) broadly defined sustainable growth as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". The focus here is more narrowly on the economic forces that may offset the exhaustibility of finite resources and how they interact with international trade.

From the economic perspective, this debate centres on whether the world as a whole can sustain the current rate of output growth in the face of a declining stock of non-renewable resources that are essential to the production process. Recent policy and academic work has emphasized that limits to growth arise, not only because of the finite supply of natural resources, but also because of "nature's limited ability to act as a sink for human waste" (Taylor and Brock, 2005). In the latter sense, sustainable growth depends on the impact that the by-products of economic activities (e.g. solid pollutants, toxic chemicals, CO_2 emissions) have on the quality of the environment. While the two interpretations of sustainable growth are related – in that the environment is itself a scarce natural resource – the following discussion focuses more on resource supply limitations than on environmental constraints.[16]

Many economists argue that the more pessimistic prognoses for the sustainability of economic growth fail to take into account adequately the forces that can offset natural resource limitations, namely technological change and the substitution of man-made factors of production (capital) for natural resources (Dasgupta and Heal, 1974). In particular, they have attempted to identify the conditions under which capital can provide an alternative to depleting exhaustible resources, and how technology can guarantee sustained production and consumption growth over time. Key to the discussion is the issue of how international trade enters into this process, and to what extent flows of goods and services may promote a sustainable rate of economic growth.

Solow (1974a) shows that constant consumption can be sustained by a suitable path of capital accumulation, despite declining resource flows. This is possible only if there is a certain degree of substitutability between capital and a natural resource, and if the latter is a non-essential input.[17] This intuition was translated into a policy rule by Hartwick (1977), who argued that the rent derived from resource extraction should be invested in building the capital stock (broadly defined to include infrastructure, physical capital, education) needed to guarantee constant consumption over time.

There are also various ways in which technological change can help to address problems associated with resource exhaustion. Resource-saving inventions can reduce natural resource requirements per unit of real output (Solow, 1974b). New technology can also have a substitution effect, increasing the demand for alternative resources. For example, as the internal combustion engine gradually eclipsed the steam engine in the early 20th century, it generated a growing demand for oil which was effectively a resource substitute for coal. Finally, improved technology can reduce extraction costs or facilitate exploration, thus increasing the availability of a given resource. Consider the case of a non-renewable resource with escalating extraction costs. If prices rise too high, demand will be extinguished, producing "economic exhaustion" even if some of the resource remains in the ground. However, the cost increasing effect of depletion can be more than offset by the cost reducing effects of new technologies and the discovery of new deposits.

Two other considerations regarding technology and exhaustibility are relevant. First, technology can influence the eventual "exhaustibility" of a resource. Consider a situation in which, at current consumption, a non-renewable resource will be fully depleted at time T. Then, a new technology is introduced which either increases resource supply (e.g. because of new discoveries, improved recycling methods), or reduces resource demand (through substitution or efficiency gains) – effectively postponing the point of depletion from T to (T+n). As a result, continuous technological change shifts this depletion point indefinitely and a non-renewable resource begins to resemble a renewable resource.

Second, while technology is generally seen as reducing the problem of resource exhaustibility, the opposite effect cannot be excluded. For instance, technologies that increase productivity in the extracting sector can also lead to an acceleration of resource exhaustion (Copeland and Taylor, 2009).[18]

A last point that should be highlighted in any discussion of technology and non-renewable resources is the role of international trade in facilitating the transfer of new technologies across national borders and in spurring research and development (R&D) activities among countries (World Trade Organization (WTO), 2008). Recent studies have found that technological spillovers are greater with imports from high-knowledge countries (Coe and Helpman, 1995) and that in developing countries total factor productivity is positively correlated to the R&D activity of their trading partners (Coe et al., 1997). This channel is termed "direct spillovers". Countries also benefit from "indirect spillovers" – i.e. the idea that a country can benefit from another country's knowledge even when they do not trade with each other directly as long as they both trade with a third country (Lumenga-Neso et al., 2005). Empirical evidence suggests that what matters most is how much knowledge a country can access – and absorb – through the totality of its global trade relations. Therefore, international trade can help guarantee sustained growth to the extent that it promotes the diffusion of technologies that offset the exhaustion of natural resources.

3. Trade theory and resource exhaustibility: The problem of open access

The previous section looked at the impact of trade on finite natural resources, and examined how markets can help to promote resource management and sustainable extraction and consumption. The following section discusses the specific problems related to "open access" – a situation where common ownership of, and access to, a natural resource can lead to its over-exploitation and eventual exhaustion. It examines how this affects the pattern of international trade, factor prices and the gains from trade. Under certain conditions, the existence of poorly defined property rights (see Box 7 for a more detailed discussion of property rights in economics) can result in the natural resource exporting country losing from free trade since, compared with autarky, free trade leads to a permanent reduction in its stock of natural resources.

This apparently overturns the standard welfare result from international trade theory which predicts that countries gain from freer trade. While this is possible, it is not the only probable outcome even if there is open access to the natural resource. The reason for this is that a lot of other things come into play. The structure of demand, population pressure, the technological capacity to harvest the resource and the strength of the property rights regime interact in a complex way to determine the final outcome. In particular, property rights are neither binary nor exogenous. Rather than being completely perfect or completely absent, the strength of property rights in a country falls along a continuum. Property rights to natural resources may be strengthened with more open trade, depending on how other elements that determine the definition and enforcement of property rights are affected.[19]

Box 7: **What are property rights?**

A full set of property rights over an asset entitles the owner to: a) use the asset in any manner that the owner wishes provided that such use does not interfere with someone else's property right; b) exclude others from the use of the asset; c) derive income from the asset; d) sell the asset; and e) bequeath the asset to someone of the owner's choice (Alston et al., 2009).

Demsetz (1967) provides one of the earliest economic analyses of property rights, explaining why it arises and the characteristics of different property rights regimes. He argues that it is the presence of externalities, whether positive or negative, which explains why property rights arise. The assignment of property rights allows economic agents to take these benefits or costs into account. The classic example he gives is the development of property rights among the Montagnes Indians in Quebec and the growth of the fur trade in the late 17th century. Before the development of the fur trade, there did not exist anything resembling private ownership in land among the Montagnes Indians. However, following commercialization of the fur trade, there was increasing economic value in being able to hunt on land on which fur-bearing animals lived. By the early 18th century, the Montagnes Indians had developed a custom of appropriating pieces of land for each group to hunt exclusively. This further developed into a system of seasonal allotment of land.

The extremes of perfect property rights and of no property rights (i.e. the tragedy of the commons) (Hardin, 1968) may be theoretically useful concepts but are unlikely to describe reality. The strength of the property rights regime applying to a natural resource may be better described as lying along a continuum (i.e. a series of intermediate cases). Ostrom (1990), for example, has documented the variety of institutional arrangements by which local communities have successfully managed common resources. These arrangements do not involve the extremes of complete privatization nor full government control. Copeland and Taylor (2009) suggest that one way to think of this continuum is in terms of the difficulty faced by a government or regulator to monitor and enforce rules on access to the natural resource.

Monitoring is imperfect so some unauthorized harvesting of the resource will take place, but it will be effective enough to deter such behaviour in many other instances. Alston et al. (2009) take a different tack by focusing on the question of who enforces property rights. They distinguish between *de jure* property rights which are enforced by the power of the state and *de facto* property rights which are enforced by the owner of the resource or in alliance with a group, e.g. tribe, community, etc. It is assumed that the state has the comparative advantage in enforcement, the individual has the least advantage and the group's ability lies in between the two. Whether the property rights regime is *de facto* or *de jure* depends on how crowded the commons become from encroachment by others. If there are few users of the common resource, rent per user is high and the individual can defend his property rights by himself. But as encroachment increases, rent becomes dissipated and there are gains from banding together to try to exclude others from the resource or seeking *de jure* protection from the state.

(a) Open access problem

Open access refers to a situation where common ownership of – and access to – a natural resource can lead to its over-exploitation and eventual exhaustion. Consider the case of a lake stocked with fish that no one owns. In the absence of defined property rights, there will be too many fishermen on the lake. This depletes the available stock of fish and reduces the efficiency of the effort to catch fish. This is obviously an economic, as well as an environmental, problem. The reason for this is that each fisherman on the lake reduces the productivity of all other fishermen. However, individual fishermen do not take into account the negative impact of their activity on the productivity of other fishermen. In effect, too much effort is spent to catch too few fish.

The result of too much entry is that the total catch from the lake is barely able to cover the cost of the effort to catch the fish. The degree to which rent – the difference between total revenues from the catch and the total cost incurred in catching the fish - is dissipated is thus a measure of the inefficiency introduced by uncontrolled access (see Box 8 for estimates of the amount of economic profits that could be generated from more efficient management of the natural resources stock).

This focus on economic efficiency is not inconsistent with the environmental desire to keep the lake stocked with fish. It could be argued that the economic and environmental interests coincide in this case because as shall be seen, the economist's preferred solution – strengthening of property rights over the natural resource – rations fishermen's access to the fish in the lake and reduces overfishing, producing an outcome that is in line with the environmentalist's goal.[20]

Since open access is such a significant feature of certain natural resources, this concept shall be explained in greater detail. The renewable resource grows at a rate that depends positively on the size of the current stock.[21] Given the ability of the resource to replenish itself, it is possible for humans to harvest the resource in a way that the size of the population remains stationary. This "sustainable" harvest will be possible only if each period's growth is harvested, leaving the rest of the stock untouched. "Sustainable" here is equivalent to what economists refer to as the steady state equilibrium so the two terms shall be used interchangeably.[22]

The quantity harvested depends on the amount of labour employed and on the size of the natural resources stock. The more fish there are in a lake, the easier it will be to catch fish. Initially, as effort is increased, so does the amount of the sustainable harvest. However, over time, increased effort results in the amount of sustainable harvest eventually declining. The reason for this decline in productivity is the negative relationship between effort and the stock of the natural resource arising from the steady state condition. The greater the effort put in, the smaller is the equilibrium stock of natural resources.[23] The smaller the equilibrium stock of the resource, the more difficult it is to harvest or catch a given amount of the resource. Eventually, the impact of a smaller equilibrium stock outweighs the impact of additional effort.

Box 8: **Rents and open access**

Box 5 has already explained various definitions of rent (differential, scarcity and quasi-rent) and has clarified how rent in the natural resources sector is best conceived as the sum of the differential rent (when producing firms operate under different conditions) and the scarcity rent, which arises when there are restrictions on the supply of a natural resource. In the case of natural resources suffering from open access, since it is not possible to exclude others from using the resource, rent goes to zero because effectively the resource is not scarce.

As discussed above, the degree to which rent is being dissipated is an important indicator of how much open access is reducing the efficiency of harvesting a natural resource. Private ownership or government ownership and regulation of the resource represent different ways of trying to address the open access problem. In both instances, access to the resource is being restricted although possibly with different considerations in mind. In the case of private ownership, and assuming that the resource owner has a zero discount rate, access will be restricted so as to maximize the rent that accrues to the owner (see fuller discussion below). In the case of government ownership, the restriction may well have maximization of rent as an objective, but it could also have some other objective in mind, e.g. biological or environmental objective such as maximum sustainable yield.

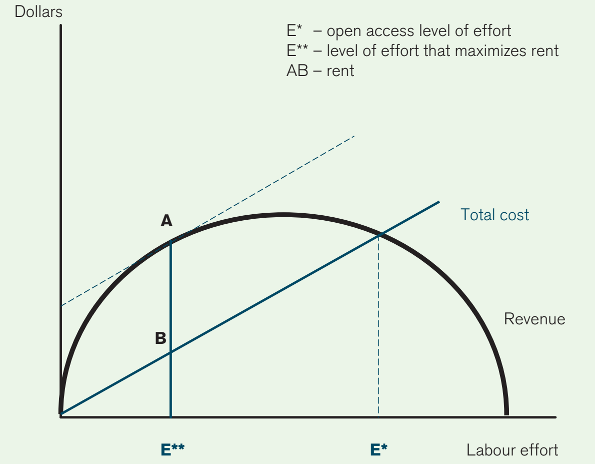
One popular method for controlling overfishing is the use of individual transferable quotas (ITQs) – permits to harvest specific quantities of fish. The total allowable catch (TAC) in a fishery is determined by a regulator, who may determine this total for a given year on the basis of economic or ecological considerations. Generally, members of the fishery are granted permits to harvest a share of the TAC. Since these permits are transferable, the current owner can sell the permit to a buyer, who will then acquire the right to harvest a share of the TAC. The sum of these shares, converted into quantities of fish, equals the total allowable catch set by the regulator. If the total catch determined by the regulator falls significantly below the open access outcome, rents will be generated and the ITQs will reflect the present value of the stream of future rents. If the total allowable catch is not substantially lower than the open access outcome, the ITQs will not have any value (there is rent dissipation).

ITQs have been used in a number of OECD countries and information on the prices of ITQs are available from studies that have examined these experiences. Perhaps the most dramatic example of the rents generated by managing fishery resources comes from Iceland. Arnason (2008) estimates that between 1997 and 2002, the value of fishery ITQs averaged about 40 per cent of Iceland's GDP and 20 per cent of the market value of its physical capital. One of the early adopters of the ITQ system was New Zealand. Using data covering nearly 15 years, Newell et al. (2002) tested the arbitrage relationship between the rate of return on ITQs and other financial assets. The reason for doing this is that if ITQs were effective instruments for fisheries management, they would bring a rate of return to quota owners comparable with other financial assets in the New Zealand economy. This was indeed what they found: the rate of return on ITQs was close to the overall market interest rate in New Zealand.

If it is assumed that the price of the natural resource is unity (one), then the yield curve is also the revenue curve, i.e. revenue = price times yield (see Figure 14). The revenue curve shows how total revenue changes with the amount of labour exerted to harvest the natural resource. Suppose that the cost of harvesting the natural resource is linear in effort i.e. $C=c * E$, where c is the per unit cost of effort. The rent or profit earned is equal to the difference between the revenue and cost curves, i.e. rent is equal to the vertical distance between the revenue curve and the linear cost.

With open access, each worker will try to capture the rent from harvesting the natural resource. There will be entry of workers until the last unit of effort just exhausts the remaining rent. This takes place at E^* where total revenue equals total cost. In contrast, if ownership of the fish stocks were assigned to a single fisherman, and if he did not discount the future, he would have an interest in maximizing the sustainable rent that could be earned from his ownership of the resource. The fisherman would limit access to the lake's fish stocks and would allow other fishermen to expend effort only

Figure 14: **Open access and optimal harvest of natural resources**



until marginal revenue equalled marginal cost. This would be at the level E^{**} where the slope of the revenue curve equals the slope of the cost line and sustainable rent is at a maximum. At this economically efficient point, the equilibrium stock will be larger than the stock corresponding to open access. An alternative way to interpret the level of effort E^{**} is that it would be the allocation of effort in the natural resources sector that would have been chosen by a regulator whose objective is to maximize social welfare.

On the other hand, if the owner of the fish stock discounts future revenues, he would choose a steady state stock that is lower than that which maximizes rent. He can achieve this by allowing greater fishing than E^{**}, reducing the existing fish stock, but yielding him additional revenues. This additional revenue will come at the expense of lower future rents because the steady state stock will be lower. But a positive discount rate means this reduction in future rent is valued less, providing the incentive for the resource owner to harvest more of the existing stock. As the discount rate goes to infinity, the owner will harvest everything today even if it means the resource is extinguished. This is because an infinite discount rate means the resource owner attaches no value at all to future revenues. [24]

Although the simple model serves as a useful illustration of the problems related to open access resources, in the real world the management of such resources is typically far more complex. For example, many fisheries operate under various government-imposed regulations, such as gear limitations, area closures, or length-of-season restrictions. This had led some economists to develop an alternative framework, "regulated open access", for analysing resource systems where authorities are able to effectively enforce regulations but where otherwise there is free entry by fishermen so that rents are fully dissipated (Homans and Wilen, 1997). The system lies somewhere between open access, at one extreme, and rent-maximization, at the other. It may well be that most fisheries in developed countries fall within this intermediate category. Since it is assumed that the regulation is effective, the stock of the natural resource will be greater in long run equilibrium under this system than in the open access case, and consequently, the quantity of fish harvested will be greater since the fishery is more productive. Simulations by Homans and Wilen (1997) for the North Pacific Halibut fishery[25] – which they consider an example of a regulated open access system – suggest that the difference in stock and harvest levels over the pure open access model can be dramatic.

(b) Patterns of trade

What is the impact of international trade on open access natural resources? To illustrate the principles at work, imagine two countries that have equal amounts of a natural resource, the same technologies and identical tastes, but differ with respect to property rights. Access to the stock of the natural resource is perfectly controlled in the first country, but there is open access to the natural resource in the second country. In autarky, it can be supposed that the second country will harvest a larger quantity of the natural resource – and at a relatively lower price – than the first country. When trade is opened up, the second country will then export the natural resource to the first country.

In standard trade theory, countries that have identical tastes, endowments and technologies have no reason to trade. However, introducing differences in the strength of each country's property rights creates the basis for trade despite the countries being identical in all other respects. This means that a property rights regime can serve as a *de facto* basis of comparative advantage – a conclusion that is supported by the economic literature on the subject – (Chichilnisky, 1994; Brander and Taylor 1997; Brander and Taylor, 1998; Karp et al., 2000).

Now suppose that the countries also differ in the size of their natural resource stocks, and that it is the country with strong property rights that has relatively more abundant stocks. One would have assumed that free trade would result in the natural resource-abundant country exporting that good to the natural resource-scarce country. However, the relative strength of the countries' property rights regimes exerts an independent influence on comparative advantage and hence on the pattern of trade. It is possible for the country which is less abundant in the natural resource to end up exporting that good to the natural resource abundant country if the former's property rights regime is sufficiently weak.

