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Analysis

Dematerialization, Decoupling, and Productivity Change

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ABSTRACT

The prospects for long-term sustainability depend on whether, and how much, we can absolutely decouple economic output from total energy and material throughput. While relative decoupling has occurred – that is, resource use has grown less quickly than the economy – absolute decoupling has not, raising the question whether it is possible. This paper proposes a novel explanation for why decoupling has not happened historically, drawing on a recent theory of cost-share induced productivity change and an extension of post-Keynesian pricing theory to natural resources. Cost-share induced productivity change and pricing behavior set up two halves of a dynamic, which we explore from a post-Keynesian perspective. In this dynamic, resource costs as a share of GDP move toward a stable level, at which the growth rate of resource productivity is typically less than the growth rate of GDP. This provides a parsimonious explanation of the prevalence of relative over absolute decoupling. The paper then presents some illustrative applications of the theory.

1. Introduction

When the UN General Assembly (2015) adopted the 2030 Agenda for Sustainable Development, it brought a renewed focus to a long-standing question: the potential for material and energy throughput to decouple absolutely from economic growth. Goal 12 is to "Ensure sustainable consumption and production patterns," including "the sustainable management and efficient use of natural resources" by 2030, while Goal 13 is to "Take urgent action to combat climate change and its impacts." As climate mitigation requires that most remaining fossil resources remain in the ground (McGlade and Ekins, 2015), taking urgent action implies an immediate decoupling of fossil energy consumption from economic output. Recently, carbon emissions from fossil fuel use and industry have slowed, or even briefly reversed, indicating some success toward this goal, although not at a rate fast enough to meet globally-agreed climate targets (UNEP, 2016). However, the wealth of nations depends on energy flows (Hall and Klitgaard, 2012), and total energy and material use has not absolutely decoupled from GDP. Rather, we have seen relative decoupling, in which material and energy intensity declines at a slower rate than GDP grows, while absolute resource and energy consumption continue to rise (Bernardini and Galli, 1993; Ayres and Warr, 2009). This pattern seems likely to continue in future (Ward et al., 2016).

The substantial literature on dematerialization and decoupling has not reached consensus on mechanisms. Two persistent and partially competing concepts are Jevons' paradox (Jevons, 1865; Khazzoom, 1980; Alcott, 2005; Sorrell, 2009) and the Environmental Kuznets Curve (EKC) hypothesis (Auty, 1985; Dinda, 2004). Jevons' paradox states that an increase in resource efficiency leads indirectly to an absolute increase in the use of that resource, as a falling price brings formerly unprofitable resource-consuming processes into production and rising incomes drive consumption. The EKC hypothesis is motivated by a narrative of economic development. Early in the process, resource-intensive industrial production dominates, and raising incomes is more important than protecting the environment. As labor productivity and wages grow, industry declines relative to services, while environmental quality becomes more important than rapid growth. Ayres and van den Bergh (2005), Warr and Ayres (2012), and Cogoy (2004) extrapolate this dynamic, arguing that decoupling can occur through value-creation in the service sector as rising demand for services relative to physical goods is reinforced by increasing service sector labor productivity through human capital accumulation.

Jevons' paradox suggests that decoupling will never happen, while the EKC hypothesis suggests that decoupling can occur after a sufficiently long period. Both are contested. For Jevons' paradox, in particular, a number of papers argue both for and against the hypothesis as it applies to mature economies (e.g., Sorrell, 2009; Cullenward and Koomey, 2016). The evolving empirical literature on the EKC appears to disprove its existence (Stern, 2004; Wagner, 2008), but the concept is attractive enough for discussion to continue (Dinda, 2004; Kijima et al., 2010). We do not address the controversies in this paper, but note that proponents of Jevons' paradox and of the EKC propose distinct causal relationships between energy and material use on long-run GDP growth. Jevons' paradox assumes that resources constrain growth, so

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releasing those constraints stimulates expansion, while the EKC hypothesis assumes that economic growth drives resource use, with a relationship that depends on the developmental stage of the economy.

The phenomenon of relative decoupling is related to the concept of the economy-wide or macroeconomic rebound effect (Thomas and Azevedo, 2013). Rebound is concerned with the unintended consequences of efficiency gains. It is often applied to household demand (as in Azevedo, 2014), but also encompasses efficiency gains by industry, as we consider in this paper. Both Dimitropoulos (2007) and Cullenward and Koomey (2016, 204) argue that the theoretical and empirical bases of the economy-wide rebound effect are weak, lacking specific causal mechanisms. The main theoretical approaches apply neoclassical production functions (notably Saunders, 1992) or computable general equilibrium (CGE) models. Results from these studies are sharply conflicting.

In this paper we provide a parsimonious explanation, different than existing explanations, for the failure of resource throughput to decouple absolutely from economic output, which we explore from a post-Keynesian perspective. We start from two assumptions: 1) innovation that saves on inputs to the production of goods and services is biased toward higher-cost inputs, as measured by the cost share; and 2) resource prices rise in the short run when demand increases relative to capacity, while manufacturing prices are administered (Lee, 1999). These two assumptions set up two halves of a process, which can be thought of as a supply-demand dynamic that plays out over time. Firms buy resources on commodity markets at prevailing and publicly-announced prices. Those prices clear their markets in a short period during which firms' production schedules determine an inelastic level of demand. Demand for resources responds to price changes indirectly, and after a delay, as firms reduce costs at prevailing prices through technological innovation, and then adjust their administered prices to reflect their revised cost structure. Industrial firms pay very little attention to demand when setting prices (Coutts and Norman, 2013), so their prices are not market-clearing; in this post-Keynesian model, it is productivity growth rates and cost shares, rather than prices, that adjust to move the system toward an equilibrium.

