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Economics and Natural Resource Constraints

Abstract In this chapter Agboraw and Jones explore theories of natural resource scarcity and economic growth. By examining how natural resources fit within current theory the issues of how scarcity of resources, or resource prices, link to a better understanding of economic risk is outlined.

Keywords Economic theory · Natural resource scarcity · Economic growth

The limited availability of natural resources and its effect on the growth of the economy through its various sectors is an issue of modern concern (Neumayer 2000). In this chapter, we initially outline theoretical and empirical analysis of the effect of natural resources on the economy as a whole. Then we will explore the finance sector, including pensions, insurance and banks, and how natural resource constraints could impact on their performance through theory and empirical literature as well. Finally, we examine potential systemic risks in the finance sector and the linkages to resource scarcity and climate change.

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The growth of an economy is fundamental to its development and economic development is one of the main objectives of every society in the world (Anwer and Sampath 1997). Sustained economic growth is the utmost dominant eradicator of poverty and therefore critical to achieving development outcomes. Livelihood improvement, job creation and the increase in household and government incomes result from the growth of the economy. Nations worldwide are therefore driven by the prospects of better living standards through the positive performance of their economies and an increase in their annual GDPs (Romer and Romer 2007). Economic growth is predominantly determined by advances in productivity, which involves the production of more goods and services with the same amount of contributions of labour, capital, energy and raw materials. Thus natural resources play an important part in the economic growth and well-being of a country given its main contribution to manufacturing, technological advancement, trade (both local and international), employment, improved standards of living and its effects on the social, political and, importantly, the financial sector.

There is, however, a complex relationship between economic growth, environmental crisis (resource constraint/scarcity) and social recession. As the economy grows, the resource implications associated with such growth expand as well even if these impacts are already unsustainable (Sustainable Development Commission 2009).

A complex relationship between natural resource scarcity, or abundance, and the economic growth of countries lead to conflicting conclusions on whether the scarcity of natural resources positively or negatively affects growth or vice versa. Before an analysis of the empirical literature on the relationship between resource constraint and economic growth, some theories on natural resource scarcity and economic growth will be examined.

2.1 Theories on Natural Resource Scarcity

Cleveland and Stern (1998) defined increases in the scarcity of natural resources as a decrease in economic well-being due to the drop in the accessibility, quality and/or productivity of natural resources. A natural resource indicator encapsulates the direct and indirect costs involved with obtaining a unit of that resource (Fisher 1979). Smith (1979) asserted that natural resource scarcity could simply be considered as a result of the demand and supply conditions of the resource, so that its price, under the best conditions, offers the best index for scarcity. Brown and Field (1978) claim that unit cost, product output prices and rental rates were all useful proxies for scarcity, though marginal discovery costs are preferred over the rival measures. Thus, there has been a constant debate in literature on the ideal measurement of scarcity; which of these units of measurement—resource prices, unit costs of extraction, resource rents, energy cost and elasticity of substitution—presented a more accurate reliable representation of natural resource scarcity (Fisher 1979; Hall and Hall 1984; Cleveland and Stern 1993; Ozdemiroglu 1993).

Tietenberg (1988) identified three key measures for choosing between scarcity indicators; Comparability, where the indicator should allow for the assessment of the level of scarcity of diverse resources and their alternatives in order to classify the level and seriousness of the problem of scarcity; Computability where the collection of data and calculation technique should be consistent and straightforward; and Foresight, where the indicator of scarcity should not only describe historic levels of scarcity but it should also essentially be able to predict and/or forecast future scarcity through the future demand for the resource, substitution possibilities and changes in extraction cost.

Cleveland and Stern (1993) classified natural resource scarcity into two main concepts: the Exchange scarcity and the Use scarcity. The exchange scarcity as commonly measured by the rent and/or price of the resource is applicable to scarcity both in output and factor markets. In other words, the 'opportunity cost of using a particular resource'. 'Use scarcity' refers to the strain involved in the production of natural resource commodities in terms of the balance between the availability and productivity of the resource base and the technological level (Cleveland and Stern 1993, 1998). Cleveland and Stern (1998) identified three models of Scarcity; the classical, neoclassical and the biophysical models of scarcity.

Following the theories of Marx and Ricardo on the labour cost of production being a measure of the use value of commodities, Barnett and Morse (1963) defined the increase in resource scarcity as 'an increase in the resistance of nature to the efforts of people to produce resource commodities'. Thus according to classical theory, the suitable measure of scarcity is the labour and capital required to produce a unit of the commodity. Rising scarcity means more labour is required.

The neoclassical model of scarcity begins with the hypothesis that owners of resources make the most of the discounted profits from the mining and sale of the resource (Hotelling 1931). This assumption is demonstrated by Fischer (1979) with a model of an optimal control problem of non-renewable resource extraction (Cleveland and Stern 1998). Fischer's model showed that price and rent were the appropriate scarcity indicators. If the main interest is the sacrifices related to the depleting stock of resources, then the rent is a better indicator. Thus according to the neoclassical view, the market price is a good indicator of scarcity for the resource commodity and rent can be used as an indicator if the resource stock is the main interest. This is in accordance with Landsberg et al. (1963) who stated that

'The "real cost" of resource products, which over the long run can be measured by the behaviour of their prices in comparison with the general price level, has shown no marked change. This is the classic economic test of increasing scarcity. Deflated prices, as adjusted to allow for the influence of the general price level upon each resource commodity, have moved erratically since 1870 with many ups and downs and possibly some slight tendency upward.… But the overall picture does not indicate that resource materials have become scarcer at any general or alarming scale over a good many decades in the past." pg. 554

The biophysical model regards the scarcity of resources based on the energy cost of transforming these resources to a more productive state (Ruth 1993). Resources are not useful in their natural state for the production process and so must undergo a transformation process (location, extraction, refinement and transportation) which involves high levels of energy. The lower the quality of resources, the more energy is required to upgrade it to a useful state (Cleveland and Stern 1993).