Of course, other things have to be taken into account. In particular, predictions about the patterns of trade also depend on the structure of demand. Building on the work of Brander and Taylor, Emami and Johnston (2000) show that if the demand for the natural resource is relatively high, then the country with the weak property rights can end up importing rather than exporting the natural resource (see Box 9). This can be explained as follows: the combination of high demand for the resource good and poor property rights leads to massive depletion of the stock, even in autarky, and a small harvest. Thus, if trade is opened up, the country with poor property rights will rapidly deplete its resource stock and end up importing the good.

(c) Gains from trade

When a natural resource sector suffers from open access or common pool problems, in principle the basic "gains from trade" result is undermined. While the long-run (steady state) welfare of the resource-importing country rises with trade, it declines for the resource-exporting country. Intuitively, this is because free trade exacerbates the exploitation of the natural resource so that the steady state stock is lower than in autarky (Brander and Taylor, 1998). Since the size of the natural resource stock affects labour productivity, the lower steady state stock means that the economy will be harvesting a smaller quantity of the natural resource good under free trade. An alternative way of understanding why the size of the natural resource stock affects welfare is that it represents capital (in this case, natural capital) from which the economy can earn a stream of future returns. The smaller the stock of the natural resource, the smaller future harvests will be. An example of how the combination of open trade and weak property rights can lead to the near extinction of a natural resource and a welfare loss for the exporter is the 19th century slaughter of the Great Plains buffalo (Taylor, 2007).

However, introducing additional features to this simplified model can produce a very different result. If the demand for a natural resource is relatively high, the standard gains from trade will result (see Box 9), and free trade will increase the welfare of both the natural resource importing and exporting countries (Emami and Johnston, 2000). As explained earlier, with high demand for the natural resource, the country with strong property rights exports the natural resource to the country with weak property rights. This implies that the long-run stock of the natural resource in the country with poor property rights will actually be higher than in autarky and so lead to a welfare gain. The welfare of the country with strong property rights also rises since its natural resource sector is being optimally managed (price equals marginal cost). In other words, even in the case of open access resources, free trade can increase the welfare of both countries.

Box 9: **The role of demand**

To better explain the role of demand, an example of two countries that produce manufactured goods and harvest a natural resource with labour is considered. The only difference between these two countries is their property rights regimes. The structure of demand is identical in both countries. We shall examine the resulting pattern of trade when they move from autarky to free trade. The result demonstrates that even though the property rights regime is critical in determining the pattern of trade and whether there are welfare gains from trade, the intensity of demand for the natural resource can dramatically alter the results.

One country has such weak property rights that it suffers from open access. Under open access, the relative supply curve (S_W) for the resource is backward bending, which means that as the price of the natural resource rises, the amount of harvest declines. The reason for this unconventional shape of the supply curve is that as the price of the natural resource rises, more labour is drawn to the sector. This increase in effort reduces the stock of the natural resource, leading to a decline in the productivity of workers. If the price rises sufficiently high enough, the loss in productivity can lead to a decrease instead of an increase in total harvest, despite the greater amount of labour being used in the sector.

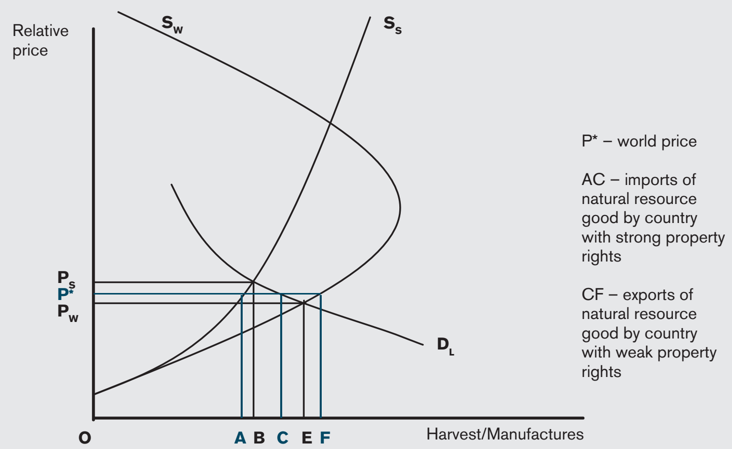
For the country with strong property rights, the relative supply curve for the resource will have the conventional shape – it is positively sloped (S_S). It corresponds to the marginal cost curve of harvesting the resource. This is because the resource owner (or the regulator) allows harvesting of the natural resource only up to the point where marginal revenue equals marginal cost. In effect, the externality posed by the individual harvester to others (his harvesting decreases the opportunity of others to catch more) is internalized by the single resource owner or the regulator. In resource systems with open access, the supply curve in contrast corresponds to the average cost curve since effort in harvesting continues until total revenue equals total cost.

What happens when both these countries open up to trade? Two scenarios can arise. In the first scenario, relative demand for the resource is low, so the demand curve intersects the upward sloping part of both these countries' supply curves. In the other scenario, demand for the resource is high, so the relative demand curve intersects the backward bending part of the supply curve of the country with weak property rights. The pattern and the benefits from trade will differ depending on the situation.

Relative demand for the resource is low (see Figure A)

Relative demand in both countries is given by D_L. In this case, the autarky price of the country with weak property rights is given by P_w with production at OE. The autarky price of the country with strong property rights is given by P_s with production at OB. When trade is opened up, the free trade price P^* will settle between the two autarky prices. The country with weak property rights will export the natural resource to the other country, depleting the stock of its resource. Its export (CF) is given by the horizontal distance at the world price between the demand curve and its supply curve. Correspondingly, the import (AC) of the country with strong property rights is equal to the distance between the demand curve and its supply curve. As a consequence of this pattern of trade, the country with poor property rights will have a lower steady state natural resource stock and suffer from a welfare loss. The country with strong property rights will reap the standard gains from trade since it suffers from no domestic distortion.

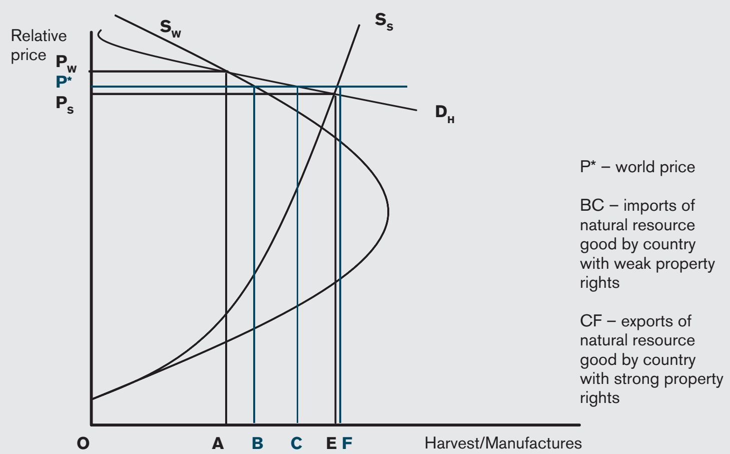
Figure A: **Free trade when relative demand for a natural resource is low**



Relative demand for the resource is high (see Figure B)

If in autarky there is a high relative demand for the natural resource (D_H) in both countries, the country with little or no property rights will be operating in the backward bending portion of its supply curve, with the average cost of harvesting the resource being very high. High demand leads to a lot of labour being devoted to the natural resource sector, causing the stock to run very low. Since the size of the stock affects labour productivity, harvest will be low in the country with poor property rights. The autarky price of the country with weak property rights will be P_w and production will be at OA. In the country with strong property rights, the autarky price is at P_s and production at OE. When trade is opened up, the country with strong property rights ends up exporting the natural resource (equal to CF) to the country with poor property rights. The country with strong property rights will reap the standard gains from trade since it suffers from no domestic distortion in the first place. The free trade stock of natural resources will be higher in the country with poor property rights than under autarky and it will also gain from trade.

Figure B: **Free trade when relative demand for a natural resource is high**



(d) Factor prices

According to the Heckscher-Ohlin theory, international trade leads to factor price equalization. In other words, trade in goods substitutes for the movement of the factors of production. In the literature on trade in renewable natural resources, the only factors of production are labour and the stock of natural resources. In almost all cases, the real wage of labour is the same across countries.

However, factor prices in the natural resources sector will not be equalized. Take the simplest example where countries differ only in property rights. In autarky, there will be rents from optimally using the resource in the country with strong property rights, whereas the rents will be driven down to zero in the country without property rights. With free trade, rents will continue to be zero in the country with open access whether it ends up importing or exporting the natural resource. If its trade partner has stronger property rights, rents will continue to be earned under free trade. The result obtained here – factor prices are not equalized by trade – should, perhaps, not come as a surprise given the existence of a market failure.

(e) How trade affects property rights

What about the case where the property rights regime is endogenous – i.e. where the ability of governments to enforce property rights is affected by trade opening and relative prices (Copeland and Taylor, 2009)? The answer to this question is a mixed one. The strength of a property rights regime depends on a variety of factors, including the ability to monitor and prevent cheating; the capacity to extract or harvest a resource; and the economic incentive to deplete a resource. An increase in resource prices as a result of free trade can affect each of these factors in different ways. For example, a higher price could increase incentives to extract more of a resource, but it could also reduce incentives to poach the resource if the penalty is to lose access to the now more valuable resource forever. Higher prices could encourage investments in resource extraction, but it could also enhance regulatory capacity, thus assisting the transition to more effective resource management.

The endogeneity of the property rights regime means that there could be a variety of outcomes from trade opening. In particular, resource-exporting countries could gain from free trade. For some economies, where the autarkic price of the resource was low to start with, the increase in relative price arising from free trade can lead to a transition to more effective management. These economies have enough enforcement capability so that rents are generated at a sufficiently high price for the natural resource. However, for some economies, it remains true that the move to free trade will lead to resource depletion and real welfare losses. These economies are those where the natural resource is slow to replenish itself, where economic agents have a strong preference for current consumption, over-harvesting is hard to detect, harvesting technology is more productive, and where a large number of agents have access to the resource.

Highlighting the variety of possible outcomes, Copeland and Taylor (2009) offer several examples where the opening of trade opportunities sometimes facilitated better management of natural resources and other times led to over-exploitation. One example of success is the geoduck[26] fishery in British Columbia, which was initially open access but became a well-managed fishery with individual harvest quotas primarily in response to export demand from Asia. One example of over-exploitation is the North American buffalo that was discussed earlier. Another example they cite is the opening of the Estonian coastal fishery to exporting in the 1990s, which contributed to the rapid depletion of fish stocks.

(f) Changes in population and technology

Does population growth lead automatically to increased pressure to circumvent property rights and exploit natural resources? A study of forest cover in India by Foster and Rosenzweig (2003) provides empirical evidence that population and economic growth can, under certain circumstances, actually encourage better resource management. Population growth has two contradictory effects: on the one hand, it raises harvesting capacity, which in turn makes it easier to deplete a given resource. On the other hand, it increases the domestic price of resource products, due to growth in demand, generating rents in that sector and reinforcing incentives to better regulate and manage the resource.

The key question is whether growing demand for the resource increases its price sufficiently to offset the increased capacity to harvest the resource. If the country experiencing population growth is small relative to global markets and cannot influence the world resource price, then the negative relationship between population size and resource stock will hold. However, if the country is large relative to the world economy – so that the population increase triggers a rise in the price of the natural resource – it is possible for resource management to improve.

Similarly, technological improvements can have a mixed impact on property rights enforcement and the depletion of natural resources. For example, improvements in surveillance technology can assist fishermen to better detect the location of fish, thereby putting more pressure on the resource; but they can also help regulators to better detect illegal fishing, which leads to better resource management.

4. Natural resources and the problem of environmental externalities

So far, two kinds of negative effects have been analysed in the context of exhaustible resources. The first is strictly related to the fact that some natural resources are finite. In such a situation, if either a producing firm or a social planner does not take this issue into account when deciding how much to extract today, consumption levels above the social optimum in the present will imply less consumption for future generations. The second effect is related to the open access problem of exhaustible resources, whereby the collective ownership of a resource might result in its overuse and depletion.

The use of exhaustible resources in production and consumption activities leads to a third kind of negative effect that manifests itself through changes to the environment. In the case of fossil fuels, for instance, oil or coal extraction causes acidification of the sea and produces atmospheric CO_2. In the case of forestry, excessive timber extraction leads to loss of natural habitat for plant and animal species due to declining soil fertility and changes in climate and biogeochemical cycles. Finally, in the case of fisheries, over-harvesting one species might have a negative impact on other species and hence on biodiversity.

This third type of effect – which economists define as environmental externalities – is the focus of this sub-section. An externality of an economic activity refers to its impact on a party that is not directly involved in such activity. In this case, prices do not reflect the full costs or benefits in production or consumption of a product or service. An example of environmental externalities is the fact that oil producers may not take into account the full costs that the extraction and use of this resource imposes (on future, as well as present, generations) through pollution. This implies that the price of oil will not reflect its environmental impact. Killing dolphins as a by-product of catching tuna is another example of environmental externalities. In this case, the market price of tuna does not take into account the negative effect of the tuna fishery on biodiversity.

This sub-section discusses the characteristics and types of environmental externalities generated by the extraction and use of exhaustible resources. The effects of trade on the environment will also be illustrated taking into account the interaction that environmental effects have with the other types of externalities previously discussed in this report.[27]

(a) Fossil fuels, pollution and trade

To understand the effects of the use of energy resources on the environment, it is useful to classify environmental externalities into two categories: flow and stock externalities.[28] Flow externalities represent the environmental damage caused by the current extraction or use of the resource. An example of flow externalities is air pollution generated by the use of energy in oil extraction or mining. Stock externalities arise when environmental damage is a function of cumulative emissions. Examples of stock externalities include the atmospheric accumulation of carbon dioxide and its effect on the global climate, contamination of ground water from oil or coal extraction that is only slowly reversed by natural processes, and irreversible damage to natural landscapes through strip mining.

A general conclusion of existing studies[29] on environmental externalities is that postponing resource extraction today – and thus reducing polluting emissions – is optimal. In the case of flow externalities, the fact that resources are exhaustible partially offsets the problem. Following the Hotelling rule,[30] a pattern of rising prices reflecting the increasing scarcity of finite fossil fuels implicitly addresses part or all of the environmental damage generated by the extraction of such resources. In addition, the market may react to price increases by developing alternative energy technologies which can also help to address the environmental damage caused by the current extraction or use of the resource.

In the case of stock externalities, the market-determined rate of depletion is too high. Studies such as Babu et al. (1997) show that a modified Hotelling rule, which incorporates costs related to damage flowing from accumulating pollution stocks, would slow down extraction today and hence would ensure a social optimum. While under the original Hotelling rule, an additional unit of resource will be conserved only if the resource price rises at a rate faster than the market rate of interest, under this new modified framework, an additional unit of resource would be conserved even if the equilibrium resource price rises at a slower pace than the interest rate. This comes from the fact that an increase in the consumption of resources today will increase the pollution stock tomorrow. In each subsequent period there will be an additional disutility (i.e. welfare loss) caused by higher pollution stock created in earlier periods. In these cases, an additional unit of resource would be conserved in the current period to prevent higher disutility in future periods even if the resource price is rising more slowly than the market rate of interest.

What is the relationship between trade in fossil fuels and environmental externalities? This question is partly answered by a series of models in which the presence of trade across countries is implicitly taken into account. In these studies, it is assumed that resources are consumed by all countries, both exporters and importers – a realistic assumption given that most non-renewable energy resources are unevenly distributed geographically (see Section B.1) and the global economy is highly dependent on fossil fuels.[31] Therefore, if the demand of non-producer countries coincides with their imports, the relationship between trade and environmental externalities will depend on a series of factors, discussed below, directly affecting the optimal rate of extraction or use of the resources.

Some of these factors may accelerate resource consumption compared with the social optimum and exacerbate the negative impact on the environment related directly to the extraction and use of fossil fuels. First, the presence of asymmetric information on resource availability can encourage both exporters and importers to behave strategically. For example, importers might have an incentive to announce the development of a backstop technology[32] to increase their bargaining power and to drive down resource costs, while exporters might be tempted to exaggerate existing resource stocks in order to delay the development of substitutes.[33] In both situations, the extraction rate of the resource will be faster than the social optimal rate, and environmental damage will increase. In the first case, exporters will react to the threat of a backstop technology by raising the extraction rate and lowering the resource price. In the second case, exporters will follow a faster extraction path that is consistent with the over-estimated resource stock, in order to lend credibility to their exaggerated claims about the extent of resource reserves.

Second, cost-reducing technologies tend to have a negative impact on resource prices, by decreasing the marginal costs of resource extraction. The overall effect on the rate of extraction of the resources and hence on environmental damage will depend on the trade-off between technological progress and resource exhaustibility. Studies by André and Smulders (2004), Farzin (1992) and Krautkraemer (1985) show that, in the short run, decreasing costs due to a technological advance tend to off-set increasing costs due to the rising in situ value of the resource. Price decreases will lead to higher consumption, and thus more pollution. In the long run, however, the rising value of the resource still in the ground will outweigh the decreasing costs of extraction, so prices will rise again. The pollution generated in the short run will persist over time, so even if the rate of resource extraction decreases in the future, the negative effect on the environment remains.

Third, the discovery of new resources can have an effect similar to that of cost-reducing technologies.[34] Because new discoveries generally mean that resource extraction becomes easier and cheaper, prices decline and consumption increases – with negative effects on the environment. In the long run, however, exploration opportunities will run into diminishing returns and resource prices will rise again.[35] The overall effect on the environment will depend on how long the additional pollution generated over the short term remains.

