Ecological Economics 146 (2018) 164–172

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Economic Growth, Income Distribution, and Climate Change☆

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ARTICLE INFO

JEL Codes:
H21
Q51
Q54

Keywords:
Climate change
Economic growth
Integrated assessment
Demand and distribution
Energy productivity
Unemployment

ABSTRACT

We present a model based on Keynesian aggregate demand and labor productivity growth to study how climate damage affects the long-run evolution of the economy. Climate change induced by greenhouse gas lowers profitability, reducing investment and cutting output in the short and long runs. Short-run employment falls due to deficient demand. In the long run productivity growth is slower, lowering potential income levels. Climate policy can increase incomes and employment in the short and long runs while a continuation of business-as-usual leads to a dystopian income distribution with affluence for few and high levels of unemployment for the rest.

1. Introduction

Since before the Industrial Revolution, exponential economic growth has supported rising standards of living around the world. Ever-increasing use of natural resources, notably energy from fossil fuels, has been key to the process. Climate change is a civilization-threatening consequence. Increasing temperature and more frequent natural disasters will impact the economy in many ways, inflicting damage on output and assets. Here we present a model of economic growth based on Keynesian aggregate demand theory to study how climate feedbacks affect the long-run evolution of the economy.

Traditional growth theory attempts to explain sustained exponential increases of labor productivity and income. Early contributions such as Solow's influential model focused on capital accumulation as the engine of growth. Capital deepening (a higher capital/labor ratio) supposedly allows workers to be more productive (Harrod, 1939; Domar, 1946; Solow, 1956). This tradition of growth theory sees technological progress — due to either scientific and technological developments external to the economy or investment in research and development — as the other main driver of growth. Innovations can be technological or organizational such as the division of labor across and within industries. Decreasing costs due to economies of scale also play a role (Smith, 1776). Potential output is determined by the size and skills of the labor force, the accumulated capital stock, and the available technology. In supply-driven mainstream models it will always be realized through full employment of the available resources.

An important alternative conception of economic growth, based on Keynes' theory of aggregate demand, developed in the work of Nicholas Kaldor, Michal Kalecki, and Joan Robinson, emphasizes demand as the immediate driver of production and income growth in capitalist economies. The model we present here combines such a short-run demand-determined model of output with a model (inspired by Kaldor's thinking on economies of scale) of endogenous long-run technical change depending on the growth of output. We follow the Kaldorian tradition of linking capital accumulation with technological progress: high demand calls forth higher output and income, which over time lead to accumulation and provide a macroeconomic explanation for productivity beyond standard growth theory.

An important strand of thought in ecological economics emphasizes that increasing labor productivity has historically gone hand in hand with rising productive use of energy (Taylor, 2008). Since the 19th century, fossil fuels have been the principal source (Georgescu-Roegen, 1975; Cleveland et al., 1984; Ayres and Warr, 2009). We extend the standard model of economic growth to allow for this productivity-energy link directly. As a virtuous circle of economic growth and technological progress boosts standards of living, the need for natural

☆ This research was supported by the Institute for New Economic Thinking (INET) (IN01400031). Rezai is grateful for financial support from the Austrian Science Fund (FWF): J 3633. Research assistance from Luiza Pires and Özlem Ömer is gratefully acknowledged.

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http://dx.doi.org/10.1016/j.ecolecon.2017.10.020
Received 22 August 2017; Received in revised form 17 October 2017; Accepted 19 October 2017
0921-8009/

resources and energy increases.

So long as energy is derived from carbon-emitting fossil fuels, however, concentration of atmospheric carbon dioxide and other greenhouse gases increases and climate damage worsens. In principle, mitigation efforts can allow energy generation without the emission of carbon dioxide (and other greenhouse gases), severing the negative climate feedback and resolving the dilemma. Mitigation efforts also have an impact on levels of employment and the distribution of income, which our current model can track.

Whether growth is socially sustainable is a further question (Foley, 2012). Mainstream growth theory assumes that labor and capital are fully employed and that the distribution of income between wages and profits is set by their technically determined "marginal" contributions to output. The alternative Keynesian tradition treats output as determined by demand. Income distribution has an immediate impact on output and growth. If there is insufficient demand for labor, unemployment results. For a given level of economic activity, higher labor productivity destroys jobs. High levels of unemployment weaken the bargaining position of workers and lead to lower wages. Faster productivity growth has the potential to increase living standards but also the potential for a less equal distribution of income and lower levels of employment. Climate change worsens the problem.

The economics of economic growth, labor productivity, climate change, and the distribution of distribution are well established but have been seen as mostly separate from each other. Climate change economics mostly uses supply-driven growth models in which the distribution of income is derived from marginal productivity rules and assumptions about the shape of production function isoquants (Nordhaus, 2014). Non-neoclassical growth theory does address the interaction of distribution and output determination, but has only recently begun to study the question of energy use and climate change (Taylor, 2004; Taylor et al., 2013). The emerging field of Ecological Macroeconomics tries to bridge this divide, in particular, the contradiction between stimulation of CO_2 and other greenhouse gas emissions by higher energy use to support output and retardation of production by climate damage (for a review see Rezai and Stagl, 2016). A natural extension is to study endogenous productivity growth and its implications for the distribution of income and aggregate demand.