The three models of scarcity have been criticised on various platforms. The classical model was criticised based on the shortcoming that unit cost as an indicator excludes all other inputs apart from capital and labour. The neoclassical model was criticised first by Fischer (1979) where he asserted that price and rent only measure 'private scarcity' and that market failures and imperfections could divert attention from private to social indicators of scarcity. Rent as well could fall to zero as a lower quality of a resource could be substituted for a depleted higher quality resource. Cleveland and Stern (1998) observed that prices were derived from restrictive assumptions about the market structure and its conditions and real world situations strip prices from its theoretical advantages. This is because the prices of natural resources are determined in more complex market scenarios than those described in theoretical models.

Stern (1996) criticised the use of energy cost as an indicator of scarcity under the premise that unless it is possible to contribute to the energy theory of value, where the efficiency of the non-energy inputs is a linear function of the energy used in their production, energy cost is not an appropriate measure of scarcity. In cases where energy could be substituted for capital or labour, the cost of energy could increase even though there is no change in the productivity of resources or in the state of technology (Cleveland and Stern 1993).

As a follow up from the above definitions, Stern (1998) decomposed the use scarcity concept using econometric models to incorporate the private and social perspectives as well as looking at the size of the capital stocks in addition to their average and/or marginal value.

According to Ozdemiroglu (1993), there are certain situations where changes in resource scarcity cannot be identified by any indicator. These include when the resources are extracted with no formal markets (and hence no data), under open access administrations (when there is an unawareness of stock levels), under conditions when the public good is not adequately captured and when there are no future markets.

2.2 Theories on Economic Growth

2.2.1 Thomas Malthus Economic Growth Theory

The debate on scarcity and growth started with Thomas Malthus' observations on the 'fecundity of human nature and the relative stinginess of Mother Nature' (Malthus 1798 in Krautkraemer 2005). Thomas Malthus established a strict model of a dynamic growth process wherein each country congregated towards a stationary per capita income. He argued that technological change improvement in standard living population growth reduced the average person to the subsistence level again. In the long run, there would be no increase in the standard of living unless there were some limits on population growth.

The concept of scarcity as it appeared in the ideological struggle about the poor laws was very crude, so Malthus' simplistic formulation served admirably as a political weapon. Malthus proved to the satisfaction of the ruling classes that they had no responsibility for the existing state of affairs (Perelman 1987).

Contrary to Smith and Ricardo, who postulate that savings is always equal to investment implying any act of savings would lead to an increase in wealth of the economy, Malthus asserted that savings brought about a reduction in effective demand by reducing the ability of people to consume, in turn bringing a decline in profits and investments.

According to Malthus, national income is created by investment and consumption, which is divided into capitalist consumption and worker consumption. As the wages of workers equals their consumption level, profits are equal to investment plus the capitalist's consumption. Malthus argues that abstinence to consume on the part of the capitalist only contributes to growth if the savings are then invested. In case this does not happen, the capitalist's savings would only reduce growth. Nonetheless, he also states that when the opportunities for profitable investment are exhausted, savings cannot be converted into investment.

Malthus' *An Essay on Population* and *Principles of Political Economy*, highlighted that the future availability of natural resources could have negative impacts on society. In particular, he showed that limits in land productivity, coupled with a finite amount of land, meant that the output per capita within a society of growing population would decrease. Even bringing previously unused land into agriculture would not see substantial improvements as this is both finite and likely to be of lower quality and hence lower productivity. However, wages would increase as overall land productivity increased. Malthus also focussed on limits to population growth and, according to his model, as wages increased then so would family size. Therefore, this interplay between population growth increasing with better wages from food output, and increased population lowering food productivity per capita meant that, eventually, through malnutrition, famine and delayed marriage, the population would be managed and the majority of people would be on a subsistence wage.

While Malthus' predictions have been heavily criticised as they did not include technological advances that significantly increased land productivity and a decline in fertility rates due to economic prosperity. However, limits on land productivity still exist, albeit higher than Malthus has envisaged.

2.2.2 Adam Smith's Theory on Economic Growth

A characteristic feature of the classical approach is the view that production involves labour, produced means of production and natural resources. In order to appreciate real growth processes, one has to come to the understanding of the related rules managing the pace of capital accumulation, the growth of population, and the rate and bias of technical innovation in an environment characterised by the inadequacy of natural resources. The core aspect of Adam Smith's theory dwelt on capital accumulation and division of labour. He viewed the growth process as strictly endogenous assigning distinctive importance on the effect of capital accumulation on labour productivity.

Smith recognised only three factors of production: land, labour and capital. In his theory, he did not consider his production function to have diminishing marginal productivity. Nevertheless, his production function is subject to increasing returns to scale (which means that, output increases more than proportionally to an equal percentage increase in all inputs). According to Smith, as the size of the market increases, internal and external economies of scale increases, which eventually lowers down the cost of production. This process would be initiated by improvement in the production techniques and a greater degree of division of labour.

Smith upheld that an examination of the growth of income per capita is first and foremost an analysis of the causes of its improvement, in the productive powers of labour, and the order, according to which its product is naturally distributed among the 'different ranks and conditions of men in the society'. The key to labour productivity is division of labour which is dependent on the extent of the market and capital accumulation. He further emphasised the effect of division of labour both within and between firms and industries which reflects on the productivity of labour in the improvement and the dexterity of the workers, time saving from movement of one activity to another and the invention of machinery.

Smith's analysis indicates the concepts of induced and embodied technical progress, learning by doing and learning by using. The creation of new machines and the enhancement of known ones is said to be originally due to the workers in the production process. 'New technical knowledge is systematically created and economically used, with the sciences becoming more and more involved in that process. The accumulation of capital propels this process forward, opens up new markets and enlarges existing ones, increases effectual demand and is thus the main force behind economic and social development' (Kurz and Salvadori 2005).

Adam Smith also pointed out the difference between the 'natural price' and the 'market price' of a commodity. The natural price is defined by the total amount of labour commanded in the market, while the market price is defined by the relative scarcity of goods. The notion of economic rent rises from this relative scarcity and can be defined as 'the price that a rational individual would pay to have one more unit of a resource available today' (Barbier 1989). Therefore, it is estimated that an increase in relative scarcity of a resource will increase the resource rent and also the market price of the resource.