Lastly, as already discussed in Section C.4, property rights in certain natural resource sectors are not well-defined or protected. Consider a situation in which concession rights to exploit a resource are granted by a government that is either corrupt or weak. Faced with political uncertainty, resource owners have an incentive to speed up resource extraction above the social optimum level in order to lock in profits – which will in turn be detrimental to the environment.

On the other hand, new technologies can also help to limit the negative impact on the environment – as, for example, when carbon-reducing technology limits the CO_2 generated by resource extraction (Welsh and Stähler, 1990; Tahvonen, 1997; Grimaud et al., 2009). In other words, if an abatement technology exists, and if its cost is sufficiently low, then the optimal rate of resource extraction speeds up and environmental constraints are partially loosened – reducing the sacrifice of the current generation. In addition, if the abatement technology helps to reduce the impact on the environment caused by cumulative emissions , then in the long run total emissions will also decrease. An abatement technology can be thought as a “cleaner” way to extract polluting resources.[36]

The role for trade in this process is worth highlighting. When energy resources are highly substitutable and when their pollution content can be clearly differentiated, trade might help to mitigate some of the environmental externalities deriving from fossil fuel use. For example, countries using oil or coal as their principal source of energy could switch to imports of natural gas – the “cleanest” fossil fuel in terms of carbon dioxide emissions[37] – thereby slowing the accumulation of pollutants and doing less harm to the environment.

(b) Renewables, biodiversity and trade

Environmental externalities can also be the by-products of harvesting natural resources such as fish and forests. The following discussion focuses on effects of trade in exhaustible resources on biodiversity.

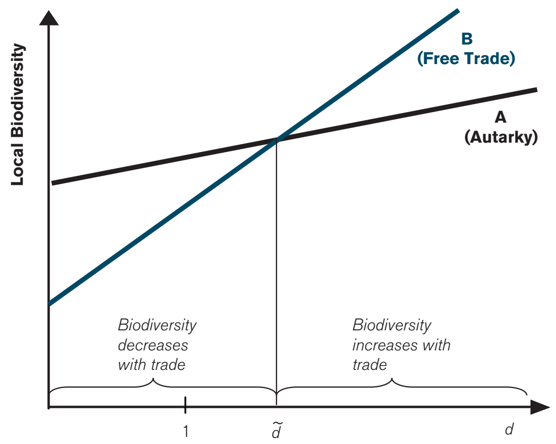
(i) Habitat destruction and trade

Because timber or agricultural production requires the use of land, habitat destruction can be a direct result of the expansion of such economic activities. Habitat destruction is a major cause of declining numbers of species – or reduced biodiversity – because it intensifies the competition among species for basic resources such as food and water and makes their survival more difficult.[38] Different studies[39] have analysed the effects of trade on production patterns across countries, on habitat destruction and on biodiversity. The general conclusion is that the classical gains from trade opening may no longer hold, once the negative impact related to declining biodiversity is taken into account.[40]

To understand the effects of trade in natural resources on biodiversity, consider two identical countries, a home country and a foreign country, which have the same fixed amount of two types of natural habitat, forest and grassland (Polasky et al., 2004). The number of different incumbent species represents the ecological productivity of each type of habitat. In addition, an increase in the size of the habitat will raise the number of species. However, marginal ecological productivity decreases with respect to habitat size.[41] In other words, the bigger the existent habitat the smaller the number of extra species that will be produced by a marginal increase in its size.

In the absence of trade, both countries produce timber and grain. For the production of timber, forestland has to be converted, whereas the production of grain requires the conversion of grassland. Once land is converted to productive use, it can no longer support native biological species. If the home country has a comparative advantage in producing timber and the foreign country in producing grain, then opening to trade will lead to an equilibrium in which the home country specializes in the production of timber and

Figure 15: **Biodiversity, ecological productivity and trade**



imports grain. The opposite will happen in the case of the foreign country. In addition, full specialization of production will lead to full specialization in natural habitat conservation. In the home country, for instance, specialization in timber production will make the country specialize in the conservation of grassland at the expense of forests. What then is the impact of trade opening on the countries' biodiversity?

The effect of trade on biodiversity will depend on the relationship between the ecological productivities of each habitat. To better understand this result, consider Figure 15 where the productivity in producing species of grassland relative to ecological productivity of forestland (d) in the home country is represented in the horizontal axis. Lines A and B illustrate respectively the local biodiversity of the domestic country in autarky and in free trade. These two lines cross each other at $\tilde{d} > 1$ because the marginal ecological production of each habitat is positive but decreasing in land size.

If both forest and grassland habitat have the same ecological productivity $(d = 1)$ and the home country starts specializing in the production of timber, the negative impact deriving from a reduction in forestland will be greater than the benefit of an increase in grassland. Trade in timber production will have a positive impact on the home country's biodiversity only if the ecological productivity of grassland relative to forestland is sufficiently large $(d > \tilde{d})$ to offset habitat damage caused by a decrease in forestland.

The impact of trade opening on global biodiversity will depend on the degree to which species are specific to a certain country.[42] More precisely, if each species is specific to each country, the effects of trade on aggregate biodiversity will coincide with those of country-specific biodiversity. If, however, prior to opening up to trade the same species live in all countries, trade can be beneficial even if both countries have the same ecological productivity. In this last case, trade opening will lead to a local decline of species in the specializing sector but also to an increase of species in the importing sector. Since each country specializes in a different product, the overlap of species will be reduced (species that existed in multiple countries exist now in only one country), but worldwide biodiversity will increase.[43]

(ii) Open access, biological interaction across species and trade

Studies looking at the relationship between trade, open access problems and biodiversity typically focus on fisheries.[44] They suggest that outcomes depend to a significant extent on the nature of the biological relationship between the traded species (see Table 6). These relationships can be classified into the following three types: a positive or symbiotic relationship (where the stocks of the two species are mutually beneficial); a negative relationship (where the stock of one species [e.g., fish parasites] reduces the productivity or survival possibilities of another species); and an asymmetric relationship (where the first species serves as prey for the second species).

Consider a situation in which there is no trade between two countries and there is a trans-boundary common pool problem, as both countries fish in the same water (Fischer and Mirman, 1996). In addition, assume that both countries catch and consume two types of species – and hence are concerned about the biological cross-effects between them. Under this scenario, the problem of over-harvesting will be mitigated if the biological relationship across species is positive and the rate of reproduction of one species is higher than the cross-effect between the two species. Since harvesting the first species will reduce the stock and hence, the total consumption of the second one, then an optimal solution will be to reduce the total harvesting of the first species. When the biological relationship between species is negative, the problem of over-harvesting is more acute. More precisely, the fact that a reduction in one species implies an increase in the stock of the other species itself leads to over-harvesting. Finally, in the asymmetric case, there will be even greater harvesting of the

Table 6: **The effects of trade on the common access problem (small country case)**

SPECIES RELATIONSHIP	AUTARKY	TRADE
Positive relationship between species	*Under-harvesting*	*Over-harvesting*
Negative relationship between species	*Over-harvesting*	*Under-harvesting*
Prey-Predator relationship	Predator: *Over-harvesting* Prey: *Under-harvesting*	Predator: *Under-harvesting* Prey: *Over-harvesting*

predator fish while over-harvesting of its prey will be reduced.

Consider now a situation in which the two countries can trade and each of them specializes in catching one of the species and imports the other (Datta and Mirman, 1999). If countries take international prices as given,[45] the fact that a country is depleting its own resource will not be reflected in the other resource's price. More precisely, agents will not care about the biological cross-effect they will produce when harvesting and therefore, in the presence of a positive biological relationship between species, countries will harvest more than what would be globally optimal. In contrast, if the biological relationship between species is negative, there will be under-harvesting. In this case, both countries could harvest more because a reduction in one species is beneficial for the other and vice versa.

As the number of countries exploiting each species rises and trade increases, there is no clear cut conclusion as to whether the common pool problem worsens or lessens in the presence of biological interactions across species. Whether there is over- or under-harvesting will depend on a variety of factors such as the number of countries, the price effect, consumer preferences and the type of biological relationship across species.

5. The natural resource curse

A distinctive feature of many natural resource endowments is that they are not widely dispersed among countries, but rather are geographically concentrated in a few fixed locations. This helps to explain why natural resources often represent a disproportionate share of economic production and exports in certain countries.[46] Oil- and mineral-rich economies, for instance, frequently exhibit very high ratios of natural resources to merchandise exports and to GDP. It is often claimed that such resource abundance does not always lead to sustained economic growth and development for the countries concerned, and that in fact it can have the opposite effect – a phenomenon termed the "resource curse hypothesis" or the "paradox of plenty". The following section surveys the theoretical and empirical literature on the mechanisms through which the natural resource curse might operate, and tries to draw some broad conclusions about its relevance.

(a) The "Dutch disease"

An increase in revenues from natural resources can de-industrialize a nation's economy by raising the real exchange rate and thus rendering the manufacturing sector less competitive. This tendency towards de-industrialization has been called the "Dutch disease".[47]

De-industrialization following a natural resources boom can be of two types: direct and indirect.[48] Direct de-industrialization, or "factor movement effect", refers to the shift in production towards the natural resources sector. In an economy with three sectors, natural resources, manufacturing and a sector producing non-traded goods, the booming natural resources sector will take factor inputs (including labour) away from the rest of the economy. This creates an excess demand for non-tradable goods, thus the relative price of non-traded goods increases. If the economy is small, with the price of traded goods determined on world markets, this is equivalent to an appreciation of the real exchange rate, which makes the manufacturing sector less competitive.

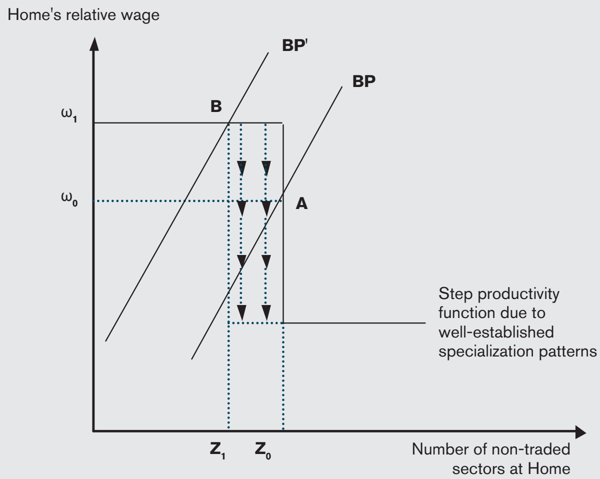
Indirect de-industrialization, or the "spending effect", refers to the fact that additional spending caused by the increase in natural resource revenues results in a further appreciation of the real exchange rate. Namely, the extra revenues originating from the resource exports boom raise domestic income as well as internal demand for all goods. Since the price of tradables is set on world markets, the additional spending boosts the relative price of non-tradables – resulting in a further appreciation of the real exchange rate.[49]

In an economy marked by perfect competition in goods and factor markets and constant returns to scale (the so-called "neoclassical economy"), the decline in the traded sector implied by the Dutch disease should not be viewed as a problem, let alone a "curse", because it is optimal for countries to specialize in those sectors where they have a comparative advantage. The Dutch disease becomes a problem if the shrinking manufacturing sector is characterized by positive spillovers on the rest of the economy (van Wijnbergen, 1984; Sachs and Warner, 1995). Krugman (1987) considers the case in which in the manufacturing sector productivity increases with production (learning-by-doing). In the short run, a natural resource boom raises the wage in the booming home economy, relative to the foreign economy. Because the home country's increase in relative wage worsens the competitiveness of the manufacturing sector, the production of some goods in this sector moves abroad, and the benefit of learning-by-doing is foregone. The home country's relative productivity worsens in those goods over time, so when the resource boom ends, market share and relative wage will have been permanently reduced (see Box 10 for a more analytical discussion of the Krugman model).

Box 10: **Krugman's model of Dutch disease with learning-by-doing**

Krugman (1987) extends the Ricardian model with a continuum of goods of Dornbusch et al. (1977), by assuming that unit labour requirements evolve over time. Respectively, the unit labour requirement in sector z at time t is equal to a(z,t) at home and to a*(z,t) abroad. As shown in the figure below, the schedule of relative productivities A(z,t) = a(z,t)/a*(z,t) is a step function, because specialization patterns become entrenched with learning-by-doing. The equilibrium in the model is obtained at the intersection between the relative productivity function A(z,t) and the balance of payments equilibrium condition, BP. A natural resources boom, modelled as a pure transfer T from the foreign country to the home country, shifts the BP curve inward (equilibrium moves from A to B). Therefore, in the short run, the transfer (resources boom) raises the relative wage in the recipient home country (booming economy) from ω_0 to ω_1. The home country has a comparative advantage in tradables, z, as long as its relative wage is lower than its relative productivity. With a large transfer, the increase in ω is enough to offset the home country's productivity advantage, thus some sectors move abroad and z falls from z_0 to z_1.

Because of foregone learning-by-doing, the shift in production from the home to the foreign country implies declining relative home productivity in the sectors between z_0 and z_1 over time. Graphically, the A(z,t) function develops a middle step, which deepens over time (downward-pointing arrows in the figure). In the long run, if the transfer is of sufficiently long duration, those sectors remain abroad even when the transfer ends. In other words, manufacturing export sectors – hit by the loss of competitiveness induced by a natural resources boom – are unable to recover when natural resources run out. Long-run welfare in the home country is permanently depressed.

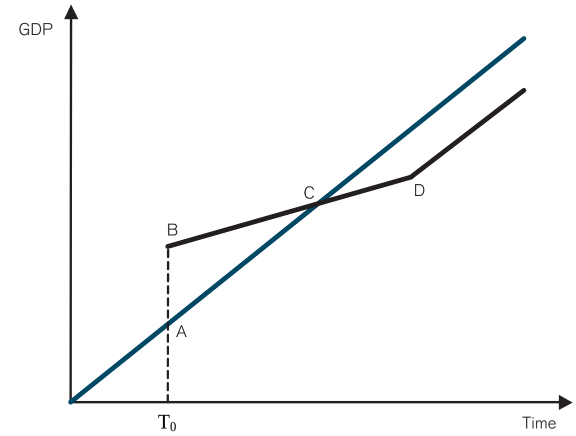


If the manufacturing traded sector is the "engine" of economic growth (Lewis, 1954) for a country, because of production externalities, increasing returns to scale or learning by doing, a contraction in its output induced by the Dutch disease is likely to reduce its growth rate, with permanent negative effects on income levels. This point is illustrated in Figure 16.[50] Suppose there are two identical economies, both initially growing at the same rate, so that GDP proceeds along the straight line between point O and point A. Now suppose that one economy has a resources boom at time T_0 so that GDP immediately rises to point B. In the short run, this economy will have a higher GDP. However, if the resources boom causes a decline in growth because it drags resources from the growth-producing sector, GDP in the booming economy will eventually fall below GDP in the other economy. Even if the booming economy eventually reverts to its pre-boom growth rate, it may still have a permanently lower level of GDP than the other economy.[51]

The Dutch disease, and its potential negative effects on income levels, can occur only if the real exchange rate appreciates following a natural resources boom. However, there might be a number of reasons why the real exchange rate depreciates, rather than appreciates, under such circumstances. For instance, the real exchange rate might depreciate if the non-traded sector is more capital intensive than the traded sector, and labour is needed to secure the windfall natural resource revenues (Corden and Neary, 1982).[52] Real depreciation can also occur in the presence of learning-by-doing and inter-sectoral learning spillovers. In a model incorporating these two features, Torvik (2001) shows that a foreign exchange gift results in a real exchange rate depreciation in the long run, due to a shift in the steady-state relative productivity between the traded and the non-traded sector. In contrast to standard models of the Dutch disease, production and productivity in both sectors may go up or down.

Allowing for real exchange rate depreciation reverts the theoretical underpinning of the Dutch disease. Since we lack empirical studies on whether natural resource booms are associated with real exchange rate appreciation or depreciation, the link between such booms and de-industrialization becomes more tenuous. The macroeconomic situation is also likely to affect the

Figure 16: **A permanent reduction in GDP following a resource boom**



likelihood of de-industrialization following a natural resources boom. If the economy is at full employment, the aggregate response to a spending boom normally runs into diminishing returns, reducing the value of spending. This is because spending translates into higher prices and crowds out alternative activities, rather than drawing more resources into use. Higher domestic prices show up as a real appreciation of the currency, the basis for Dutch disease effects. However, if there are under-employed resources ("Keynesian economy"), this crowding-out effect need not materialize. In this case, extra demand can be met by drawing under-employed resources into use. Due to multiplier effects, the final increase in income is larger than the increase in demand. Income will continue to rise until the increase in income equals the extra foreign exchange supplied by the windfall divided by the marginal propensity to import (Collier et al., 2009).[53]

The theoretical predictions of the Dutch disease have been tested both in simulations and econometric analyses, which indicate that the phenomenon is empirically relevant. Several studies have measured the net effect of expansion in the energy sector on the output of other tradable sectors. In a simulation model of a multi-sector open economy, Bruno and Sachs (1982) show that this effect is negative, with its size depending on government budget policies concerning the redistribution of oil-tax revenues to the private sector. Other studies use an econometric approach to examine the impact of energy booms on the manufacturing sector. In a cross-country study comprising Norway, the Netherlands, and the United Kingdom, Hutchison (1994) finds little empirical evidence supporting the Dutch disease hypothesis that a booming energy sector will draw resources out of the manufacturing sectors (Norway being the only exception, and the adverse effects were short-term). However, Brunstad and Dyrstad (1992) explain that Hutchison's analysis is most likely to capture effects coming through the spending channel. In a study using Norwegian data, they find that manufacturing industries have been affected by the energy boom through the resources movement effect rather than through the spending effect.[54]

Other studies have looked at the effects of resource abundance on the growth of the manufacturing sector, using data from many countries. In a cross-section of 52 countries, Sachs and Warner (1995) show evidence that resource-intensive economies did indeed have slower growth in manufacturing exports, after holding constant the initial share of manufacturing exports in total exports.[55] The most direct test of Dutch disease effects is provided by the gravity model of Stijns (2003), who estimates the impact of a natural resources boom on real manufacturing exports. The author finds the Dutch disease hypothesis to be empirically relevant. The price-led energy boom tends to systematically hurt energy exporters' real manufacturing trade. A 1 per cent increase in a country's net energy exports and a 1 per cent increase in the world energy price are associated with a reduction in the energy exporting country's real manufacturing trade of 0.47 per cent and 0.08 per cent, respectively.

