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DEMAND-LED GROWTH AND ACCOMMODATING SUPPLY

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ABSTRACT

This paper presents a “supermultiplier” model in which the growth of autonomous demand (demand independent of the state of the economy) determines the steady-state growth rate of output. With reasonable parameters, endogenous adjustment of labor supply and productivity causes supply to accommodate the demand-led growth path, reconciling Harrod’s warranted rate of demand growth with the growth of supply. The model delivers a range of feasible aggregate growth paths and unemployment rates rather than a single “natural rate.” The results explain how economies can become trapped with low growth due to weak demand or fiscal austerity and suggest policy responses to “secular stagnation.”

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Demand-Led Growth and Accommodating Supply*

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Abstract

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Key words: demand-led growth, autonomous demand, supermultiplier, aggregate demand and supply reconciliation, secular stagnation.

JEL codes: E12, O40, E32

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1. Introduction

The question of what determines medium-term macroeconomic growth looms large in developed countries. A decade after the financial crisis burst the US housing bubble growth remains disappointing, well below the pre-crisis trend. In Europe, growth has fallen short of expectations (or expectations are continually revised downward) with fiscal austerity as a likely culprit in many countries. Growth in the Japanese economy has underperformed for more than two decades.

In a market economy, profit-seeking firms hire workers and produce output because they expect to sell output, an expectation is grounded in actual sales. Thus, aggregate economic growth requires growing aggregate demand. Of course, demand growth is not sufficient to generate expansion. Growth also requires the resources and technology to produce output that fulfills growing demand. In a very general sense, therefore, growth depends on the dynamics of both demand and supply

Mainstream growth models, going back at least to Solow (1956), treat the demand and supply sides asymmetrically. Demand is assumed to accommodate to supply automatically "beyond the short run." Growth models based on the neoclassical synthesis perspective assume (often implicitly) that market adjustments of nominal wages and prices close any gap between aggregate demand and the supply-determined output path. More recently, in the so-called "New Keynesian" models, wise monetary policy reconciles demand and supply which again implies that growth beyond the short run is driven by the supply side with the dynamics of aggregate demand pushed entirely offstage.[1]

We challenge the view that economic growth beyond the short run can be explained by the supply side alone. The idea that nominal adjustment eliminates demand constraints over a time horizon relevant for medium-run economic growth has always been a weak link in mainstream

[1] In mainstream models of endogenous growth, aspects of the demand side can affect the level or even the growth rate of output by affecting the conditions of supply. For example, a change in consumption and saving behavior can affect capital accumulation and, therefore, the supply-determined level of potential output. But in these models, the proximate determinant of long-run output and growth is still supply.

macroeconomics.[2] The general ability of monetary policy to close demand gaps has also been questioned, especially in the stagnant aftermath of the Great Recession.[3] For these reasons, we propose a model in which demand constrains output over a medium-run to long-run horizon. This approach is consistent with the perspective of heterodox research on demand-led growth models.[4] That said, these models often leave the supply side implicit or assume an infinitely elastic supply of labor (see Dutt, 2012 and Freitas and Serrano, 2015, for recent representative examples).[5] This approach may have empirical relevance in emerging-market economies that can draw large numbers of workers from subsistence agriculture into market production. But developed economies have operated for much of the time in recent decades not so far away from conventional estimates full employment. In this situation, it is unreasonable to assume that arbitrary increases in demand growth can be accommodated without limit by the supply side. Setterfield (2013, page 24), following Cornwall (1972) describes this context as a "mature economy in which conditions of full employment may, in principle, be approached." Skott (1989, 2010) considers the importance of labor supply constraints even when demand dynamics determine growth. Therefore, this paper begins from the perspective that the dynamics of both demand and supply must be modeled explicitly to understand economic growth beyond the short run in developed economies.