2.2.3 David Ricardo's Theory of Economic Growth

Ricardo's theory is mainly centred on the law of diminishing returns which states that if more units are added to one of the factors of production, and the rest is kept constant, the quantity of output produced by the additional units will ultimately become smaller down to a point where the overall output will begin to fall.

Economic rent, according to Ricardo, is 'that portion of the produce of the earth, which is paid to the landlord for the use of the original and indestructible powers of the soil'. The 'powers of the soil' such as its fertility determined this rent rather than the quantity of soil available. With increased population and demand for agricultural output, the average quality of arable land drops and is therefore seen as more scarce in the market. This allows increased profit from increased rents. This is in particular because 'resource use follows the natural quality pattern of the resource, i.e., the best quality is extracted first and the worst quality extracted the last' (Ozdemiroglu 1993). In the end, the profit earners would increasingly gather wealth from renters. However, this trend is unsustainable over the long term and a class war between the renters and profit earners would result.

Following from the classical view of economic growth through production, Paul Douglas and Charles Cobb came up with a production function to better present the relation between labour and capital. The description of the production function is a distinct case of the constant-elasticity-of-substitution production function (CES), with the elasticity of substitution being equal to one and with the usual theoretical assumptions used in the empirical literature (Barro and Sala-i-Martin 2004). In using the Cobb-Douglas production function, it is possible to consider changes in the supply-side performance on the foundation of the concurrent developments detected in the quantity of labour, capital and total factor productivity. For example, an upsurge in the rate of capital growth supplemented by a growth in total factor productivity may indicate enhancement in the supply-side performance. The production function thus represents a useful and powerful tool for the macroeconomic analysis and evaluation of the governmental structural policies.

2.2.4 Keynesian Economics

Reference to Keynesian Economics on environmental and natural resource issues is extremely rare (BERR 2008). Keynesian Economics lays most stress on supply and demand of goods and services. However, the New Keynesian economics emphasises efficiency wage theories, capital market imperfections and credit rationing which could be linked to natural resource scarcity and investment in natural resources.

In his general theory, Keynes needed to find a source of fluctuations in economic activity. It was apparent that changes in technology, in supply, could not account for what was occurring in the Great Depression. He therefore naturally turned to changes in demand. Those brought up in the Marshallian tradition were schooled in analysing demand and supply disturbances separately. Keynes's reliance on the Marshallian demand/supply framework posed problems which he never satisfactorily resolved. The Marshallian theory suggests that firm equilibrium is at the point of intersection between demand and supply. Thus firms in solving their profit maximisation problems, act as though price and quantity are fixed and thus do not consider prices to affect sales quantity.

In saving and investment, there was the difference between the funds within a firm and that of households. If capital markets were perfect, there would be no difference between firms and households. Exogenous increases in spending, such as an increase in government expenses, increases total spending by a multiple of that increase. A government could arouse a great deal of new production with a modest expenditure if the people who receive this money spend most on consumption goods and save the rest, and this extra spending gives businesses the opportunity to hire more people and pay them, which in turn allows a further increase in consumer spending.

This process continues. At each step, the increase in spending is smaller than in the previous step, so that the multiplier process tapers off and allows the attainment of equilibrium. This story is modified and moderated if we move beyond a 'closed economy' and bring in the role of taxation: The rise in imports (of natural resource substitutes) and tax payments at each step reduces the amount of induced consumer spending and the size of the multiplier effect.

According to Keynes, capital market imperfections are a derivative from imperfect information. There are asymmetries of information between managers of firms and potential investors, which could result in 'equity rationing'. Equity rationing matters because it means that if firms desire to acquire more capital, to invest or to increase production, they must borrow the funds, thus the exposure to considerable risk, including the risk of bankruptcy. The repercussions of this are firms cannot sell the goods which they plan to produce until after they have produced them and such risks are aggravated by the non-existence of futures markets. Every decision made by management is a risk decision especially production decision, a risk which the managers and equity holders must bear, and which they cannot easily shift on to others. Unexpected changes in its working capital base (caused for instance by unexpected changes in the prices at which it can sell its existing stock of goods) could, for instance, have a deleterious effect on its willingness to produce (Greenwald and Stiglitz 1987).

The economic theory of Keynes covers key areas in the research such as investments, savings, risks which require insurance and most importantly the issue of demand and supply which could relate to natural resources.

2.2.5 Exogenous (Neoclassical Growth) Versus Endogenous Model

The most basic proposition of the Exogenous growth theory is that in order to sustain a positive growth rate per capita, in the long run, there must be continual advances in technological knowledge in the form of new goods, new markets, or new processes. This proposition can be demonstrated using the neoclassical growth model which shows that if there were no technological progress, then the effects of diminishing returns would eventually cause economic growth to cease (Aghion and Howit 1998). According to Cesaratto (1999), exogenous growth implies that the long run growth rate depends on the growth rate of the labour force and on labour augmenting exogenous technical progress. Thus savings have no effect on the rate of capital accumulation.

In a nutshell, it attempts to explain long run economic growth by looking at productivity, capital accumulation, population growth and technological progress (Solow 1956; Swan 1956).

However, the explanation of exogenous growth by neoclassical economists have 'run into difficulty' and criticisms by unsatisfied economic practitioners (Nelson and Winter 1974; Rynn 2001). The theory, in general, is built and heavily reliant on diminishing returns. It is particularly difficult to describe how something increases if the main process used to describe the increase is a process of decreasing values (Rynn 2001). The theory failed to take into account the role of entrepreneurship and the power of institutions which promote growth. It is also criticised for concentrating too much on short run scenarios and processes, failing to provide long-term solutions and benefiting the population as a whole, thus enhancing unsustainable development. Therefore, the NeoClassical model is based on the premise of weak sustainability, which is a fairly simple premise which states overall capital stock should be non-decreasing. It allows natural resources to be completely depleted as long as other forms of capital compensate for this loss. It also failed to explain how and why technological progress occurs and how saving rates come about. Due to the failure of the Exogenous growth model to explain the rate of savings and rate of technological progress, the endogenous model was developed in an attempt to overcome the shortcomings of the exogenous model.