(b) Weakening of institutions

It would seem that the resource curse operates in some political contexts, but not in others. And that it is strongly associated with certain natural resource sectors, but leaves others largely immune. In attempting to explain these differences, theories stressing political economy considerations, such as rent-seeking, have gained prominence (Deacon and Mueller, 2004).

Institutions, such as legal systems, have been shown to be crucial determinants of growth and development (Acemoglu et al. (2001) and Rodrik et al. (2004)). Resource dominance will therefore have an indirect effect on economic growth through institutions – beyond any direct effect through de-industrialization. It can either hamper growth in the presence of weak institutions, or it can itself contribute to institutional weakening.

First, resource abundance hampers economic growth in the presence of weak institutions, such as poorly defined property rights, poorly functioning legal systems, weak rule of law and autocracy. For instance, Bulte and Damania (2008) claim that under autocratic leadership, policies are guided by the desire to extract bribes from firms rather than by welfare considerations.[56] When a resources boom occurs, the value of government support for the resources sector increases, thereby raising the incentives to bribe the incumbent. Sectoral support policies become more biased towards the resources industry at the expense of manufacturing. If the latter sector benefits from network effects and other spillovers, the fact that it is receiving less than a social optimum level of support works to the detriment of economic growth.

Second, when natural resource booms occur, there might be a tendency for institutions to weaken because of rent-seeking. On the demand side, agents have an incentive to engage in rent-seeking to appropriate some of the resource income available in the economy (so-called "voracity effect", described by Tornell and Lane, 1999). On the supply side, a natural resource boom can stimulate corruption among bureaucrats and politicians who often allocate the rents deriving from the exploitation and exportation of natural resources. When agents switch from profit-making economic activities to rent-seeking activities, it generates negative self-reinforcing effects that more than offset the extra income from resource revenues, thus lowering social welfare.

In their pioneering empirical study, Sachs and Warner (1995) argue that resource-rich economies generally grow at a slower pace. Countries with high ratios of natural resource exports to GDP in 1970 were found to have low average annual rates of growth in real GDP over the two subsequent decades.[57] This negative correlation remains significant after taking into account other traditional determinants of growth, such as initial income level, trade openness, investment rates, and institutional quality (see also Torvik, 2009). However, this broad conclusion has been contested by a number of follow-up studies. For instance, Papyrakis and Gerlagh (2004) find that while resource wealth (measured by the share of mineral production in GDP) seems to impede economic growth, the coefficient on this measure of resource abundance becomes insignificant – and even turns positive – after taking into account corruption, investment, openness, terms of trade and schooling.

Sala-i-Martin and Subramanian (2003) use a two-stage empirical strategy to demonstrate that natural resources have strong, robust and negative effects on long-run growth, but only indirectly via their detrimental impact on political and social institutions.[58] Once institutions are taken into account in their growth regressions, natural resources either have little remaining harmful effects or even beneficial effects. However, this conclusion is disputed by Alexeev and Conrad (2009), who claim that the statistically significant negative coefficients of the resources (oil) wealth in the institutional quality regressions presented in Sala-i-Martin and Subramanian (2003) are largely a consequence of the positive link between GDP and oil, rather than some substantive negative influence of the oil endowment on institutions.

Finally, some studies test the hypothesis that resource abundance negatively affects economic growth in the presence of growth-adverse institutions, by including interaction effects between resource abundance and institutional quality. Mehlum et al. (2006) find a positive and significant interaction, which implies that in countries with institutions of sufficient quality there is no resource curse. This result, too, has been contested by Alexeev and Conrad (2009). They claim that there is no negative indirect effect of resource abundance on the quality of institutions when per capita GDP, rather than average growth rates over a given period of time, is used as a dependent variable.[59] They conclude that countries with good institutions that would have been rich anyway tend to benefit less from the positive effect of natural resources, while countries with weak institutions that would have been poor in the absence of substantial natural endowment reap relatively large benefits from their natural resources wealth.

(c) Conflict

The most severe manifestation of the resource curse is the onset, or continuation, of civil conflict. Two widely cited explanations of how natural resources may cause conflicts are the so-called "looting" (or "greed") mechanism and the "grievance" mechanism (Collier and Hoeffler, 2004; Ross, 2004). According to the first explanation, primary commodities represent profitable opportunities for emerging rebel groups, who can raise money either by extracting and selling the commodities directly, or by extorting money from others who do. By enabling nascent rebel organizations to fund their start-up costs, natural resources increase the probability of civil wars. In the grievance model, resource extraction creates grievances among the local people who feel they are being insufficiently compensated for land expropriation, environmental degradation, inadequate job opportunities, and the social disruptions caused by labour migration. These grievances in turn lead to civil wars.

The link between resource abundance and conflict is particularly strong for easily appropriable "point-source" natural resources - that is, resources that occur naturally in dense concentrations, such as oil and minerals, rather than forestry which is more diffused throughout the economy. These resources induce intensified rent-seeking because revenues and rents are easily appropriable.[60] Moreover, as claimed by Deacon and Mueller (2004), countries with abundant point resources will tend to evolve governance structures based on centralized agglomeration of power directed at controlling those resources, and their histories will be replete with struggles to retain that control.[61]

The empirical literature on conflict has investigated the role of ethnic divisions in the build up of civil wars (Montalvo and Reynal-Querol, 2005). Natural resources are often unevenly distributed within countries: think for instance of the oil-abundant Niger Delta region in Nigeria, or minerals in the Congo's south-eastern Katanga region. Morelli and Rohner (2009) develop a theoretical model where civil conflict arises from the interconnection between uneven distribution of natural resources within a country and conflicts of interest that assume an ethnic character. Consider that there are two ethnic groups, group j that controls the government and group i that is dominated. Groups i and j have to agree on any of four potential outcomes, two peaceful ones (peace or accepted secession) and two conflictual ones (secessionist or centrist conflict).[62] Preferences over these possible outcomes are essentially determined by the surplus-sharing agreement – that is, the share of total surplus of natural resources production accruing to the disadvantaged group i.

If there were only one form of conflict (centrist conflict), bargaining and transfer could always assure peace, as the destruction of war creates some peace dividend to be distributed. In the presence of multiple forms of conflict, however, it is not always possible to find an agreement that assures peace, because there might be a war dividend that makes bargaining fail despite the availability of credible transfers. Bargaining failure is most likely under two conditions. The first of these is when the amount of natural resources extracted in the region more densely populated with the dominated group i (denoted r_1) is large. The second condition is when the winning probability of group i in secessionist conflict, relative to the winning probability of group i in centrist conflict (p_S/p_C), is large. Intuitively, for low r_1 or p_S/p_C, secessionist conflict becomes less attractive, and the situation would be similar to when there is only one form of salient threat (i.e. centrist conflict).

The empirical evidence regarding natural resources and civil conflict is mixed, and sometimes contradictory. On the one hand, Collier and Hoeffler (2004) find that countries relying heavily on exports of primary commodities face higher risk of civil war than resource-poor countries, and that this is true for primary commodities of all types – including oil, minerals, and agricultural goods. On the other hand, subsequent studies have challenged the claim that natural resources invite civil conflict. Brunnschweiler and Bulte (2008) find that civil war creates dependence on primary sector exports, but the reverse is not true, and that resource abundance is associated with a reduced probability of war onset. Others have noticed that the relation between natural resource abundance and war onset depends on the type of natural resources involved.

De Soysa (2002) and Fearon and Laitin (2003) suggest that resource abundance being associated with a greater likelihood of war only applies to oil. In contrast, Humphreys (2005) points out that it is dependence on agricultural production that matters. Using newspaper reports of violent skirmishes in 950 Colombian municipalities between 1988 and 2005, Dube and Vargas (2006) find that violence was negatively correlated with coffee prices in locations where a large fraction of land area was under coffee cultivation. In other words, more violence occurred when coffee prices were low. The opposite was true for oil: it was higher prices that intensified conflict in areas with productive oil wells or pipelines.[63]

The studies focusing on conflict duration do not reach consensus either. Doyle and Sambanis (2000) demonstrate that civil wars are harder to end when they occur in countries that depend on primary commodity exports. However, Collier et al. (2004) show that primary commodities have no influence on the duration of conflicts. The most solid pattern identified by this literature is that “lootable” commodities that are prone to contraband, such as gemstones and drugs, are linked to the duration of conflict. For instance, Fearon (2004) finds that gems and drugs tend to make wars last longer. [64]

(d) Is the natural resource curse empirically relevant?

As already noted, the claim that resource-rich economies generally grow at a slower pace has been challenged and qualified in empirical work following Sachs and Warner (1995). A number of recent studies have further questioned the validity of previous empirical tests of the resource curse hypothesis, based on doubts about the measures of resource abundance, the failure to take into account additional variables that are linked with resource abundance in cross-country regressions and the failure to assess the impact of resource depletion over the sample period.

The first critique concerns how sensitive the resource curse is to the measurement of resource abundance. Lederman and Maloney (2007) use net natural resource exports per worker to measure resource abundance, finding that it has a positive effect on growth. Any negative impact on growth relates to the high export concentration that is typical of resource exporters. Rambaldi et al. (2006) and Brunnschweiler and Bulte (2008), on the other hand, argue in favour of alternative measures of resource abundance to replace the commonly used output- and export-related variables which are prone to endogeneity problems and can lead to biased estimates. Endogeneity is an econometric problem that may emerge, for example, because there is a two-way relationship between a country’s economic growth and its natural resource exports. They suggest, respectively, using (non-renewable) resource rents per capita and total natural capital, or mineral resource assets, in US dollars per capita. With such measures, the negative relationship between resource abundance and economic growth no longer holds. Rambaldi et al. (2006) do not find either direct or indirect evidence of a resource curse. Brunnschweiler and Bulte (2008) show that resource abundance is significantly associated with both economic growth and institutional quality but, contrary to the predictions of the resource curse hypothesis, greater resource abundance leads to better institutions and faster growth.[65]

The second critique concerns the issue of omitted variables. Manzano and Rigobon (2007) find that the negative influence of resource production on economic growth is confirmed in the cross-sectional framework of Sachs and Warner (1995), but that the result disappears in fixed effects panel regressions. This indicates the omission of one or more variables correlated with resource abundance, which biases the regression coefficients in the cross-sectional work. Manzano and Rigobon (2007) argue that the omitted variable is debt-to-GNP ratio, which is positively correlated with resource abundance. When debt-to-GNP ratio is included in the cross-sectional estimates, the resource curse disappears. The message, as emphasized by Davis (2008), is that a large pre-existing public debt and inappropriate risk management, rather than resource abundance, are the problem.

Finally, Davis (2006) and Alexeev and Conrad (2009) notice that, even if the existing empirical literature is correct, it is possible that a large resource endowment results in high growth rates in the early stages of extraction and slower growth rates as depletion sets in.[66] Davis (2006) shows that after taking changes in the level of resource production over the sample period into account, the resource curse disappears: economies with shrinking minerals-sector output saw slower growth, while those with increasing mineral output grew faster. This observation may also help to explain why some studies find evidence of a resource curse, while others do not. Measuring the rate of minerals output only at the start of the growth period would tend to identify mineral producing countries that are subject to depletion, not those that are subject to slow growth. Likewise, measuring the rate of minerals output at the end of the period would tend to identify as mineral producing countries those whose mineral output has grown over the sample period. This is why papers that measure mineral production (or reserves) near the end of the sample period find no evidence to support the resource curse (Brunnschweiler and Bulte (2008) is an example), while Sachs and Warner (1995) and others who measure mineral production at the start of the sample period find the opposite.

In order to take into account the effect of resource depletion, Alexeev and Conrad (2009) measure long-term growth via GDP per capita levels rather than by calculating growth rates over a given period of time. Their conclusion is that countries endowed with oil resources tend to have relatively high levels of GDP, suggesting that natural resources enhance long-term growth.

In conclusion, the empirical literature does not reach a consensus on whether natural resource abundance leads to slower or faster growth. What does seem clear is that the literature has progressively moved away from the initial consensus on the existence of a "resource curse" and towards a more benign view of the impact of natural resource abundance on economic growth (see example in Box 11).

Box 11: **How Botswana escaped the resource curse**

The mineral sector in Botswana – largely dominated by the diamond industry and, to a smaller extent, by copper and nickel mining – has been a major generator of economic production, government revenues and export earnings. The mineral shares of total GDP, government revenues and export earnings increased from almost zero in 1966 (year of the first diamond mine discovery) to around 50 per cent, 60 per cent and 90 per cent, respectively, in 1989 (Sarraf and Jiwanji, 2001). Mineral development has led to an extraordinary economic record. GDP grew at an annual average of 13.9 per cent in the period 1965-80, 11.3 per cent in the period 1980-89, and 4.75 per cent in the period 1990-98 (Sarraf and Jiwanji, 2001).

The reason underlying the country's success is the way in which the mineral boom of the 1970s was handled. Botswana beat the natural resources curse thanks to sound macroeconomic policies and prudent management of windfall gains (Modise, 1999). The government essentially decided not to increase public spending whenever mineral revenue increased, but to base expenditure levels during boom periods on longer-term expectations of export earnings. This is relatively unusual behaviour in a booming economy, where the tendency is to over-spend when times are good (see Section D.5). Instead, any excess revenue was used to accumulate foreign exchange reserves, and build up government savings and budget surpluses. These were drawn on in leaner years, thus avoiding drastic expenditure cuts and/or surges in public borrowing and external debt when export receipts started to decline. Such policy conduct was a strong stabilizing force; it helped reduce inflationary pressures, keep healthy public finances, and set the economy on a sustainable growth path.

Botswana also escaped the "Dutch disease" thanks to the accumulation of international reserves, which sterilized the monetary impact of the mineral export surge and prevented the national currency from strengthening. This control over the nominal exchange rate allowed other tradable goods (namely manufacturers) to maintain competitiveness on world markets, and hence encouraged economic diversification. Preserving jobs (or promoting the creation of new ones) in non-mineral sectors, including services, proved highly beneficial, given that the labour requirements of the mineral sector are limited by the capital-intensive nature of mining operations (Sarraf and Jiwanji, 2001). Therefore, thanks to a combination of mineral wealth and high-quality political institutions and macroeconomic management, Botswana achieved output and employment growth.

6. Natural resources and price volatility

Section B.1 (e) noted that an important characteristic of natural resources is their price volatility over certain periods of time. In the past, these price swings were principally supply-driven, often linked to geopolitical events – an example being the oil price shocks of the early and late 1970s. More recently, demand-driven factors, such as the rapid income growth of key emerging markets, have also influenced resource prices (Kilian, 2009b). This is particularly true for the most recent commodity boom – one of the largest and most long-lasting in history, covering a broad range of commodities – where no single and straightforward cause exists for the price acceleration and subsequent decline. This is an important development, since the economic implications of volatility may differ depending on the underlying factors driving the sudden swings in commodity prices. Box 12 discusses the above argument for the case of oil.

From 2003 to early 2008, the prices of a wide range of commodities rose sharply and over a sustained period of time. By mid-2008, energy prices were 320 per cent higher in dollar terms than in January 2003, and mining products were 296 per cent higher. By November 2008, however, all commodity prices were falling, with the dollar price of crude oil having fallen more than 60 per cent (World Bank, 2009). This considerable volatility in commodity prices can be seen in Figure 17 which depicts price trends for major commodity groups.

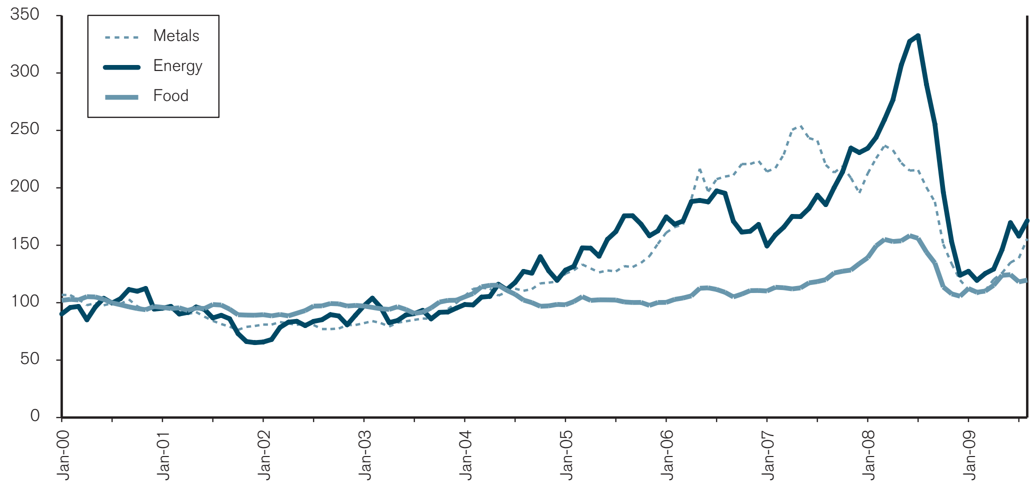
Box 12: **Economic implications of the changing nature of oil price shocks**

The large increases in the price of oil triggered by the Arab-Israeli war in 1973, and the Iranian revolution of 1979, respectively, have been conventionally associated with low growth, high unemployment and high inflation in most industrialized economies. Since the late 1990s, however, the global economy has experienced two periods of oil price volatility of a magnitude comparable with those of the 1970s but, in contrast with the latter episodes, GDP growth and inflation have remained relatively stable in much of the industrialized world.