We begin with a model of aggregate demand dynamics following the basic approach of Harrod's (1939) seminal contribution. As in Fazzari, et al. (2013), however, the inherent instability of

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[2] The conventional view that Keynesian results depend on nominal rigidity and that nominal adjustment eliminates demand constraints is ironic considering Keynes's own arguments in chapter 19 of the *General Theory*. For summaries of theoretical and empirical problems with the assumption that nominal adjustment renders demand irrelevant in the "long run," see Fazzari et al. (1998), Palley (2008), and Ferri et al. (2011) and the research cited in these articles. Bhaduri (2006, p. 70) makes similar arguments in the specific context of growth theory.

[3] See Cynamon, Fazzari, and Setterfield (2013) and Summers (2014).

[4] For surveys and comparisons of heterodox research on demand-led growth, see the books by Setterfield (2010), Hein (2014), and Lavoie (2014).

[5] In an overview of demand-led growth theory Keen (2012, p. 273) writes "most Post Keynesian work on growth has presumed that the main constraint of the rate of economic growth comes not from supply-side issues as in neoclassical theory, but from effective demand constraints."

the Harrod growth model is contained from above by the supply of resources and from below by autonomous demand, that is, demand that does not depend on the state of the economy. If autonomous demand grows at a constant rate, this growth rate determines the steady-state growth rate of demand, a result that reflects what Serrano (1995) labeled the "supermultiplier" model (also see Cesaratto, et al., 2003; Allain, 2015; Freitas and Serrano, 2015; and Serrano and Freitas, 2017). We derive this result here in an original framework and interpret the relevance of the steady-state results for understanding actual economic growth.

The main contribution of this paper is to introduce dynamics of supply that link both labor supply growth and labor productivity endogenously to the growth of actual output. We show that demand leads supply in the sense that supply growth will converge to demand growth determined by the path of autonomous demand and the supermultiplier. Therefore, there is no single "natural" rate of supply growth. Instead, different levels of autonomous demand growth can generate a continuum of dynamic paths for actual output and the unemployment rate. This model truly delivers demand-led growth, with the dynamics of supply adapting to the path of demand, just the opposite of the mainstream perspective about economic growth. The model also proposes a solution to Harrod's "reconciliation problem" between the growth of supply and demand.

While growth is demand led, supply constraints in our model limit the maximum feasible rate of growth. We link labor supply growth negatively to the unemployment rate, but labor supply is not infinitely elastic. As a result, if the unemployment rate is bounded below (even at zero) the range of demand growth rates that supply can accommodate is bounded above. Therefore, demand cannot generate arbitrarily high rates of growth. That said, a simple calibration of the model shows that the range of feasible demand growth rates that can be accommodated by supply easily covers a wide range of empirically relevant growth rates. We use this result to interpret how, for example, the loss of autonomous demand growth from the end of unsustainable household financial dynamics or from misguided fiscal austerity can trap an economy on a low-growth path of both demand and supply, well below what is feasible. This approach links our model to the interpretation of "secular stagnation" (see Summers 2014 and Cynamon and Fazzari, 2015) in the U.S. and other developed economies.

Section 2 of this paper presents the demand side of our growth model and develops the basic supermultiplier steady-state results. The endogenous dynamics of supply are discussed in section 3 and section 4 shows how the demand and supply sides are reconciled. Issues of dynamics stability of the steady state are considered in section 5. Section 6 discusses the implications of our model for understanding how the practical dynamics of demand lead economic growth with the conclusion and suggestions for further research in section 7.

2. Aggregate Demand and Steady-State Supermultiplier Growth

Aggregate demand consists of three components, business investment that builds the productive capital stock, consumption spending induced by income, and an autonomous component. Autonomous demand is defined as spending with dynamics independent of the state of the economy that does not build productive capacity. It could consist of autonomous consumption spending (as in Freitas and Serrano, 2016), government spending (Allain, 2015, for example), or exports (Nah and Lavoie, 2017, for example).[6]

We assume that firms choose investment in period t to reach a target expected capital-output ratio in t+1: $\hat{v}_{t+1} = K_{t+1}/EY_{t+1}$. Firms forecast output for period t+1 at the beginning of period t with knowledge of actual data up to period t-1. The target $\hat{v}_{t+1}$is analogous to desired capacity utilization. We treat $\hat{v}_{t+1}$ as a behavioral choice by firms rather than as an endogenous outcome that depends on