The Endogenous growth model, on the other hand, is dependent and controlled by economic agents. The Endogenous growth theory holds that economic growth is primarily the result of endogenous and not external forces. The theory holds that investment in human capital, innovation and knowledge are significant contributors to economic growth. The theory also focuses on positive externalities and spill over effects of a knowledge-based economy which will lead to economic development (Romer 1990). The endogenous growth theory primarily holds that the long run growth rate of an economy depends on policy measures. For example, subsidies for research and development or education increase the growth rate in some endogenous growth models by increasing the incentive for innovation (Rebelo 1991).

The endogenous growth theory, therefore, allows the investigation of the impact of innovation in overcoming resource scarcities. However, resource scarcity itself could also inhibit technology innovation (Barbier 1999). Therefore, the ability of innovation to underpin economic growth depends critically on assumptions on how it either overcomes or is constrained by resource scarcity.

2.2.6 Rostow's Stages of Economic Growth

One of the developmental theories of economic growth was suggested by Walt Rostow in 1960. Rostow contended that economies must undergo a number of developmental stages towards better economic growth. He argued that these stages followed a consistent succession, where each stage could only be reached through the completion of the previous stage. 'It is possible to identify all societies, in their economic dimensions, as lying within one of five categories: the traditional society, the preconditions for take-off, the take-off, the drive to maturity, and the age of high mass-consumption' (Rostow 1960). The model proposed that all countries exist somewhere on this linear pathway and climb upward through each stage in the development process.

The first stage is the traditional society, dominated by agriculture and barter exchange, with intensive labour and low levels of trading, and where the population that does not have a scientific perspective on the world and technology. The concept of the traditional society, however, does not eliminate increases in output. According to the theory, these societies due to the limitations in productivity devote a very high proportion of their resources to agriculture; and flowing from the agricultural system there is a hierarchical social structure, with relatively narrow scope for vertical mobility. This stage, to some extent, reflects the stage where most low-income countries find themselves in.

In the second stage, known as the Pre conditions to Take-off, the economy begins to develop manufacturing and a more national/international outlook. It is mainly characterised by the development of education and an understanding of science, the application of science to technology and transport, and the emergence of entrepreneurs and a simple banking system, and consequently an increase in savings. According to Rostow (1960) this stage of growth hardly ever, if it does, arise endogenously, but from some intrusion of more advanced economies. Thus the emergence of the technology to be able to extract, refine and use stocks of resources for production purposes.

The third stage of growth is the Take-off stage where there is a brief period of intensive growth, in which industrialization commences, and workers and institutions become concentrated around a new industry with positive growth rates occurring in particular sectors and where organised systems of production and remuneration replace traditional methods and norms. During the take-off, the rate of effective investment and savings may rise, new industries develop quickly, yielding profits in large proportions which are reinvested in new plants and these new industries, consecutively, stimulate a further expansion in urban areas and in other modern industrial plants. The whole process of expansion in the modern sector yields an increase of income. New techniques are introduced and spread in agriculture, as agriculture is commercialised. The revolutionary changes in agricultural productivity are an essential condition for successful take-off; for modernization of a society increases radically its bill for agricultural products. In a decade or two both the basic structure of the economy and the social and political structure of the society are transformed in such a way that a steady rate of growth can be maintained (Rostow 1960).

The Drive to Maturity stage takes place over a long period of time, with improved standards of living, increased use of technology, a significant growth rate in many sectors and a more diversified national economy. This is the stage in which an economy displays the capacity to move ahead of the original industries which powered its take-off and to absorb and apply the technology efficiently over a very wide range of its resources. In other words, 'an economy that demonstrates that it has the technological and entrepreneurial skills to produce not everything, but anything that it chooses to produce' (Rostow 1960). Many developed countries are in this stage of growth. With the power to be able to be more technologically capable production wise, the depletion of natural resources increases tremendously at this stage.

In the final stage, the Age of Mass Consumption, a country's economy flourishes in a capitalist system, characterised by mass production and consumerism and where citizens enjoy high and rising consumption per head, and where rewards are spread more evenly. Rostow believed at that time that the USA was in this stage of growth and development. In this stage the leading sectors shift towards durable consumers' goods and services, real income per head rise to a point where a large number of individuals gain a command over consumption which transcends basic food, shelter and clothing, and the structure of the working force transforms in ways which enhances not only the proportion of urban to total population, but also the proportion of the population working in offices or in skilled factory jobs. In addition to these economic changes, the society ceases to accept the further extension of modern technology as an overriding objective and resource are shifted to the promotion of welfare and security.

2.2.7 Lewis Theory of Economic Development

Lewis' theory elucidates the mechanism of the changing structure of underdeveloped economies from subsistence agriculture to a more modern and urbanised system. This model turned out to be the generally accepted theory of the course of development during the 1960s and early 1970s.

In this theory, Lewis divided the underdeveloped economy into two sectors; the capitalist/industrial sector and the agricultural/subsistence sector. The agricultural sector is assumed to have huge amounts of excess labour that result in an awfully low, almost zero, marginal productivity of labour. The agricultural wage rate is believed to follow the sharing rule and be equal to average productivity, which is also known as the institutional wage. This sector exists alongside a high-productivity modern urban industrial sector into which labour from the subsistence sector is gradually transferred. The non-agricultural/industrial sector has an abundance of capital and resources relative to labour. It pursues profit and employs labour at a wage rate higher than the agricultural institutional wage by approximately 30% (Lewis 1954).

The major relationship between the two sectors is that when the capitalist sector grows, it draws labour from the subsistence sector. In other words, the non-agricultural sector accumulates capital by drawing surplus labour out of the agricultural sector. The expansion of the non-agricultural sector takes advantage of the infinitely elastic supply of labour from the agricultural sector due to its labour surplus. When the surplus labour is exhausted, the labour supply curve in the non-agricultural sector becomes upward-sloping. As employment increases, there will be more output hence more income and proceeds. Additional income will increase demand for domestic goods and services while increase in profits will be reinvested. The rural–urban migration, therefore, offers self-generating growth. Lewis' theory has been proven applicable in the real world by empirical studies (Ranis and Fei 1961; Minami 1967; Ohkawa 1965). They found that agricultural labour migration promoted economic growth in developing economies.

The table below gives an overview of the views of the various economists on economic growth with possible similarities and differences (Table 2.1).