The assumption that resource productivity growth is driven by resource costs is an extension to natural resources of theories of cost-share induced technological change, in which the relative pace of labor-saving or capital-saving innovation increases with the shares of labor and capital costs in production (Hicks, 1932, 124 ff.; Duménil and Lévy, 1995; Foley, 2003a, 42 ff., 2003b; Kemp-Benedict, 2017). This can be contrasted with neoclassical theories of induced technological change, in which profit-maximizing firms choose technologies within a space of possibilities that is bounded by an expanding production possibilities frontier (Kumar and Managi, 2009; Acemoglu, 1998, 2002). The approach to cost-share induced technological change followed in this paper, and described in detail in Kemp-Benedict (2017), does not require a production possibilities frontier. Instead, consistent with evolutionary theories of technological change (Nelson and Winter, 1982; Duménil and Lévy, 1995), firms seek marginal improvements on existing technology, and adopt discoveries that increase profits at prevailing prices. The result from Kemp-Benedict is quite general: the Jacobian matrix expressing the change in productivity growth rates with respect to cost shares is symmetric and, to a good approximation, positive semi-definite. These characteristics permit a stability analysis with very few additional assumptions.

In post-Keynesian theory most firms operate in an oligopolistic environment and have considerable flexibility in setting prices, including wages. Prices are cost-based, largely insensitive to demand, and maintained across pricing periods that can be several quarters long (Coutts and Norman, 2013). The price system is determined by the costs of inputs, inter-industry relationships, and profit margins, which are set high enough to maintain the enterprise as a going concern but not so high as to encourage entry by rivals. Firms tend to engage in non-price competition because price wars, in which firms seek to undercut each other, are costly to all participants. Markets in natural resources are different, because they are commodities, so one producer's output is indistinguishable from that of any other. Thus, even in oligopolistic industries, producers are not free to set their prices because they cannot engage in non-price competition. Commodities are graded, bundled and sold on exchanges, where prices respond to changes in demand relative to storage and to local supply conditions (Gray and Rutledge, 1971; Williams, 1986). While the post-Keynesian literature recognizes that resources are priced differently than other goods (Kalecki, 1969, 11; Kriesler, 1988; Coutts and Norman, 2013, 8), that distinction is rarely taken into account in post-Keynesian models. We therefore devote a section of the paper to resource pricing. We apply conventional post-Keynesian pricing in the productive sector and resource pricing in extractive sectors.

We present the theoretical arguments in terms of a two-sector model, consisting of an extractive and a productive sector. While keeping the fossil extractive industry in mind throughout the analysis, we refer to a generic “resource”. Addressing resource costs in the productive sector separately from labor and profits, we show that resource costs as a share of GDP (the “resource share”) and resource productivity growth rates move toward stable levels, at which the growth rate of resource productivity is nearly always less than the growth rate of GDP. That is, we find relative but not absolute decoupling arising from the behavioral assumptions of the model. We then show that the same result holds when labor costs and profits are included. For this demonstration, we extend the analysis to a three-sector model with two extractive sectors: renewable and non-renewable. The model has an equilibrium defined in terms of cost shares and productivity growth rates rather than prices.

The main novelty of this paper is its explanation of decoupling, or the lack of it, using a recent innovation in the theory of cost-share induced technological change (Kemp-Benedict, 2017). We identify general economic behaviors that can underlie both relative and absolute decoupling in different environments. We show that when resources are comparatively abundant, relative decoupling should occur, while absolute decoupling should not, although transitory deviations are possible during technological or structural transitions. Thus, with few assumptions, the model explains the dominant pattern of resource use observed in high-income countries, helping to fill gaps in the theory of decoupling and the related concept of the macroeconomic rebound effect. As we seek to describe generic outcomes from a minimal set of assumptions, the paper is necessarily theoretical, but to make the ideas more concrete we show how the theory can be applied in practice.

2. Extractive Industries and Commodity Prices

Post-Keynesian pricing theory is well developed for the manufacturing sector (Coutts and Norman, 2013). It accounts for the oligopolistic nature of most industries, the need to plan for a fundamentally uncertain future, and, most importantly, the pricing strategies and procedures actually used in firms. Post-Keynesian firms have considerable freedom to set their prices in order to meet target profit rates, constrained mainly by their desire to discourage their rivals from emulating their successes. The theory is less well developed for natural resources such as mining, oil, coal, and natural gas. While fossil fuel industries are oligopolistic, they are not as free as manufacturing firms to set their prices, because they produce interchangeable commodities for a global market. Prices for commodities are set in markets for contracts of different maturities, including for immediate delivery (spot prices). Spot prices for oil and gas are reported for benchmark commodities or at the port of Rotterdam, while futures contracts are traded on exchanges. For example, Brent crude is a benchmark light (low-density) and sweet (low-sulfur) crude oil, as is West Texas Intermediate (WTI). Large producers manage price fluctuations by starting up or shutting down wells with different operating costs depending on the current price.