It has been argued that improvements in monetary policy, the lack of concurrent adverse shocks, a smaller share of oil in production and more flexible labour markets all played an important role in determining the mild effects on inflation and economic activity of the recent increase in the price of oil (Blanchard and Gali, 2007). However, the literature has not found a consensus on this point.

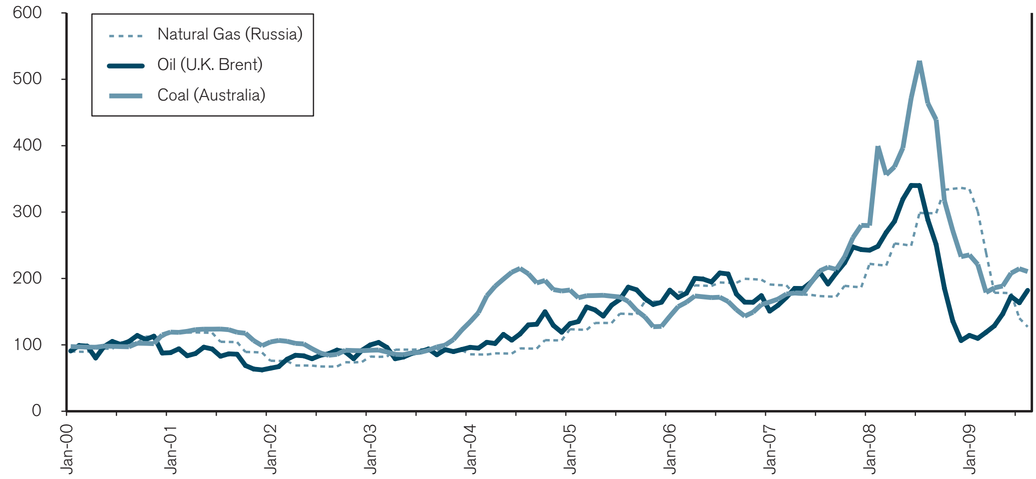
Edelstein and Kilian (2009) and Kilian and Lewis (2009) argue that there is no compelling evidence that the evolution of the share of energy in consumer expenditures or in value added, a decline in the volatility or magnitude of energy price shocks, reduced real-wage rigidities, or improved monetary policy responses can explain the declining importance of oil price volatility. A possible explanation of this phenomenon that has been advanced relates to changes in the nature of the oil price fluctuations. For instance, the recent surge in the price of oil did not cause a major recession even after years of rising oil prices partly because, unlike in the past, much of that increase was driven by unexpected strong global demand for industrial commodities (Hamilton, 2009a).[67] Such global demand shocks have both a stimulating and an adverse effect on economic growth, with the latter working through higher oil and commodity prices. Empirical estimates for the US economy suggest that, in the short run, the positive effects are strong enough to sustain growth, as global commodity prices are slow to respond and the world economy is booming. US real GDP gradually declines subsequently, as energy price increases gain momentum and the economic stimulus from higher global demand weakens (Kilian, 2009c). A more complete discussion on the causes of recent commodity price volatility is provided below.

Figure 17: **Real prices of selected commodities, Jan. 2000-Aug. 09** (Index Average of Year 2000 = 100)



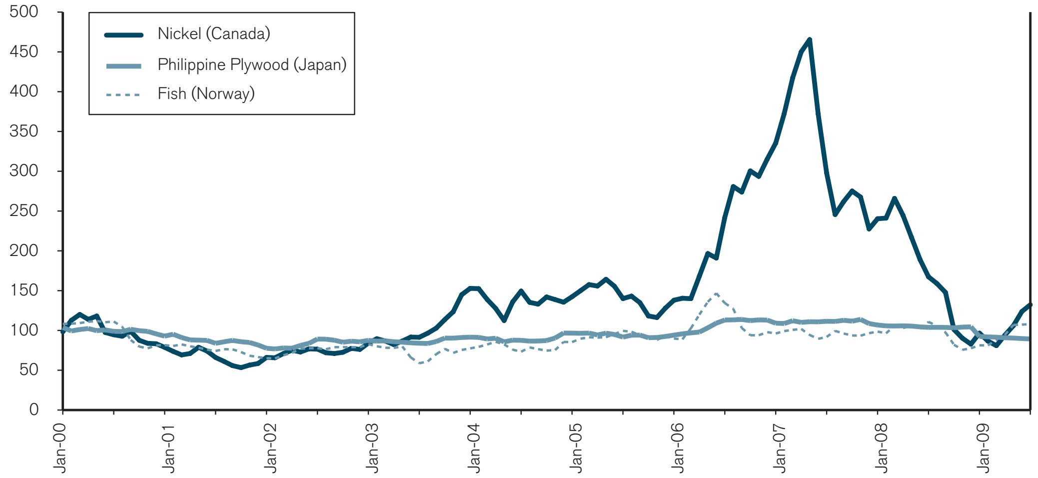
Note: Prices are deflated by world CPI, average of year 2000=100. In this database, the category of "metals" includes minerals such as iron ore.
Source: IMF, International Financial Statistics.

Figure 18: **Real prices of energy commodities: oil, natural gas and coal, Jan. 2000-Aug. 09**
(Index, Average of Year 2000 = 100)



Note: Prices are deflated by world CPI, average of year 2000=100.
Source: IMF, International Financial Statistics.

Figure 19: **Real prices of nickel, plywood and fish, Jan. 2000-July 09**
(Index, Average of Year 2000 = 100)



Note: Prices are deflated by world CPI, average of year 2000=100.
Source: IMF, International Financial Statistics.

Figure 18 depicts a similar boom and bust cycle for different energy commodities, the category characterized by the highest price volatility. Figure 19 does the same for a metal commodity and contrasts this with the markets for plywood (forestry product) and fish. The dramatic acceleration of prices from 2006 onwards for a range of commodities created the suspicion that, in addition to fundamental economic factors, prices were being pushed up by a "speculative bubble" (Talley and Meyer, 2008).

This sub-section reviews possible explanations for the observed commodity price volatility in recent times, starting with the controversial debate on the role of "speculators" (i.e. non-traditional investors betting on price movements with no interest in physically acquiring the underlying commodity) in driving prices. Thereafter, the role of fundamental economic factors in explaining the recent period of commodity price volatility will be discussed. The sub-section concludes with a brief review of some of the consequences of commodity price volatility in both importing and exporting countries.

(a) Speculation in commodity markets

(i) Speculation: definition

"Speculation" is often referred to as the assumption of the risk of loss in return for the uncertain possibility of a reward (Robles et al., 2009). It usually entails the purchase of an asset for resale rather than for use, or the temporary sale of a borrowed asset with the intention of repurchase at a later date in the hope of making a profit from a price change in the intervening period. In other words, speculators can be on the long or short side of a transaction, where the former refers to the purchase of an asset with the expectation that it will rise in value and the latter implies the sale of a borrowed asset with the expectation that it will fall in value. Speculation may be driven by expectations of future demand and supply, which represent market fundamentals, or by self-fulfilling expectations that result in a speculative bubble.

(ii) Speculation: theory

In a seminal article, Fama (1970) presented the case for the "Efficient Market Hypothesis" (EMH), which argues that prices are always consistent with market fundamentals. The underlying logic is that, assuming rational expectations and perfect information (e.g. in the stock market), prices fully reflect all known information, thereby implying that tomorrow's price change will reflect only tomorrow's news and will be independent of the price changes today. However, news is, by definition, unpredictable and, thus, resulting price changes must also be unpredictable.[68] In this context, prices may change in response to any news about future demand or supply because it alters the expectations of market participants. Such "speculative" shocks have their roots, however, in market fundamentals and are consistent with the EMH. This is because forward-looking expectations of traders are incorporated into their actions today and hence are reflected in current prices.

Over time, the intellectual dominance of the EMH has diminished, largely due to the emergence of "behavioural economics", which argues that psychological elements make prices at least partly predictable (DeLong et al., 1990; Shleifer and Vishny, 1997; Abreu and Brunnermeier, 2003; Miller, 1997; Harrison and Kreps, 1978; Scheinkman and Xiong, 2003). It emphasizes a "feedback", "bandwagon" or "herding" effect that is indicative of the "irrational exuberance" (Shiller, 2000) of market participants, which leads to self-fulfilling speculative bubbles.[69] This divergence of prices from their fundamental values may be explained as follows. When prices go up, it generates word-of-mouth enthusiasm and heightens expectations for further price increases. In turn, this increases investor demand, and thus generates another round of price increases. If this feedback is not interrupted over a period of time, it creates a speculative bubble, in which high expectations for further price increases support high current prices.

The high prices, however, are ultimately not sustainable, since they are high only because of expectations of further price increases. Hence, the boom is followed by a bust (Stiglitz, 1990; Brunnermeier, 2008). Anecdotal evidence of such self-fulfilling speculative bubbles includes the rise and crash of the stock market during the 1980s, the dot-com bubble in the late 1990s and exchange rate overshooting in the Republic of Korea and Thailand in 1997 (Flood and Hodrick, 1990).

(iii) Speculation in commodity markets: the role of non-traditional investors

The speculation debate in commodity markets centres on the role of non-traditional investors, such as index funds,[70] hedge funds and others who have no interest in buying or selling the actual underlying commodity (Masters, 2008; Robles et al., 2009). Since they do not take or make physical delivery of the commodity, these non-traditional investors participate in futures markets, but not in spot markets, where physical delivery of a product is immediately arranged. They engage in futures trade to make a profit from the successful anticipation of price movements (United Nations Conference on Trade and Development (UNCTAD), 2001). For example, a speculator might purchase a futures contract today believing that once it expires in six months, it will sell for a higher price. A speculator thereby enables hedging by taking on risk that other market participants want to shed (see Box 13).

The increasing importance of these non-traditional investors in commodity markets during the last few years is attributable to the following. First, natural resource commodities have emerged as a new "asset class", enabling investors to better diversify their overall portfolio. This is because commodities are negatively correlated with other asset classes, such as stocks and bonds, but positively correlated with inflation (Gorton and Rouwenhorst, 2004).[71] Second, low nominal interest rates coupled with inflation can lead to the availability of "cheaper-than-free money",[72] thus enabling investors to

Box 13: Investment in commodity futures: providing insurance

Taking the example of the live cattle market, Greer (2005) describes the crucial role that futures investors can play in providing price protection. Assuming that a producer has cattle coming to the market six months from now, he/she will market the cattle regardless of price. Obviously, the producer will need to cover its unit costs of production if it wishes to stay in business. If there is a common belief (assuming markets are efficient) that price will be 10 per cent higher than cost at that future point in time, it would be advantageous for the producer to lock in this price with the client at the present day. However, the processor (buyer) may not be amenable to such a deal. If the buyer sells a certain amount of processed meat to a steak house at market price, the same price protection as the cattle producer is not needed.

In fact, if the processor were to lock in the input cost without having a guaranteed sales price of the final product, the processor would be increasing its business risk. By contrast, a futures investor may be willing to take on the producer price risk, albeit at a discount ("insurance premium"). By the same token, the producer is now sure to sell its cattle with a benefit, although at a slightly lower price than currently expected. Both parties "win" (unlike in financial futures markets, which are often considered to be "zero-sum"), since the objectives of producers in the commodity futures market are different from investor objectives.

Besides the risk premium, another component of total return is rather specific to investment in commodity futures and has to do with commodity consumption relative to inventories. Staying with the example above, assume that as the delivery date approaches, cattle supply turns out to be lower than expected (e.g. owing to disease). The processor may wish to ensure that its contractual commitment to supply a certain amount of meat to the steak house is honoured and that all processing capacities are fully employed. It may therefore decide to buy the imminent futures contract, which allows it to take delivery at several designated locations and to gain certainty to have sufficient animals to process. At the same time, if the anticipated cattle shortage further drives up prices, the processor can use the proceeds from its long futures position to help finance the purchase of the more expensive cattle.

Hence, the price of the nearby future contract may go up if processors are ready to pay for the "convenience" of knowing that they will have enough cattle to process. Depending on the "precariousness" and volatility of the market, this "convenience" yield can be a quite important source of returns to investors (Lewis, 2005). This has been the case, for instance, in the oil market, where shutting down and restarting refinery capacity is costly and demand is inelastic (i.e. demand is not linked to price fluctuations). In other markets, such as gold, where inventories are large compared with consumption, the convenience yield has been low. However, more recently, especially due to demand from emerging economies, certain industrial non-ferrous metals have seen positive convenience yields due to strong declines in inventories.

increase their demand for commodities through a simple income effect (Larson, 2008). Third, the development of commodity-based instruments, such as index certificates, has made investment in commodities more accessible to a larger number of people (Greer, 2005).

In sum, the increasing importance of commodity-related financial markets creates new opportunities as well as challenges. On the one hand, financial markets can enhance the liquidity of commodity trades, help price discovery (i.e. to determine market prices) and contribute to the efficient allocation of risk. On the other hand, the simultaneous increase in prices and speculator interest in commodity futures markets can potentially magnify the impact of supply-demand imbalances on prices. Some have argued that the high activity of non-traditional investors has increased price volatility and pushed prices above levels justified by market fundamentals. These arguments, counterarguments and the related empirical evidence are reviewed below.

(iv) Role of speculation in the recent commodity price boom and bust

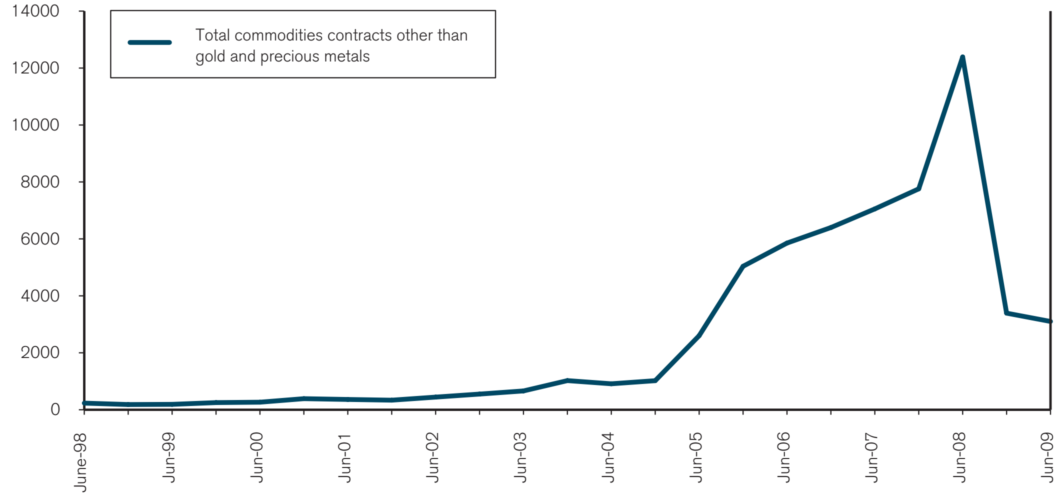
The main thrust of the argument that commodity markets have been characterized by speculation is that large amounts of money from non-traditional financial investors, who take long positions in the futures market (in both organized exchanges and over-the-counter (OTC) markets), have resulted in a significant upward pressure on prices.[73] This may be indicative of the "feedback" or "herding" effect mentioned above, whereby futures prices may have been high only because these investors believed that prices would be higher at a later date, when "fundamental" factors did not seem to justify such expectations, i.e. speculative bubbles. However, it may also reflect the expectations of participants that are based on economic fundamentals. For instance, suppose markets expect the occurrence of a natural disaster or a certain geopolitical event which would adversely affect production capacity, creating concerns about future shortages of a resource. This could lead to a genuine desire to hold increased inventories, thereby pushing up prices (Costello, 2008). In this context, Kilian (2009c) argues that Iraq's invasion of Kuwait in 1990 is a case in point.

Kilian argues that crude oil prices saw a significant rise in the mid-1990s not merely because of decline in production in Iraq and Kuwait, but also because of concerns that Iraq might also invade Saudi Arabia, causing a much larger oil supply disruption. Empirically, it is difficult to distinguish between the two sources of speculation. But given that non-traditional investors view commodities as a financial investment and are not necessarily well-acquainted with the workings of the commodity business, their behaviour in these markets may be associated with a "herding" effect.

As evidence, proponents of the speculation hypothesis highlight the increased involvement of non-traditional investors in commodity markets. For example, Büyükşahin et al. (2008) report that from 2004 to 2008, the market share of financial traders in the oil futures market increased from 33 to 50 per cent, while the share of traditional traders, such as oil producers, refiners and wholesalers, fell from 31 to 15 per cent.[74] In addition, as shown in Figure 20 for a sample of advanced countries, the number of commodity contracts traded in OTC markets increased in the first half of 2008. In view of the fact that these are largely unregulated markets, the argument has been made that this rise in activity may be indicative of the role of speculation in the recent commodity price hike (Masters, 2008).

The empirical literature examining more specifically the relationship between speculative money flows and commodity prices is rather thin. While Robles et al. (2009) show that some indicators of speculative activity can help forecast spot price movements, other studies merely present anecdotal evidence or simple correlations between futures investment and commodity prices (Masters, 2008). Some studies seem to work under the assumption that speculators have an undesirable impact on market prices. For instance, for a range of commodity markets, Chevillon and Rifflart (2009), Cifarelli and Paladino (2009) and Sornette et al. (2009) claim that because changes in supply and demand fundamentals

Figure 20: **Notional amounts outstanding of OTC commodity derivatives, June 1998-June 2009** (Billion dollars)



Note: Countries covered are Belgium, Canada, France, Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, the UK and the United States.
Source: Bank for International Settlements, Quarterly Review.