2.3 Natural Resources and Economic Growth

Hotelling's rule focusses on the decision required by an owner of a non-renewable natural resource with regards to maximising value from that resource. For the owner, it becomes a choice of extracting the resource now and achieving the current value or leaving it unextracted to gain some future increased value (Gaudet 2007).

For a non-renewable resource, the stock cannot increase over time and the rate of return on such a resource is influenced by the rate of marginal productivity, the resource's changing physical characteristics and any changes in market value. If no use is made of such a resource the marginal productivity is zero. All other things being equal, technological progress should reduce the cost of extraction of natural resources (Gaudet 2007). The market value of a scarce resource should increase with time as the resource becomes more scarce if no alternative for that resource is found.

Table 2.1 Summary of views on economic growth

Category	Name	Key element	Result
Classical economists	Adam Smith	Capital accumulation and division of labour	Growth in the labour force and stock of capital Improvement in the efficiency with which capital is used in labour through greater division of labour and technological progress Promotion of foreign trade that widens the market and reinforces the other two sources of growth
	Thomas Malthus	Population growth versus economic growth	Growth falls as the population increases
	David Ricardo	Law of diminishing returns in growth	The diminishing economic return was the cause of the diminishing quality of resources, not their absolute scarcity
Keynesian economists	J.M. Keynes	Inducement to invest	Low-interest rates, government investment and redistribution to the poor
	Harrod/Domar	Growth depends on the quantity of labour and capital	Economic growth depends on policies to increase investment, by increasing saving and using that investment more efficiently through technological advances

(continued)

Table 2.1 (continued)

Category	Name	Key element	Result
Neoclassical economists	Solow/Swan	Explain long run economic growth by looking at capital accumulation, labour or population growth, and increases in productivity, commonly referred to as technological progress	Exogenous growth implies that the long run growth rate depends on the growth rate of the labour force and on labour augmenting exogenous technical progress
Development economists	W.W. Rostow	Economies must undergo a number of developmental stages towards better economic growth	Economies actually undergo a number of developmental stages towards better economic growth
	W.A. Lewis	Mechanism of the changing structure of underdeveloped economies from subsistent agriculture to a more modern and urbanised system	Two types of economies live and interrelate with each other; subsistence and urban economies

However, a typical non-renewable resource, if extracted, results in a lower average quality of that resource in the remaining stock as most extraction will be done of high-quality resource in the first instance. Therefore, the quality and return of such a resource will reduce over time. This is consistent with a price path that would be at first decreasing and then increasing (Gaudet 2007). As the resource stock gets depleted, it can be assumed that the marginal cost of extraction has to increase, due to the fact that the resource tends to be less easily available and of lesser grade. A marginal addition to current resource extraction not only uses up the resource stocks, but it uses up the cheapest available and hence increases all future cost (Hotelling 1931). The net price per unit of product received by the owner of a mine depends not only on the current rate of production but also on past production. The accumulated production affects both cost and demand. The cost of extraction increases as the mine goes deeper; and durable substances, such as gold and diamonds, by their accumulation influence the market (Hotelling 1931).

In a hypothetical market with free competition, Hotelling assumes the resource owner is indifferent whether he receives a price for a unit of his product now or a price after some time has elapsed. This will not apply to monopoly, where the form of the demand function is bound to affect the rate of production, but is characteristic of completely free competition. The various units of the mineral are then to be thought of as being at any time all equally valuable, excepting for varying costs of placing them upon the market. If interest rates vary among the resource owners, this fact will also affect the order of extraction.

In an imperfect market situation, if the resource stock is in under monopolistic protection, the marginal value to the owner of the stock of resource left in the ground will be equal to the marginal profit it can bring on the flow market once extracted. To a monopolist, this is less than the net price. The asset markets equilibrium condition will still require that the rate of return on the resource stock be equal to the rate of interest. Only now the rate of appreciation of the 'in-situ' value is not measured by the rate of change of the net price, but by the rate of change of the monopolist's marginal profit. Hence, marginal revenue will rise at the rate of interest (Gaitan et al. 2006).

Natural resources are as important to the growth and development of an economy as physical and human capital. Natural resources are part of the real wealth of a nation and they are the natural capital where all the other forms of capital are made (OECD 2011). They add value to fiscal revenue, income, and poverty reduction and natural resource related sectors provide jobs and are often the basis of livelihoods in poorer communities. Figure 2.1 illustrates the role and importance of natural resources to the growth of an economy.

The UK has a variety of natural resources including both geological (coal, petroleum, natural gas, limestone, chalk, gypsum, silica, rock salt, china clay, iron ore, tin, silver, gold, lead) and agricultural (arable land, wheat, barley, sheep). The UK has large coal, natural gas and oil resources; primary energy production accounts for 10% of GDP, one of the highest shares of any industrial nation. UK Gross Domestic Product (GDP) has steadily increased over the past 30 years (see Fig. 2.2) with a significant fall occurring after 2007 following the global financial crisis. The highest recorded UK GDP was $3.063 trillion in 2007 just before the crisis, which fell, by $188 billion to $2.875 trillion in 2008. The UK economy almost reached its 2007 level in 2014 ($2.999 trillion) then fell slightly to $2.858 trillion in 2015.

Food and oil prices have traditionally been fairly constant during periods of economic growth (see Fig. 2.3). Up until the year 2000 both were, while exhibiting some volatility, stable. However, since 2000 both have steadily risen. Food prices recorded its lowest level at $91 per basket in 2000, then rose steadily to its first peak at above $201 per basket in 2008, a steep drop to $160 a basket in 2009, then rose to its second peak at $229 in 2011, then steadily and slowly dropping. Oil prices followed a somewhat similar pattern; beginning at a very low price at $12/barrel, oil prices steadily increased to its first peak a $96/barrel in 2008, falling sharply to $61 in 2009, then increased to another peak in 2011 at $111.26/barrel, increased slightly to $111.63/barrel in 2012, then fell to $108 in 2013. It should be noted the initial rise in both food and oil prices occurred before, and in the run up to, the global financial crisis and both dropped following the crisis.