In the short run in our model, economic output is determined by aggregate demand that depends on the distribution of income, labor productivity, the amount of accumulated capital, and climate change. If the economy is operating at a high level of aggregate demand, employment grows and the distribution of income shifts toward labor. Greenhouse gas accumulation accelerates. Both factors induce a squeeze on profits, which ultimately limits demand. Over a period of decades, ongoing climate change lowers profitability and investment sufficiently to reduce output to sustainable levels where emissions and climate change stabilize. This process will entail overshooting of emissions and atmospheric carbon concentrations and cyclical adjustment due to the long lags in the climate system. The impacts on the distribution of income and employment levels will depend on society's institutions. Mitigation has the potential to take off the brakes: decarbonizing energy generation avoids carbon emissions and reduces the negative impact of growth-induced climate change. In the absence of other resource limitations, the economy resumes a stable path of continued economic and labor productivity growth. In Section 3 we present illustrative numerical simulations of the model, with details of the specification in the Appendix.

2. A Post-Keynesian Model of Economic Growth and Climate Change

Keynesian models basically say that spending determines income which includes profits P and wages W. In practice, a portion of profits is retained within business (with an implicit saving rate of 100%) and the rest distributed to households via interest, dividends, and capital gains. Rich households receive the bulk of distributed profits; the remainder with low or negative saving rates mostly receive wages (and government transfers). These observations suggest that the saving rate from profits (s_c) exceeds the rate from wages (s_w). The profit rate is equal to profits over capital stock, $r = P/K$, the wage share equals wages over total income, $\psi = W/X$, and the profit share is $\pi = P/X = 1 - \psi$.

Aggregate private sector saving is

$$S = s_c P + s_w W = s_c r\, K + s_w \psi\, X = s_c r\, K + s_w (1 - \pi) X$$
$$= (s_c - s_w)\, r\, K + s_w X \quad (1)$$

with $rK = \pi X$.

Firms hire labor at the total wage bill W. They also undertake investment into new capital stock. We assume a linear independent investment function in which capital formation responds to profits and economic activity. Autonomous investment is scaled to capital via the coefficient g_0.

$$I = \alpha\, P + \beta\, X + g_0 K. \quad (2)$$

Output creates emissions which lead to climate change. The government spends a fraction of GDP on mitigation to reduce these emissions. Throughout this section we assume that it does so without balancing its books and ignore business cycle complications.[1] Total mitigation expenditure M is thus proportional to output,

$$M = m\, X. \quad (3)$$

Under "business-as-usual" (BAU) the government does not undertake any mitigation, $m = 0$.

In the model at hand, the *level* of the capital stock, K, scales the system. Its use is not subject to decreasing returns so that marginal productivity rules to determine r and π do not apply. As described in Eq. (7) below, *growth* of capital stimulates rising labor productivity.

2.1. Short Run Equilibrium

In accordance with the principle of effective demand, output adjusts in the short run so that saving equals the sum of conventional and mitigation investment. At any time the capital stock is given and the output-capital ratio, $u = X/K$, equals[2]

$$u = \frac{g_0 + m + [\alpha - (s_c - s_w)]r}{s_w - \beta}. \quad (4)$$

The Keynesian stability condition requires that investment responds less strongly than savings to output so $s_w > \beta$.[3] Output responds positively to profits in the short run if $\alpha > (s_c - s_w)$. Higher government expenditure to fight global warming, which in this section is financed by public debt, increases output unambiguously. Given a level of labor productivity, ξ, output determines employment: $L = X/\xi$. Higher output increases employment, while higher productivity at a given level of output leads to loss of jobs. Output is constrained by aggregate demand, not aggregate supply, in our model. This implies that output remains below capacity, despite aggregate demand and supply equalizing much quicker than the geological time scales considered in our model (see Taylor (2004) and Lavoie (2014) for introductions to demand-constrained traditions).

[1] Our assumption of the government taxing the private sector and using these funds to finance mitigation efforts is a simplification which allows by-passing the intricate dynamics of the energy system. In a more decentralized framework, the government would use several policy instruments (e.g. carbon taxes, renewable subsidies) in addition to direct investments to guide private investment behavior.

[2] Eq. (4) follows from solving Eqs. (1)–(3) for X and dividing by K. The ratio u is basically a scale-free gauge of economic activity. As discussed below, its level feeds back into the profit rate.

[3] The stability condition ensures that a small demand injection (e.g. consumption or investment) is met by larger demand leakage (e.g. saving) such that overall demand moves back toward its previous level. In this case the equilibrium level of output is dynamically stable.