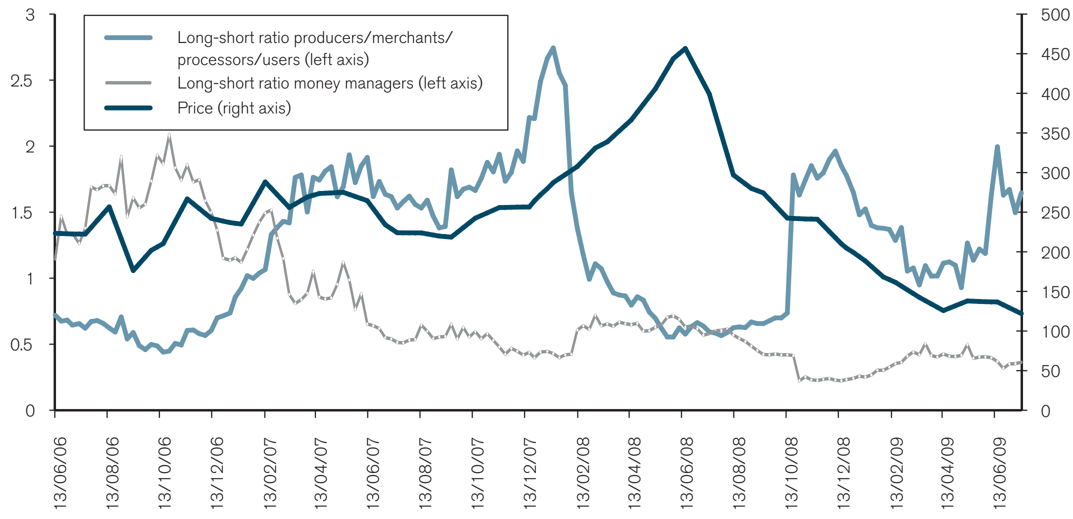
cannot fully explain the recent drastic increase in prices, large flows of money, typically in long positions, must have pushed commodities to extremely high levels. This leads to another section of the literature which argues that the body of evidence described above ignores the inherent complexity of price determination in commodity markets and is often not based on rigorous statistical methods.

(v) Not speculation after all?

A range of authors disagree with the proposition that "speculators" played a major role in the recent commodity boom and bust. First and foremost, it is argued that money flows into futures markets should not be equated with demand for physical commodities because futures contracts are settled for cash (Hieronymus, 1977). These are zero-sum markets where buying by non-traditional investors is "new demand" just as the corresponding selling by hedgers is "new supply". Second, the rigid classification of traditional investors as risk-avoiders and non-traditional investors as risk-seekers or speculators may not necessarily be true. This is because many traditional traders speculate (Stultz, 1996) and many non-traditional investors sell short in anticipation of a future decline in equilibrium prices (Frankel, 2008).

Third, the participation of financial traders is limited to futures markets, which consist of purely financial transactions. Even if their purchase of a futures contract leads to a future price increase, its eventual sale negates their existing long position and their account is closed. These financial traders do not take or make physical deliveries and hence do not participate in the spot market

Figure 21: **Natural gas – long-short positions by class of investor, June 2006-July 09** (Ratio and dollars)



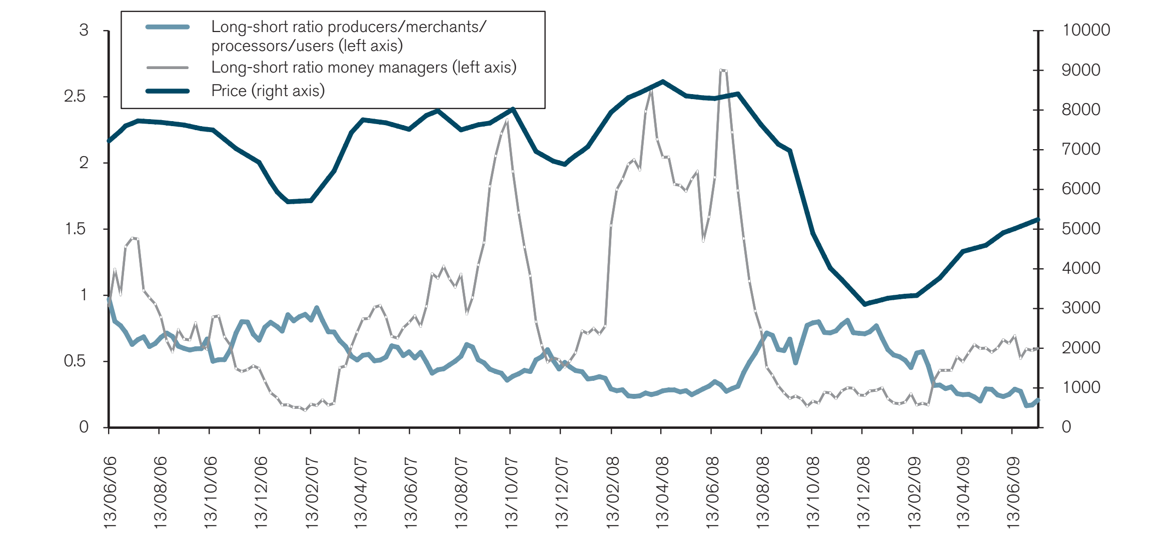
Note: left y-axis – long and short positions in contract units of 10 billion British terminal units.
Right y-axis – nominal spot price, henry hub, louisiana, united states of america.
Money managers comprise commodity trading advisors (CTAs), index funds and hedge funds.
Source: United States Commodity Futures Trading Commission and IMF, International Financial Statistics.

where long-term equilibrium prices are determined (Smith, 2009; Garbade and Silber, 1983). Speculative trading may raise spot prices only if it induces participants in the physical market to hold commodities off the market and build up inventories ("hoarding").

Anecdotal evidence suggests that the current situation in commodity markets is inconsistent with the arguments of a speculative bubble. First, the increase in "long" speculation has not been excessive when compared with the increase in "short" hedging (Irwin et al., 2009). Second, speculators have often been net "short" sellers rather than "long" buyers. Hence, they may have delayed or moderated the price increases, rather than initiating or adding to them (World Bank, 2009). Both these facts are reflected in Figure 21, which correlates the ratio of long-to-short positions, by category of participant, to prices for natural gas at the New York Mercantile Exchange (NYMEX). It shows that, in the early half of 2008, while prices increased, this ratio was fairly flat for money managers (investment funds). This lack of correlation, however, is not as evident in certain commodity markets. Figure 22 shows the case for copper.

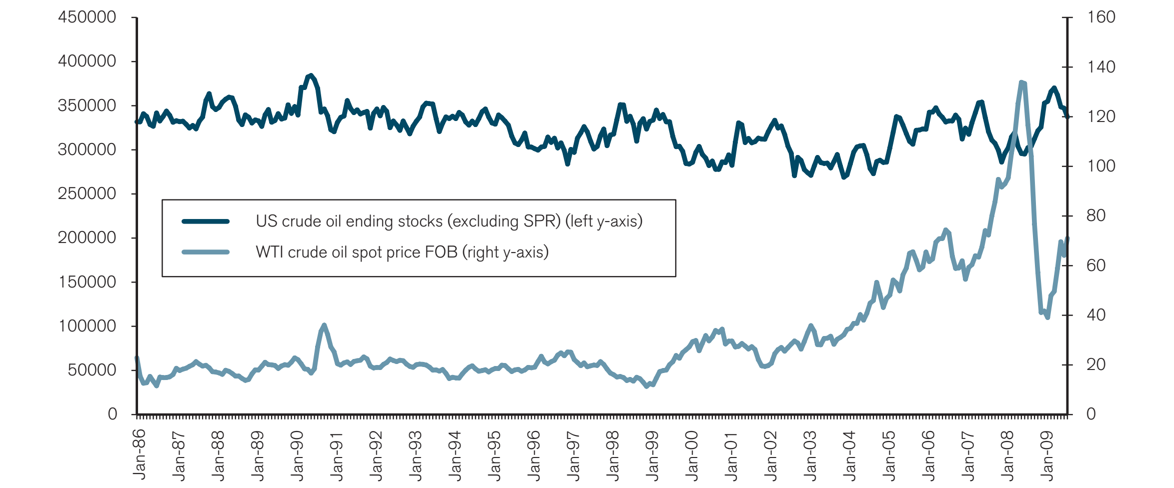
Third, Irwin and Good (2009a) show that from 2006 to 2008, high prices have been observed for commodities with no futures markets. Furthermore, spectacular price increases were concentrated in commodity markets with little index fund participation, whereas modest or no price increases were seen in markets with the highest concentration of index fund positions (Irwin et al., 2009). Fourth, data suggest that inventories of, for instance, crude oil have stayed relatively flat and have fallen sharply for a range of other commodities from 2005 to 2008 (Smith, 2009; Krugman, 2008). Figure 23, which depicts the case of United States oil stocks, shows that there is no clear evidence of "hoarding", especially when prices increased steeply in 2008.

Figure 22: **Copper – long-short positions by class of investor, June 2006-Aug. 09** (Ratio and dollars)



Note: Left y-axis – Long and short positions in contract units of 25000 Pounds, NYMEX, United States of America.
Right y-axis – Nominal spot price in U.S.$ per metric ton, London Metal Exchange, U.K. (original monthly data linearly interpolated to get weekly data).
Source: United States Commodity Futures Trading Commission and IMF, International Financial Statistics.

Figure 23: **United States monthly oil stocks and oil price, Jan. 1986-Aug. 2009**
(Ten million barrels and dollars per barrel)



Note: WTI refers to the West Texas Intermediate Exchange.
Source: US Energy Information Agency.

A number of recent studies use a variety of sophisticated econometric methods to make a more formal assessment of the role of speculation in the recent commodity price boom (Sanders et al., 2004; Sanders et al., 2008; Sanders et al., 2009; Sanders and Irwin, 2009; Bryant et al., 2006). For instance, using publicly available data on positions of different trader groups in the United States, Sanders et al. (2008) find that measures of position change have a statistically significant effect on commodity futures prices in only five out of 30 cases. In contrast, reversing the causality test indicates statistical significance in all but three cases.

In sum, empirical evidence points towards a range of fundamental market factors as the major explanation for the dramatic increase in commodity prices in recent years, with less emphasis on speculative forces. This is analysed in the section to follow.

(b) Role of economic fundamentals in explaining commodity price volatility

Commodity prices during the recent boom may have been affected by a variety of fundamental market forces on the demand and supply side (Irwin and Good, 2009b; Hamilton, 2008; Headey and Fan, 2008). These include buoyant global economic growth, limits to increasing production capacity in the short-run, relative prices of substitutes and government policies. Again, much of the literature is on the oil market, which will be used on several occasions for illustrative purposes, but is applicable to other natural resources as well (Davis, 2009).

(i) Demand

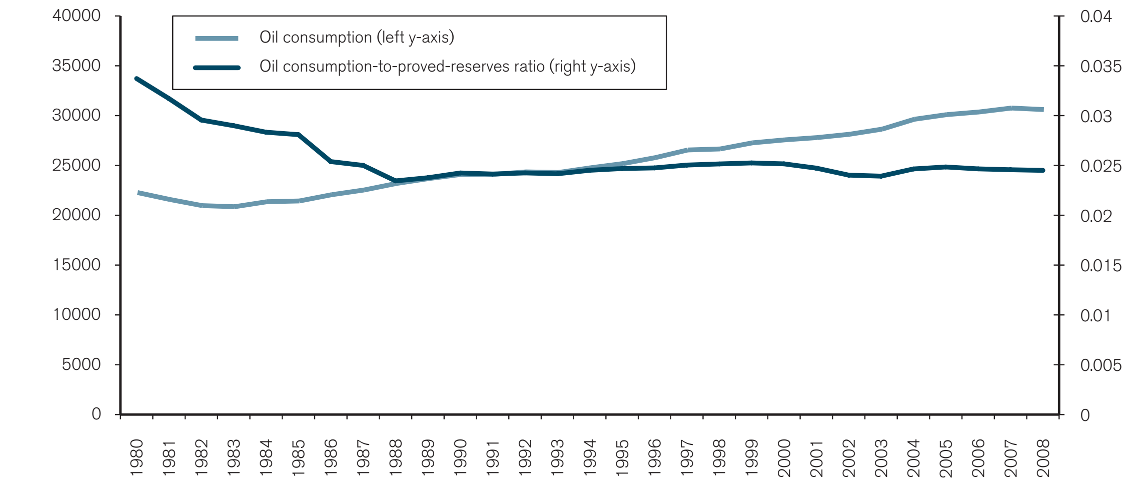
Annual increases in the global consumption of major commodities from 2002 to 2007 were larger than they had been during the 1980s and 1990s (Helbling et al., 2008). Strong income growth in some major emerging economies has been a major contributing factor in this regard (Cheung and Morin, 2007). For example, during this period, demand from China, India and the Middle East accounted for more than half of the growth in oil consumption and China alone accounted for about 90 per cent of the increase in the world consumption of copper (Helbling et al., 2008). The latter may be attributable to rapid industrialization and urbanization characterized by a high metal-intensity of growth in the early stages of development (World Bank, 2009). On the other hand, the sharp decline in commodity prices since mid-2008 may be explained, in part, by a contraction of world demand owing to slower GDP growth during the recession. Figure 24 reveals an increasing world demand for oil, which Kilian (2009c) argues is a result of unexpected growth in emerging Asian economies together with solid growth in the OECD.

Figure 24 shows that while world consumption of oil increased from 1980 to 2008, world proved reserves of the commodity also increased. A falling consumption-to-proved reserves ratio until the late 1980s implies that reserves increased faster than consumption until that point in time. Thereafter, the ratio remains about constant as the increase in proved reserves is more or less in tandem with rising consumption. The less pronounced increase in proved reserves may be attributable to the technological challenges involved in exploiting non-conventional sites such as deep sea fields or oil sands.

(ii) Limits to increasing supply capacity in the short-run

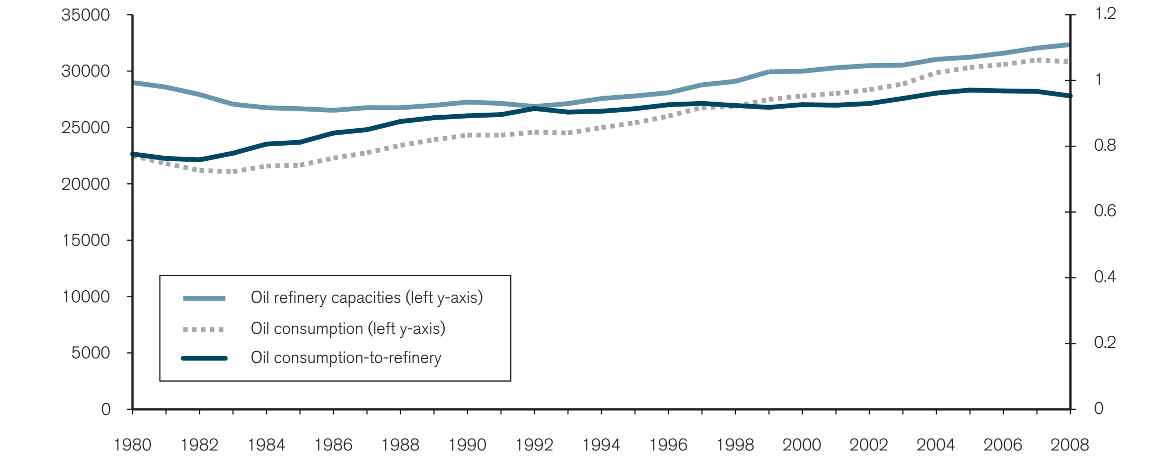
Despite the steady increase in proved reserves of energy commodities such as oil and natural gas, extraction, production and refinery capacity have not followed suit, leading to a subdued supply response in the short-run, as witnessed during the recent commodity boom. One of the reasons for the lack of investment in new capacity was the build-up of idle capacity in several resource sectors during the 1980s and 1990s, which in turn was attributable to the following. First, for oil, global

Figure 24: **World oil consumption and consumption-to-proved-reserves ratio, 1980-2008**
(Million barrels and ratio)



Note: Proved reserves are the portion of known deposits that can be economically extracted at prevailing prices using available technology.
Source: British Petroleum Statistical Review of World Energy 2009.

Figure 25: **World oil refinery capacities, consumption and consumption-to-refinery capacities ratio, 1980-2008** (Capacity and consumption in thousand barrels per day)



Source: British Petroleum: Statistical Review of World Energy 2009.

demand fell sharply following the 1980s oil shock. Second, for oil, metals and minerals, demand among former Soviet bloc countries fell by almost 50 per cent during the 1990s, as these countries began to allocate resources in a more market-oriented way (World Bank, 2009; Borensztein and Reinhart, 1994).

Given the above, excess demand was accommodated by a run-down of inventories, and prices increased when all idle capacity was finally absorbed in the first half of the early 2000s (Helbling et al., 2008). Figure 25 shows that in the case of oil, for example, refinery capacity declined or remained relatively constant from 1980 to the early 1990s, after which it saw an upward trend. Despite this, we can see that the consumption-to-refinery ratio remained relatively constant from the early 1990s to 2006, implying that consumption grew at approximately the same rate. This reinforces a section of the literature which argues that high and sustained oil prices after 2003 are primarily driven by demand, especially because the ability to increase production or refining in the near future is limited (Kilian, 2009c).