When a particular country has natural resources, such as oil or food, this tends to increase levels of investments, especially in the extractive, agriculture and transportation sectors. Such increases in investments contribute to the growth of the finance sector through the borrowing, lending, liquidity and credit activities involved in investment. This growth in investment and the finance sector increases human capital development and economic growth. Human capital development is increased and developed through training and education.

In the UK, natural resources are playing a vital role:

- The agricultural resources (food sector) alone contributed £97.1 billion or 7.4% to national Gross Value Added in 2012 and 3.6 million or 13% of national employment in 2013. Total Factor Productivity in the food sector (excluding agriculture) stabilised in 2012 having risen gradually since 2002.

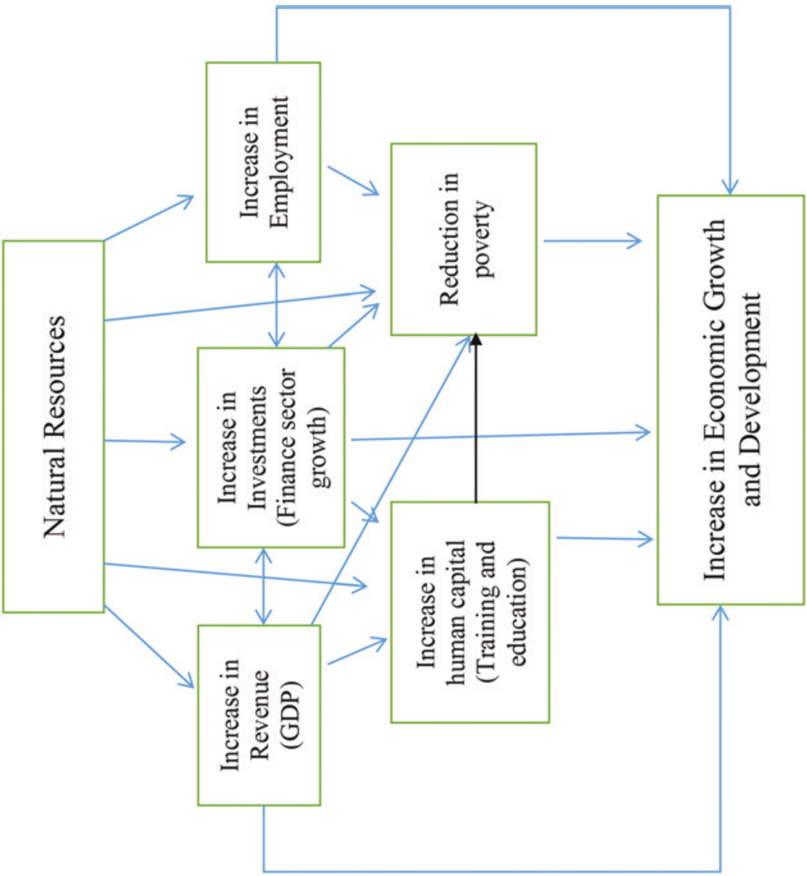

Fig. 2.1 Role of natural resources in economic growth

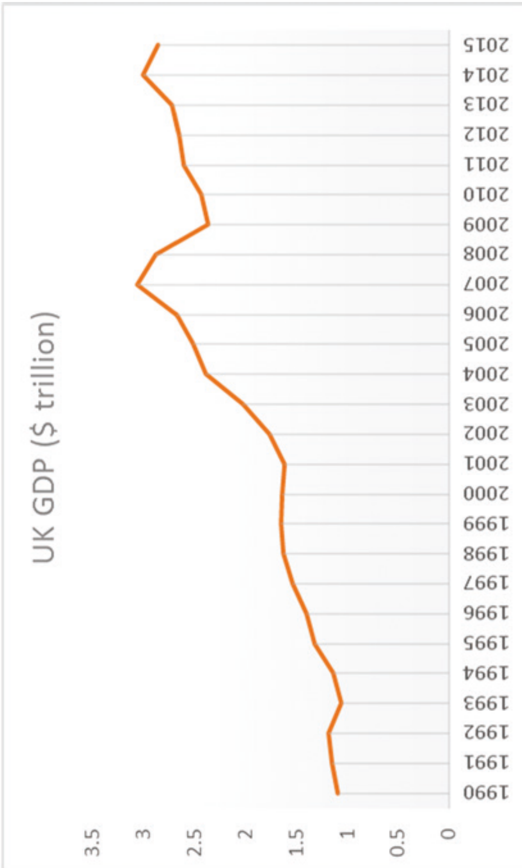

Fig. 2.2 UK Gross Domestic Product (GDP)

- The energy sector's direct and indirect contribution to the UK economy in 2011 was estimated to be £89bn (Ernst and Young 2012). The energy sector's total employment impact to the national economy in 2011 amounted to 137,000 full time and part time jobs.

2.3.1 Oil Shocks and Economic Growth

Krautkraemer (2005) asserts that empirical literature on natural resource scarcity/constraint spells 'impending doom' on economic growth and technological progress which is not necessarily true, 'at least not yet…. If there is any systematic bias to past predictions of the future, it is an underestimation of the ability of technological progress to overcome natural resource scarcity'. However, academic and professional literature has differing opinions on the effect of resource scarcity on the growth of an economy. For instance, any scarcity of energy resources could trigger a rise in oil prices in a classic supply-side shock (Balke et al. 1999). As a result of the increase in price, or because of physical scarcity of resources, economic growth is slowed (Stern 2010). Slower growth reduces real wage growth and increases unemployment rates (Rasche and Tatom 1977, 1981; Barro 1984; Balke et al. 1999).

Brown et al. (2011) examined the causal relationship between energy and economic growth by using 'a macro ecological approach to integrate perspectives of physics, ecology, and economics with an analysis of extensive global data to show how energy imposes fundamental constraints on economic growth and development'. Results showed that most metrics of well-being, including GDP, literacy, etc., were all positively correlated with, and caused by, energy consumption.

Hamilton (1988) asserted that oil shocks affect the macro economy primarily through the depression of demand for important consumption and investment goods. Historically, oil shocks have been characterised by widespread concerns about the price and availability of energy which could cause investment decisions to be postponed, thereby adversely affecting economic growth.

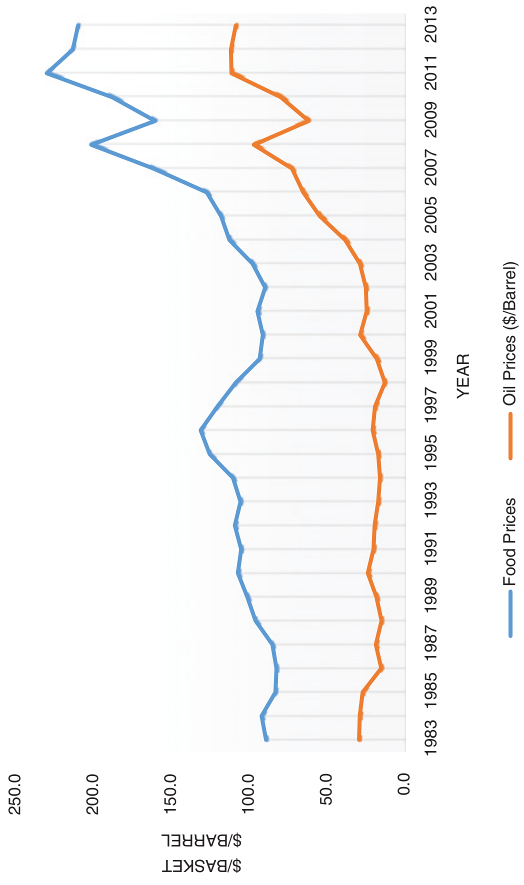

Fig. 2.3 Food and oil prices (Food and Agricultural Organisation 2013)

Hirsch (2008) demonstrated the connection between world oil production and GDP between 1986 and 2005. Oil price shocks preceded 11 of the 12 recessions in the USA since 1945 (Rubin 2008; Hamilton 2009; Alpanda and Peralta-Alva 2010). While the claim may be controversial, Hamilton (2009) also showed that the oil price shock in 2007–2008 was sufficient to explain the 2008–2009 recession of the USA.

Beyond the USA literature has explored the different impacts that resource shocks may have. Using Granger causality tests and cross correlations, various relationships between oil prices and macroeconomic variables have been found (Lescaroux and Mignon 2008) over both long and short term considerations. A particularly strong relationship was found between oil price and the performance of stock markets.

Bildirici and Kayikci (2012) concentrated on analysing the relationship between oil production and economic growth in major oil exporting Eurasian countries. Empirical results reveal that oil production and economic growth are cointegrated for these countries. Furthermore, there is positive bidirectional causality between oil production and economic growth both in the long run and in the short run which supports the policies of investing in energy infrastructure. Creti et al. (2014), on the other hand, attempted to complement existing analysis of the impact of oil price shocks on the growth of importing countries by assessing such impacts on the growth of oil exporting (OPEC) countries. Their analysis indicated that oil exporting countries were more sensitive to oil shocks than oil importing countries, significantly affecting real economic activity.

Berument et al. (2016) found mixed results with oil prices having significant effects on growth outputs of Algeria, Iran, Iraq, Kuwait, United Arab Emirates, Oman, Libya, Syria and Qatar, and no significant effects on Bahrain, Israel, Egypt, Djibouti, Tunisia, Morocco and Jordan. However, Sotoudeh and Worthington (2015) assert and conclude that the economies of oil producing (oil exporting) and oil consuming (oil importing) countries react in a similar manner to global oil price shocks.

Mehrara (2007) identifies two emerging points in literature on the energy-economic growth analysis; energy consumption is a limiting factor to growth and energy consumption is neutral to growth.

He examined the causal relationship between energy use and consumption and economic growth for 11 oil exporting countries and the results showed a strong unidirectional relationship from economic growth to energy consumption. Thus trends in economic growth could forecast increases in energy consumption and energy conservation measures can be imposed with no significant impact on economic growth.

The energy consumption-economic growth nexus was reinvestigated by Mahadevan and Asafu-Adjaye (2007) in a panel error correction model using data on 20 net energy importers and exporters over a period of 30 years. There was bidirectional causality between economic growth and energy consumption among the energy exporters in the developed countries in both the short and long run. However, energy consumption stimulates growth only in the short run in the developing countries. The former result was also found for energy importers and the latter result exists only for the developed country importers within this group. Furthermore, developed countries have a higher response elasticity in terms of economic growth from an increase in energy consumption compared to that of developing countries, although its income elasticity was lower and less than unitary. Ozturk et al. (2010) use panel data of energy consumption and GDP for 51 low- and middle-income countries to investigate the relationship between the two factors. Results showed that energy consumption and GDP were cointegrated and a long run causality ran from GDP to energy consumption for low-income countries and a bidirectional relationship for middle-income countries.

Lee and Chang (2008) found that although economic growth and energy consumption had no short run causal relationship in 16 Asian countries from 1971 to 2002, there is long run unidirectional causality running from energy consumption to economic growth. This means that reducing energy consumption does not adversely affect GDP in the short run but would in the long run.

For developed countries, Soytas and Sari (2003) found a bidirectional causality for Argentina, a unidirectional causality for Italy and Korea running from GDP to energy consumption and a unidirectional relationship ran from energy consumption to GDP in Turkey, Germany, Japan and France indicating a possibility of energy conservation affecting the growth of these four countries. For developing countries Balassa (1985), in his study of 43 developing countries in the 1973–1978 period of oil price shocks, showed that inter-country differences in the rate of economic growth are affected by differences in investment rates and by the rate of growth of the labour force, by the initial trade policy stance and by the adjustment policies applied, as well as by the level of economic development and the product composition of exports. The results also showed that the oil policies adopted have importantly influenced the rate of economic growth in developing countries. In particular, an outward-oriented policy stance at the beginning of the period and reliance on export promotion in response to these shocks, appear to have favourably affected growth performance. The results further indicated the possibilities for low-income countries to accelerate their economic growth through the application of modern technology in an appropriate policy framework as well as the advantages of relying on manufactured exports.