Higher oil prices do not stimulate global production in the near future because the short-run price elasticity of oil supply is near zero (i.e. oil supply is not very responsive to price changes in the short-run) (Kilian, 2009b). At the same time, in the case of oil, there is no evidence to suggest that, on the supply side, the Organization of the Petroleum-Exporting Countries (OPEC) attempted to act as a cartel and hold back production from 2004 to 2008 (Smith, 2009; Kilian, 2009c). On the flipside, high commodity prices during the boom are likely to have stimulated investment in production capacity, thereby alleviating supply-side constraints to an extent. Together with contracting world demand, this may have been a contributing factor for the bust following the boom.

(iii) Linkages across commodities

Linkages across different commodity markets have played a role in recent price increases. For instance, higher oil prices have had an important effect on other commodities not only through the traditional cost-push mechanism, but also through substitution effects, e.g. natural rubber prices have risen because its substitute is petroleum-based synthetic rubber and coal prices have risen because of utilities switching from more expensive oil to coal for power generation (Helbling et al., 2008).

Furthermore, high oil prices have led to a surge in the use of bio-fuels as a supplement to transportation fuels, thereby diverting a significant share of feedstock, especially corn, rapeseed and sugar from food supplies in major producing countries (Helbling et al., 2008). This has naturally pushed up the prices of some major food crops. Hence, this inter-linkage may explain part of the correlation between energy price and food price developments, as presented in Figure 17. On the other hand, the bust which followed the recent boom in oil markets may have contributed to the overall decline in commodity prices by reducing the demand for bio-fuels. In the long-run, the linkage between energy and food markets may weaken with the development of alternative sources of energy, e.g. solar power (World Bank, 2009).

(iv) Effective dollar depreciation

Several resource commodities are priced in US dollars and hence movements in the dollar exchange rate may affect demand and supply. The effective dollar depreciation seen over the past few years has made commodities less expensive for consumers outside the dollar area, thereby increasing the demand for those commodities (Helbling et al., 2008). On the supply side, the declining profits in local currency for producers outside the dollar area have put price pressures on the same commodities (Helbling et al., 2008).

Consider a foreign firm that produces a commodity which is priced in dollars. A depreciating dollar implies that producers will increase prices as they demand more dollars from each sale as compensation. Investors anticipate this and start putting money into these commodities, thereby driving prices higher. Hence, it may be argued that investors have been pouring resources into the commodities market to protect themselves against the depreciating dollar. On the flipside, with the onset of the financial crisis, this source of the commodities boom reversed and possibly contributed to the sharp price decline in mid-2008. It was attributable to increased investment in "less-risky" US treasury bills, thereby resulting in an appreciation of the US dollar vis-à-vis the currencies of most developing countries.

In a speech in March 2009 on the reform of the international monetary system, the Governor of the People's Bank of China proposed a more prominent role of the IMF's Special Drawing Rights (SDR) as an international reserve currency (Zhou, 2009). One of the objectives of this proposal is to address the volatility of commodity prices denominated in a national currency (generally US dollars). Specifically, Zhou (2009) argued that promoting the role of the SDR in international trade and commodity pricing could effectively reduce price fluctuation relative to a system where commodities are denominated in a single national currency.[75]

(c) Consequences of price volatility in importing and exporting countries

In view of the dominance of natural resources in the economy of many exporters and their strategic importance in the production of importing countries, commodity price volatility has often been of widespread political concern. Below, the effects of volatility in both exporting and importing countries are discussed in turn.

(i) Effects of volatility on natural resource exporters

Hausmann and Rigobon (2003) show that in an economy where an extractive resource (say, oil) represents about 20 per cent of GDP, a shock to the price of oil has a significant effect on GDP.[76] This empirical finding is indicative of the fact that price volatility has long been considered a problem for exporters that mainly rely on natural resource exports as a source of revenues. The literature attributes this to the following reasons: risk-averse consumers, fiscal implications, and volatility as a channel of the natural resources curse.

Risk-averse consumers

If consumers are risk-averse, volatility may have an adverse effect in exporting countries, because consumers are willing to spend some of their income on hedging against the risk of large swings in resource prices. Hausmann and Rigobon (2003) hold that this negative impact on economic growth is likely to be small in the absence of further disruptions to the economy.[77]

Fiscal implications

Focusing on oil exporters, Kilian (2009c) notes that falling prices can put serious strains on their fiscal balances and ability to borrow from abroad. In contrast, rising prices can typically be accommodated easily, by financing imports from the rest of the world and recycling some of the additional oil revenues into the global financial system.[78] However, a sudden increase in natural resources wealth may induce policy-makers to increase public spending in a way that is impossible to finance once the natural resource revenues dry up.

For instance, during the episodes of high oil prices in the 1970s, banks identified oil producers as creditworthy borrowers, extending them large loans. These loans, however, financed higher imports and higher domestic consumption levels, and proved to be a miscalculation because oil prices did not remain high forever. This led these oil-rich countries into default, threatening the stability of the international financial system (Kilian, 2009c). Similarly, after the discovery of natural gas in the Netherlands and the global oil price shocks during the 1970s and 1980s, successive Dutch governments responded with large public spending increases. It then took two decades to put the Dutch welfare state on a financially sustainable footing again (Van der Ploeg, 2006).

Volatility and the natural resources curse

In a framework proposed by Hausmann and Rigobon (2003), volatility arises from an interaction between specialization and financial market imperfections, and can be a source of the resources curse.[79] They consider an economy that is specialized in the resources (non-tradable) sector, which fully employs a fixed quantity of labour. The sector's supply can be expanded only by increasing the level of capital per worker. Given fixed labour, this implies that the productivity of each additional unit of capital would be falling. Capital is, however, required to get the international rate of return, hence the price of non-tradables must increase. This would lead to an appreciation of the real exchange rate. At the same time, an increase in the price of non-tradables will cause expenditure-switching away from the now more expensive non-tradables into tradables, raising the price of tradables. This would lead to a depreciation of the real exchange rate.

Unlike a diversified economy which will have a constant real exchange rate because it can absorb demand shocks with intersectoral reallocation of labour, a specialized economy will experience a volatile real exchange rate. In addition, if this specialized economy is marked by financial market imperfections, interest rates are likely to be sensitive to the volatility in the real exchange rate. According to Hausmann and Rigobon (2003), under reasonable assumptions the interest rate is bound to go up as the volatility of the real exchange rate increases, making it even more difficult for the economy to attract investment into the "dynamic" tradable sector. The authors note that this volatility-induced channel of the resources curse is more compatible with GDP and price developments experienced in certain resource-rich economies than competing explanations, such as the Dutch disease or rent-seeking approaches discussed earlier.

There is a vast literature on the negative effects of volatility (in commodity prices, terms of trade, unanticipated output growth or government spending) on growth performance.[80] A recent study (Van der Ploeg and Poelhekke, 2009) tests for the direct effects of natural resource abundance on economic growth and its indirect effects through volatility of unanticipated output growth.[81] The authors find that the resource curse exists only for countries affected by high volatility. Although the level of resource abundance may have a positive direct effect on growth, this effect can be swamped by the indirect negative effect resulting from volatility. Therefore, natural resources abundance may be a curse for countries affected by high volatility (e.g. Zambia and some other African countries), but a boon for those less affected (e.g. Norway and the Asian Tiger economies). In light of these results, a reduction of volatility may be desirable from the point of view of resource exporters.

(ii) Effects of volatility on natural resource importers

Price volatility is as important a concern for natural resource importers as it is for exporters. This can, in principle, be the case for any commodity imported in large quantities, and has especially been the case for oil, due to its eminent role as an input in production in virtually every sector. Since the 1970s, and at least until recently, macroeconomists have viewed changes in the real price of oil as an important source of economic fluctuations (so-called "business cycle"), as well as a paradigm of a global shock, likely to negatively affect many importing economies simultaneously.[82] The following is an analysis of the various transmission mechanisms of real oil price shocks on oil-importing economies, and how their relative magnitude has evolved over time.

Supply-side channel

An increase in the real price of oil from the point of view of an oil-importing economy is a terms-of-trade shock (i.e. an increase in the price of imports relative to exports). Such terms-of-trade shocks traditionally have been thought to matter for the oil-importing economy through their effects on production decisions, with oil being treated as an intermediate input in domestic production. A widely addressed but still unresolved issue is whether, and to what extent, oil price changes can explain real GDP fluctuations, based on this intermediate input cost or supply channel. Some argue that oil price fluctuations are not a major determinant of the business cycle (e.g. Backus and Crucini, 2000) while others argue that oil price shocks exert major effects on real GDP (e.g. Rotemberg and Woodford, 1996; Atkeson and Kehoe, 1999; Finn, 2000). However, the latter studies do not appear to have much empirical support.

Demand-side channel

According to another branch of the literature, a key mechanism whereby oil price fluctuations affect the economy is through a reduction in consumers' and firms' spending. This view is consistent with evidence from recent surveys (Hamilton, 2009b) and industry sources (Lee and Ni, 2002). Energy price changes have direct effects on private expenditure.[83] The effects on consumption and investment expenditures all imply a reduction in aggregate demand in response to unanticipated energy price increases. Recent empirical evidence confirms the predominance of such demand effects over the supply-side channel.[84]

Monetary-policy channel

Monetary policy is another channel that may amplify the effects of oil price fluctuations on the real economy. A central bank, when faced with potential or actual inflationary pressures triggered by oil price shocks, may respond by raising interest rates, thereby exacerbating the drop in real output associated with rising energy prices. The extent to which monetary policy contributes to the drop in real output following a rise in the price of oil has been estimated using a range of econometric models (Bernanke et al., 1997; Hamilton and Herrera, 2004; Leduc and Sill, 2004; Carlstrom and Fuerst, 2006). However, the various estimates obtained from these studies are sensitive to model specification, and thus the reliability of results remains questionable. In a recent study, Kilian and Lewis (2009) find no evidence that monetary policy responses to oil price shocks were to blame for the recessions of the 1970s and early 1980s.

(d) Summary and policy linkages

This sub-section has presented the causes and consequences of price volatility in natural resources, focussing particularly on the most recent commodity boom and bust.

Commodity price changes are influenced by a multitude of factors that work simultaneously. Economic fundamentals, such as a levelling out of production capacities, linkages across commodities, effective dollar depreciation and strong demand from emerging economies, are important factors in explaining the recent commodities boom. Similarly, market fundamentals such as slower income growth due to the recent financial crisis and the build-up of supply capacity following the long boom period are important factors in explaining the sharp decline in commodity prices in mid-2008. In the short-run, this sharp decline may also have been attributable to forward-looking expectations of slower growth as underlying supply and demand conditions are unlikely to have changed instantaneously. In the long-run, the extent to which demand slows down and supply catches up with demand will depend on population growth, global economic growth, trade policies, technological change, and other factors such as climate change (World Bank, 2009).

From the recent commodity boom and bust cycle, it has also become clear that excessive price volatility in energy and other essential natural resources can generate important transfers of income within and between countries. Impacts have been particularly large among poor urban populations and in countries with fewer domestic alternatives to those energy and food items whose prices increased the most (World Bank, 2009). With certain commodities being vital for the well-being of many poor people around the world, a possible role (even if not the main cause) of traders not connected to the commodity business in bringing about price volatility has been a matter of concern. The social unrest provoked by these developments led certain countries to adopt extreme measures, such as export prohibitions. Despite their immediate price-dampening effect at home, such measures are likely to have exacerbated and prolonged high market prices, notably by reducing incentives to increase production.

These events have fed into at least two important debates on the need for international policy coordination. First, there is the question of the relationship between export measures and global commodity price volatility (see Section D). Second, the need to address problems of price volatility at their source has been highlighted, notably by appropriately regulating financial markets. This includes, for instance, a discussion of better reporting and registration requirements of OTC commodity derivatives trading in order to improve transparency and thus pricing efficiency in these markets (Pace et al., 2008). Questions on the need for further international policy coordination and cooperation in the field of trade will be further discussed in Section E.

7. Conclusions

Understanding the effects of trade opening on the exploitation of natural resources requires a dynamic approach that takes into account the trade-off between extraction today and extraction tomorrow. This significantly complicates the economic analysis in natural resource markets. As a result, economic literature on natural resources is fragmented and does not provide a comprehensive account of the effects of trade on the allocation of the resources and on their long-run sustainability.

Existing trade theory of natural resources shows that the traditional prediction that trade reflects comparative advantage also holds when the specific feature that natural resources are exhaustible is explicitly taken into account. However, traditional assumptions about the overall gains from trade hold true only under certain assumptions, such as the absence of externalities and imperfect competition. Such market failures are empirically relevant in natural resource sectors, whose markets have been often characterized by various forms of market power (e.g. cartels), weak property rights and environmental externalities. The dominance of natural resources in certain countries' economies and the prevalence of high price volatility also place limitations on traditional expectations regarding the gains from trade.

First, when the imperfectly competitive structure of some natural resource markets is taken into account, economic theory predicts that, in general, resources will be depleted more slowly than under perfect competition. However, the existing literature does not provide an account of the extent to which these results hold true in a more general model of trade, with countries endowed with different types of natural resources. Nor does it explain the impact of this more complex global market on the gains from trade.

Second, when the open access problem associated with weak property rights is taken into account, some of the standard predictions from the theory of international trade about the patterns of trade and the gains from trade may be reversed. When property rights are poorly defined, trade may exacerbate the problem of resource over-exploitation and make the resource-exporting country worse off. However, this is not the only possible outcome. The final result will depend on the specific structure of demand, population pressures and harvesting technologies. More importantly, trade may be beneficial in terms of helping to strengthen a country's property rights regime. One important situation that the existing literature does not address is when natural resources are shared by two or more countries – a situation where open access problems are most acute.

Third, trade may not necessarily generate overall gains when the negative effects of extraction of natural resources on the environment are taken into account. For example, opening up to trade can exacerbate or mitigate the common pool problem depending on the relationship between species (that is, whether the stock of two species are mutually beneficial or one reduces the survival productivity of the other) and on the number of countries involved. Although economic models that study the environmental effects of the extraction and use of non-renewable resources do not generally look at the impact of trade, trade can have a positive impact on the environment if it is associated to the transfer of emission-reducing technologies or access it allows to alternative (less environmentally damaging) resources.

Fourth, when examining the dominance of the natural resources sector in certain economies, existing studies are divided on whether resource abundance translates into faster or slower economic growth. Some stress the risks of over-specialization in the resources sector, including de-industrialization (the so-called Dutch disease), problems associated with excessive price volatility, economic instability and civil conflict. Others, however, point to examples of economies that have successfully harnessed resource specialization for economic growth, and conclude that other factors, besides resource endowments, are key predictors of economic success or failure.

Finally, studies examining the causes and the effects of high price volatility in natural resource markets have emphasized the two-way relationship between volatility and trade. On the one hand, trade allows for a more efficient diversification of input sources, thus reducing the sensitivity of natural resource prices to commodity-specific shocks. On the other hand, volatility may also adversely influence countries' openness to trade (triggering export-restricting policy responses) or how they trade (e.g. organized exchanges versus bilateral long-term contracts). The literature also stresses the important role that commodity-based financial instruments may have in providing a hedge mechanism against the risk of volatility or in contributing to sudden price swings via herding effects. One weakness of the literature is that it focuses mainly on oil price movements. While some of the insights may be applicable to other commodities, the absence of studies on the causes and consequences of volatility in other resource sectors is regrettable.

Endnotes

1 See WTO (2008) for a discussion of these extensions.

2 The opportunity cost of depletion is also known as user-cost, in situ-value or resource-rent.

3 The list of extensions of the Hotelling model is not an exhaustive one. For recent surveys of the theoretical and empirical literature on non-renewable resource economics, see Livernois (2009) and Krautkramer (1998).

4 Some underlying assumptions are built into the models. First, each country is small relative to world markets and is able to sell and buy at a given and constant terms of trade. Second, markets are perfectly competitive. Third, no economic or political distortion exists: a social planner chooses the allocation of resources to maximize present and future social welfare (i.e. the present discounted value of the flow of future utilities).

5 The only departure from the Heckscher-Ohlin theory (under the "Hybrid" scenario) is that an economy would obviously switch its specialization from one commodity to another when the rate of resource extraction declines to zero and its initial comparative advantage disappears.

6 These issues will be addressed in Sections C.3 and C.4.

7 Fixed costs are those that firms have to pay for certain goods or services independently of how much they ultimately produce. As the overall level of output rises, the fixed costs get distributed over a larger number of units, and, hence, the firm's average costs of production decline.

8 In particular, theoretical literature has followed two approaches to model a partially cartelized industry with a competitive fringe. Some have modelled market competition as a Cournot-Nash equilibrium, in which each producer is assumed to choose output to maximize its own profits, taking as given the production schedules of the others (Salant, 1976; Pindyck, 1978; Ulph and Folie, 1980; Lewis and Schmalensee, 1980). Others have treated the cartel as a dominant firm in a so-called Stackelberg game, in which the cartel acts as a leader. The competitive fringe will have to accept the price fixed by the cartel, but the cartel will have to fix the price taking into account the output produced by the competitive producers (Gilbert, 1978; Newbery, 1981; Ulph, 1982; Groot et al., 1992; Groot et al., 2003).

9 For a discussion on the possible role of forward trading on the allocation of resources under imperfect competition see Liski and Montero (2008).

10 At each moment in time prices will exceed marginal costs by a markup. This markup will depend on (is the reciprocal of) the price elasticity of demand. In particular, the more rigid world demand, the higher the cartel markup.

11 In the simpler model considered by Hotelling, marginal costs are negligible. When they are not, the Hotelling rule is in terms of prices (for a perfectly competitive economy) and marginal revenue (for a monopoly) net of marginal costs.

12 Economic theory has shown that in the absence of methods to enforce long-term commitments, time consistent equilibria exist under a set of very limited conditions (Newbery, 1981; Ulph and Folie, 1980; Maskin and Newbery, 1990).