Using causality analysis over 31 years of data it can be shown that there is bidirectional causality between oil energy consumption and growth in Brazil, Russian, India, China, Turkey and South Africa (Bildirici and Bakirtas 2013). For coal consumption there is bidirectional causality for China and India and for gas a bidirectional causality relationship for Brazil, Russia and Turkey. By examining the impact of energy shocks it has been found that negative shocks have a larger impact on output growth than positive shocks (Arac and Hasanov 2014) in Turkey. In addition, larger negative shocks have a much larger effect on growth than small negative shocks.

Chen et al. (2014) assert that despite the accumulation of empirical evidence on the effects of energy consumption and oil prices on growth there are, nevertheless, two major flaws in the conventional method of modelling oil price shocks frequently used in the literature. First, oil price shocks are assumed to be exogenous even though a reverse causality may run from real economic activities to oil prices. Second, recent literature also presents evidence of the relation between oil prices and stock prices depending on the origin and nature of oil price shocks (Ciner and Lucey 2013; Degiannakis et al. 2013). These results show that the macroeconomic effects of oil price shocks could depend on other underlying causes, which have not been fully accounted for in previous analyses.

In order to overcome such deficiencies, Kilian (2009) proposed a two-step approach to the analysis of the macroeconomic impacts of oil price shocks. In the first step, a vector autoregression (VAR) which included oil production, global economic activity and oil prices as endogenous variables was estimated in order to classify three categories of structural shocks that caused oil price changes: an oil supply shock, an aggregate demand shock and an oil market-specific demand shock that mirrored unexpected changes in precautionary oil demand. In the second step, ordinary least squares (OLS) regressions were estimated to evaluate the impact of the identified and classified structural shocks on the macroeconomic indicators. The framework was adopted to demonstrate that US macroeconomic indicators responded differently to oil price shocks depending on the types of underlying shocks.

Fang and You (2014) modified this framework to analyse the impact of oil price shocks to the stock market prices of the New Industrialised Economies (NIEs) (China, India and Russia). They find that the impact of oil price shocks on stock prices in these large NIEs is mixed, partly in contrast to the effects on the US and developed countries' stock markets. This result is also consistent with the previous empirical findings that the NIEs' stock markets are 'partially integrated' with the other stock markets and oil price shocks. Similar results come from the analysis carried out by Narayan et al. (2014) on the predictability of growth from oil prices from 28 developed and 17 developing countries. Their results showed that there was greater evidence of predictability in developed than developing countries.

The financial services sector, defined here as private and public institutions that offer insurance, banking and pension services, is an exclusive pointer to the potential socioeconomic impacts of resource scarcity because it is an integrator and spreads the effects on to other sectors and the society (Vellinga and Mills 2001). However, there seems to be a viscous cycle running from oil price shocks to financial shocks, especially in financial markets. Chen et al. (2014) in their investigation on the macro economic impacts of oil prices, identified financial shocks as one of the shocks underlying oil price shocks making it a major determinant of oil price. Thus if oil price shocks affect the finance sector, the finance sector could, in turn, influence oil prices and if this viscous cycle is not curbed from one party or both, the effects could escalate to risk levels which could be difficult to manage in the future.

2.3.2 Water and Economic Growth

Turning now to another resource, current water usage in the majority of countries around the world does not constrain growth. However, in some countries extreme water scarcity could impact growth although investing in increasing water output counters this impact. Rijsberman (2006) reviewed water scarcity indicators and global assessments based on these indicators. The most widely used indicator, the Falkenmark indicator, was popular because it was easy to apply and understand the true nature of water scarcity, though it didn't give a full explanation of the nature of scarcity in question. He found that there is definitely water scarcity in densely populated arid areas, such as Central and West Asia, and North Africa. This scarcity relates to water for food production and in most of the rest of the world water scarcity at a national scale has as much to do with the development of the demand as the availability of the supply. Accounting for water for environmental requirements showed that abstraction of water for domestic, food and industrial uses already have had a major impact on ecosystems in many parts of the world, even those not considered 'water scarce'. He thus predicted that water would be a major constraint for agriculture in coming decades and particularly in Asia and Africa this will require major institutional adjustments.

Water is, of course, a vital resource for every nation. It is also embedded, so called virtual water, in many export products including food and textiles. Therefore, to model water risk fully requires a detailed understanding of the international trade in these related products (Berrittella et al. 2007). Using a general equilibrium model five alternative scenarios for water scarcity were modelled (Berrittella et al. 2007). Four scenarios were based on a 'market solution', where water owners could capitalise their water rent or taxes were recycled. In the fifth 'non-market' scenario, supply restrictions implied productivity losses. Each scenario saw a shift in trade patterns which were larger if the restriction was larger and if the use of water in production was more rigid. The non-market scenario saw much more significant negative impacts. However, there were regional winners and losers from water supply constraints.

The CERES report (2009), identified eight water-intensive industry sectors affected by water-related risks. Three prominent sectors include:

- The High-Tech industry where 11 of the world's 14 largest semiconductor factories in the Asia—Pacific region, are severely affected by water quality risks. Revenue of up to $100–$200 million or $0.02 or $0.04 per share could be lost as a result of water-related risk shutdown at a fabrication facility operated by these firms.
- The Beverage industry where the Coca-Cola and PepsiCo bottlers lost their operating licenses in parts of India due to water shortages and all major beverage firms were facing stiff public opposition to new bottling plants—and to bottled drinking water altogether.
- Reduced water availability in agriculture had already been impacting food commodity prices, as shown by the previous year's sharp increase in global prices triggered by a drought-induced collapse of production in Australia. Approximately 70% of the water used globally is for agriculture, with as much as 90% in developing countries where populations are growing fastest.

The report also identified water-related risks for electric power/energy, apparel, biotechnology/pharmaceutical, forest products and metals/mining firms. For companies in these and other sectors, climate change would further reduce the availability of reliable and high-quality water, impacting productivity, costs, revenues, public goodwill and reputation. The report also highlighted the escalating struggle between energy use and water availability. With increasing regularity, selecting one of these resources could mean undermining the other—the other, usually being water.

Another CERES report (2012) on water risks to economic growth and investment asserted that water risks and stress continued to intensify as a result of the droughts which occurred in 2011 and 2012 in the USA which has made the nation's supply of water vulnerable and the cause of economic losses worth billions of dollars. Consequently, the pricing of water risks in the market is beginning to change as an investment in public water systems is taking a different perspective.

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