13 Recall that the Hecksher-Ohlin theorem only explains inter-industry trade, that is the exchange of different goods between two different countries. In an Heckscher-Ohlin framework trade takes place because countries are different, therefore there is no reason for countries to exchange identical goods.

14 Two-way trade in horizontally differentiated goods is explained in economic theory by the so-called "new" trade theory. In this set up, increasing returns to scale favour each country's specialization in a limited number of varieties and consumers' love of variety ensures that foreign and domestic varieties of a certain product are consumed. The model assumes that firms operate under monopolistic competition. But, this assumption is the necessary consequence of increasing returns to scale, rather than the determinant of trade.

15 This decision depends on whether the firm perceives its sales in the foreign market to be more responsive to price reductions than in the domestic market.

16 Refer to Block and Taylor (2005) for an extensive review of the economic literature on the link between growth and the environment.

17 More technically, if the elasticity of substitution between the non-renewable resource and other inputs is greater than or equal to one, and if the elasticity of output with respect to the natural resource is lower than the elasticity of output with respect to physical capital, then it is possible to guarantee a constant consumption path with a growing population (Stiglitz, 1974; Solow, 1974b; Solow, 1974a).

18 In some ways, these results parallel the findings of the literature on environmental quality: technological progress can have opposite effects on the environment depending on what sectors are involved. Indeed, technological change in goods production has a "scale effect" that raises emissions, while technological progress in the abatement sector drives emissions downwards, through a pure "technique effect" (Taylor and Brock, 2005).

19 It is important to point out one limitation in the literature reviewed in this sub-section. The papers all consider a situation where the natural resources stock is subject to exploitation only by citizens of the country and do not consider the circumstance where the resource is shared by two or more countries. However, some of the most severe forms of open access problems are transboundary in nature, e.g. fish in the open ocean that are not under the jurisdiction of any single nation or migratory/straddling stocks that pass between jurisdictions. A complete discussion of transboundary problems associated with natural resources are found in Section D on regional agreements and in Section E of this report.

20 Unfortunately, this will not always be the case. First, the environmentalist may have the size of the stock corresponding to maximum sustainable yield as an objective. But the size of the natural resources stock corresponding to maximum rent will usually be smaller. Second, if the discount rate is higher than the maximum rate of growth of the resource, the economically efficient decision will be to extinguish the stock.

21 The growth function is $\frac{dS(t)}{dt} = rS(t)(1 \frac{S(t)}{K})$, where $\frac{dS(t)}{dt}$ is the rate of change of the stock; r is the maximum possible biological growth rate of the resource; S(t) is the size of the current stock which depends on time, and K is the environmental carrying capacity of the resource. The solution to this first-order differential equation is a logistic function. The relationship is often called the Schaefer curve after fisheries biologist Schaefer (1957) who used it extensively in his work.

22 The steady state condition is given by: $\frac{dS(t)}{dt} = h(E,S)$ where $h(E,S) = E * S$ is harvest. Harvest depends positively on effort (E) and the stock of natural resource (S). Using these relationships and the growth rate, it is possible to solve for the stock as a function of effort and substitute the result into the harvest equation, which finally gives harvest (or revenues) as a function of effort in Figure 14.

23 Using the growth function and the steady-state condition, it is possible to show that there is a negative relationship between stock and effort in the steady state.

24 For a fuller discussion of the role of the discount rate, see chapters 2 and 3 of Clark (1990).

25 This fishery is located in the Northwestern Pacific waters of Canada and the United States.

26 Geoduck is a species of very large saltwater clam that is native to the northwest coast of Canada and the United States.

27 This report focuses on trade in natural resources and hence it will not deal with the literature analysing the effect of trade on the environment when environmental externalities are mainly generated in the production sectors (e.g. industrial pollution). For a description and analysis of this literature see WTO-UNEP (2009).

28 This classification is also valid for renewable resources. An example of flow externalities is forest harvesting. The stock externality of this activity involves deforestation, soil erosion, species extinction, and an increased concentration of carbon in the atmosphere.

29 While models such as Sinclair (1994), Ulph and Ulph (1994), Withagen (1994), Hoel and Kverndokk (1996), Kolstad and Krautkraemer (1993), Babu et al. (1997) and Welsh and Stähler (1990) consider the externalities in a partial equilibrium framework, Stollery (1998), Schou (2000) and (2002), Grimaud and Rougé (2005) and (2008), Groth and Schou (2007) and Acemoglu et al. (2009) use general equilibrium models.

30 For a discussion of the Hotelling rule see Section C.1.

31 Data show that 87 per cent of total consumption of energy in 2000 was represented by fossil fuels such as oil (40 per cent), coal (25.7 per cent) and natural gas (22 per cent). See Kronenberg (2008).

32 The concept of backstop technology was first introduced by Nordhaus (1974) and refers to an alternative way of producing a certain output which does not rely on exhaustible resources. Examples in the context of electricity generation are solar or wind energy.

33 OPEC countries also have an incentive to boost their reserve estimates, because their export quotas depend on the total amount of reserves they have. See Campbell and Laherrère (1998).

34 See for instance Krautkramer (1998).

35 It is assumed that the probability of a new discovery is decreasing over time.

36 This technological option has currently become promising for the fossil energy extraction industry. In fact, the possibility and viability of capturing and sequestering some fraction of the carbon dioxide arising from fossil fuel combustion has been recently demonstrated. This process, often labelled as CO_2 capture and storage (CCS), consists of separating the carbon dioxide from other flux gases during the process of energy production; once captured, the gases are then disposed into various reservoirs.

37 While the combustion of natural gas releases 117,000 pounds per billion btu of energy input (p/btu) of carbon dioxide, 92 p/btu of nitrogen oxides and 1 p/btu of sulfur dioxides, burning oil and coal produces respectively 164,000 and 208,000 p/btu of carbon dioxide, 448 and 457 p/btu of nitrogen oxides and 1,122 and 2,591 p/btu of sulfur dioxides, see IEA (1998).

38 According to Barbier and Rauscher (1994) and Swallow (1990) habitat destruction is one of the obstacles to the long-run viability of more than 50 per cent of those species currently threatened by extinction.

39 Barbier and Schulz (1997), Smulders et al. (2004) and Polasky et al. (2004) illustrate the effect of trade in natural resources on biodiversity through the effect on natural habitat. Brock et al. (2007) analyse the effect of trade-induced biological invasion on biodiversity.

40 Here the discussion will be restricted to identical countries. In general however, the literature takes into account the fact that countries differ in size, productivity and tastes and shows that in these cases, the effect of trade opening on biodiversity is not clear and will depend on multiple factors such as the sectors in which the countries will specialize, the relative size of the species habitat across countries or differences in the eco-systems across countries.

41 This description of "species-habitat area" curve comes from MacArthur and Wilson (1967) and is widely used in ecological theory.

42 See Polasky et al. (2004).

43 The welfare effects of trade depend on how biodiversity affects the utility of consumers. Consider, for example, that a certain species provides services to the population. The impact of trade on welfare will depend on whether the species has to be located in the same country of the consumer (e.g. species of sedges, which are primarily used to filter water in wetland ecosystems) to provide a positive effect on its utility, or whether the location of the species is not relevant (e.g. species such as chimpanzees for which people care that the worldwide population does not become extinct).

44 However, results can be extended to other natural resources such as forestry and hunting of wild animals.

45 When countries have market power and tastes are identical the price effect will offset the biological externality and an efficient level of harvesting will be reached.

46 Resource concentration is a sufficient, but not necessary condition for concentrated trade patterns. The "new trade theory" allows for extreme concentration even where endowments are similar across countries. Moreover, even if it was the geographical distribution of factor endowments that led to these trade patterns, extreme trade concentration could be the result of geographically concentrated capital, or skilled labour. For the sake of the arguments put forth in this section, it suffices to note that trade in resources is a predominant share of production and export activities in a few abundant countries, regardless of the underlying reason.

47 The term was coined in 1977 by *The Economist* to describe the decline of the manufacturing sector in the Netherlands after the discovery of a large natural gas field in 1959.

48 See Corden and Neary (1982) and Corden (1984).

49 It might be the case that the natural resource sector does not employ a factor that is mobile across sectors, and is effectively an enclave in the economy. In this situation there is only a spending effect, because there is no intersectoral reallocation of productive resources.

50 Figure 16 is from Sachs and Warner (1995).

51 A few caveats are in order. First, the existence of external economies in the manufacturing sector has not yet been determined. Sachs and Warner (1995) themselves state that "the links of these Dutch Disease effects to the loss of production externalities, however, remains speculative and as yet unproven". Second, the presence of external economies justifies government subsidization of the growth-driving sector. The lower growth path BCD of Figure 16 may then be due to government failure rather than to the resource boom *per se*. Third, the same growth path BCD could be due to resource depletion, which – as shown among others by Nordhaus (1992) and Boyce and Emery (2006) – is a drag on economic growth when it is not offset by technological progress. Fourth, Alexeev and Conrad (2009), who study the effect of oil abundance on GDP levels, have not determined any resource extracting economy to be on part CD of Figure 16. They are all on part BC, and it is not known whether CD will happen.

52 By the Rybczynski theorem, the non-traded, capital intensive sector expands and the traded sector contracts; the resulting increase in the relative supply of non-traded goods causes a depreciation of the real exchange rate. Other cases are discussed in Van der Ploeg (2006).

53 Collier et al. (2009) notice that this is a theoretical possibility. In practice, however, even in the presence of under-employed resources, supply responses are dampened, producing higher wages and a higher price of domestic output as a whole relative to the price of foreign goods, therefore a real appreciation of the currency.

54 Brunstad and Dyrstad (1992) find that occupational groups in areas close to the booming sector which did not experience positive demand effects experienced a decrease in their real wages as a result of the petroleum boom.

55 Sachs and Warner (1995) also show that resource-intensive economies had a higher ratio of output of services to output of manufactures. This is consistent with the prediction of the Dutch disease models that the ratio of non-traded to (non-resource) traded output will be higher in resource intensive economies, to the extent that services proxy the non-traded sector and manufactures proxy the non-resource traded sector.

56 When there is more political competition, on the other hand, the government would try to retain its power and thereby it might be forced to spend more on provision of public goods to promote growth. Bhattacharyya and Hodler (2009) make a similar point by arguing that the relationship between natural resource abundance and corruption depends on the quality of the democratic institutions: resource abundance is positively associated with corruption only in countries with low net democracy score.

57 There is a potential endogeneity concern, namely reverse causality from economic growth to resource endowment. Sachs and Warner (1995) argue that the relationship is robust to the introduction of an alternative measure of natural resource abundance – arable land area to population – which is relatively less endogenous than the ratio of natural resource exports to GDP.

58 For the period 1970-98, they estimate a growth regression including institutional quality and natural resource abundance in the set of explanatory variables. Institutions are instrumented with variables that do not affect growth between 1970 and 1998 – namely mortality rates of colonial settlers, as in Acemoglu et al. (2001) and fraction of the population speaking English and European languages, as in Hall and Jones (1999). The first-stage regression results allow one to test the indirect effect of natural resources on growth via their impact on institutional quality.

59 The inclusion of levels, rather than growth rates, of per capita GDP is justified by observing that if a country has a higher per capita GDP than another, it must have experienced faster growth over the long term than the other.

60 For similar reasons, conflict is more likely for capital-intensive resources than for labour-intensive ones (Dube and Vargas, 2006).

61 Since they induce rent-seeking, point-source resources will also tend to deteriorate institutions (and therefore growth), beyond their effect on the likelihood of conflict. This is confirmed by the empirical literature. For instance, Isham et al. (2003) show that export concentration in point-source natural resources and plantation crops is strongly linked to weak public institutions and governance indicators which, in turn, generate lower capacity to respond to shocks and, ultimately, lower economic growth – as compared with more diffuse natural resources such as agricultural products. Therefore, it seems that the type of natural resource exports is a crucial determinant of whether natural resources become a curse or a blessing (for a study based on panel data econometric modeling, see Murshed, 2004).

62 Secessionist conflict refers to war started with the aim of splitting up a region of the country and founding an autonomous state, while centrist conflict is about gaining the control of the whole country.

63 Fisman and Miguel (2008) propose shifting some amount of international development assistance away from long-term investment and toward short-term emergency aid for countries hard-hit by a collapse in prices of labour-intensive commodities such as coffee. This aid would kick in as soon as prices fall, potentially avoiding the occurrence of violent conflict.

64 See also Ross (2004).

65 An earlier comparative analysis by Davis (1995) also found no evidence of a resource curse; the observed mineral economies had done well in a number of development indicators against non-mineral economies over the same period, even outperformed them in some cases.

66 A related idea, explored in Rodriguez and Sachs (1999), is that with constant or declining resource production and exogenous growth, GDP per capita asymptotically approaches that of a non-mineral economy from above, thus exhibiting negative growth rate during the transition to steady state.

67 According to Kilian (2009a), this interpretation is however not entirely consistent with a wide range of evidence that indicates a central role for oil demand shocks in all previous oil price shock episodes since 1972, except the oil price shock triggered by the outbreak of the Iran-Iraq War in late 1980.

68 This is associated with the idea of a "random walk", which is a term loosely used in the finance literature to characterize a price series where all subsequent price changes represent random departures from previous prices. It implies that experts in the field cannot systematically outperform uninformed investors, except through luck.

69 The idea of "herding" in financial markets may be traced back to Keynes's Beauty Contest where he described the behaviour of market participants using an analogy based on a fictional newspaper contest. He argued that investors in equity markets anticipate what average opinion expects average opinion to be, rather than focusing on things fundamental to the market (Keynes, 1936).

70 These are investors who distribute their wealth across key commodity futures according to popular indices, such as Standard & Poor's or Goldman Sachs Commodity Index.

71 Commodities provide diversification to an investment portfolio for at least two reasons. First, commodities are subject to factors, such as weather conditions or miners' strikes, that have little or nothing to do with expectations about stock or bond markets. Second, if there were, for instance, widely held beliefs about rising inflation, bond prices would fall as interest rates rise and stock markets might be negatively affected as well. However, since commodity investments reflect expectations about further price increases over "real" products, their prices should be expected to rise along with expectations about higher inflation (Greer, 2005).

72 In other words, the real interest rate could be negative.

73 It has been argued that as speculators drive commodity futures prices higher, the effects are felt in spot markets and the real economy, since spot market participants typically base their supply and demand decisions, at least in part, on expected price changes in the future (Masters, 2008; Hamilton, 2008).

74 'Swap dealers" who provide trades, which cater to the needs of commercial entities, account for the balance.

75 The speech can be accessed at: http://www.pbc.gov.cn/english/detail.asp?col=6500&id=178

76 More precisely, Hausmann and Rigobon (2003) show that a 1 standard deviation shock to the price of oil represents an income shock equivalent to 6 per cent of GDP.

77 Hausmann and Rigobon (2003) make the following example: Assuming an economy where oil accounts for 30 per cent of national income and has a standard deviation of about 30 per cent per year and given a constant relative risk aversion (CRRA) utility function with a relatively high risk aversion coefficient of 3, a typical consumer would be willing to sacrifice 4.05 per cent of national income in order to make oil revenues perfectly certain.

78 Since the oil producers' ability to absorb infusions of capital is likely to be limited, they inevitably invest the revenue that cannot be invested domestically in oil-importing economies. A good example is the sovereign wealth funds maintained by many oil-producing countries (Kilian, 2009c). Because of this transfer of financial wealth from oil exporters to oil importers, positive oil demand shocks or negative oil supply shocks should be associated with a temporary capital gain in oil importing countries. This is the so-called "valuation channel" of transmission of oil price shocks across countries. Another, real channel of transmission of oil price shocks across countries is the "trade channel", which works through changes in the quantities and prices of goods exported and imported, and is reflected in the response of the trade balance. Kilian (2009c) explains that supply disruptions, by increasing the price of oil, cause a surplus in the oil trade balance and a deficit in the non-oil trade balance (net exports of non-oil products) of the exporter. By construction, the response in the importing economy will be the mirror image of that of the exporting economy. Demand shocks – associated for instance with productivity improvements in the oil-importing country that raise demand not only for crude oil, but for all other industrial commodities as well – have two opposing effects. On the one hand, they raise the price of oil, causing a surplus of the oil trade balance and a deficit in the non-oil trade balance of the exporter. On the other hand, they represent a short-run stimulus for the oil-importing economy, which will tend to cause a non-oil trade surplus for the exporter. Empirical research by Kilian (2009b) and Kilian and Park (2009) on the US economy (net oil importer) suggests that the latter effect dominates in the short run, while the former effect dominates after one year.

79 See Section C.4 for a discussion of other channels of the natural resource curse.

80 See, among others, Aghion et al. (2009) and Ramey and Ramey (1995).

81 The authors develop a theoretical model showing that volatility in natural resource revenues, induced by volatility in primary commodity prices, curbs growth in economies with poorly functioning financial systems. This prediction is similar to Hausmann and Rigobon (2003).

82 Blanchard and Gali (2007). Since the late 1980s, however, the effects of real oil price shocks on oil importing countries have been significantly smaller. This is discussed in Box 12.

83 This occurs through four mechanisms: (i) the discretionary income effect, that refers to the reduction in income available for non-essential spending brought about by higher energy prices, as consumers have less money to spend after paying their energy bills; (ii) the uncertainty effect, that refers to the postponement of irreversible purchases of consumer durables, as changing energy prices may create uncertainty about the future path of the price of energy; (iii) the precautionary saving effect, that refers to the increase in the uncertainty-related component of savings, and the consequent fall in consumption, in response to energy price shocks; (iv) the operating costs effect, that refers to the delayed or foregone purchasing of energy-intensive durables, whose consumption will tend to decline even more than consumption on other goods.

84 See Hamilton (2008) and Kilian and Park (2009).