[6] Autonomous demand could also include government capital spending as long as the target stock of public capital is independent of the state of the economy.

the state of the economy, as is the case in many demand-led growth models.[7] This point is explained clearly by Skott (1989, p. 53): "investment is primarily induced rather than autonomous, and in steady growth the utilisation ratio of capital must be at the desired level" and by Cesaratto et al. (2003, p. 41): "capacity-creating expenditures basically depend on expectations about the evolution of effective demand over the life of the equipment." But despite their intention to invest so as to reach $\hat{v}_{t+1}$, firms may not exactly hit the target because of uncertainty and time lags between the investment decision and the time that the capital becomes productive. We will discuss expectation formation and the choice of the target $\hat{v}_{t+1}$ later when we further develop the dynamics of the model out of steady state.

Gross investment in period *t* is:

$$I_t = K_{t+1} - (1-\delta)K_t = \hat{v}_{t+1}(1+Eg_t)^2 Y_{t-1} - (1-\delta)K_t$$

where δ is the geometric depreciation rate of the capital stock and Eg_t is expected growth in output between periods *t*-1 and *t*+1. For notational convenience, we normalize expected growth to a rate that corresponds to a single period. We also restrict gross investment to be non-negative ($I_t \geq 0$).

Induced consumption depends on income. Again, to keep the model strictly recursive, we assume that consumption plans during period *t* are made by projecting *t*-1 income forward one period:

$$C_t = (1-s)(1+Eg_t)Y_{t-1}$$

where s is the constant marginal propensity to save out of expected income.

Aggregate demand (Y_t^D) is the sum of the demand components:

$$Y_t^D = C_t + I_t + F_t$$

where F_t represents autonomous demand. Substituting the specifications for consumption and investment gives

$$Y_t^D = (1-s)(1+Eg_t)Y_{t-1} + \hat{v}_{t+1}(1+Eg_t)^2 Y_{t-1} - K_t(1-\delta) + F_t. \tag{1}$$

[7] See Lavoie (2014, section 6.5) for an overview of the extensive literature on this issue.

Suppose, initially, that demand is less than supply so that demand constrains the economy in both periods *t* and *t*-1. In this case output and income are determined by demand ($Y_t = Y_t^D$). Divide equation 1 by Y_{t-1} to obtain the law of motion for demand-determined output growth:

$$1 + g_t = (1 - s)(1 + Eg_t) + \hat{v}_{t+1}(1 + Eg_t)^2 - \frac{K_t}{Y_{t-1}}(1 - \delta) + \frac{F_t}{Y_{t-1}}. \tag{2}$$

where $g_t = Y_t/Y_{t-1} - 1$. Solve this equation for a time-dependent equilibrium growth rate g_t^* such that expectations are realized ($g_t = Eg_t$). Furthermore, set the target capital-output ratio equal to its long-run desired level that depends on the production technology and the long-run desired rate of capacity utilization ($\hat{v}_{t+1} = v^*$). The growth rate g_t^* that satisfies these conditions is obtained as:

$$\begin{aligned} 1 + g_t^* &= (1 - s)(1 + g_t^*) + v^*(1 + g_t^*)^2 - \left(\frac{K_t}{Y_t}\right)\left(\frac{Y_t}{Y_{t-1}}\right)(1 - \delta) + \left(\frac{F_t}{Y_t}\right)\left(\frac{Y_t}{Y_{t-1}}\right) \\ &= (1 - s)(1 + g_t^*) + v^*(1 + g_t^*)^2 - v^*(1 + g_t^*)(1 - \delta) + f_t(1 + g_t^*) \\ g_t^* &= \frac{s - f_t}{v^*} - \delta \end{aligned} \tag{3}$$

where the autonomous demand ratio is $f_t = F_t/Y_t$. As discussed in Fazzari et al. (2013), the definition of g_t^* is closely related to Harrod's warranted rate of growth (set the autonomous demand ratio and the depreciation rate to zero).[8] But g_t^* varies over time unless the ratio of autonomous demand to aggregate demand is constant.

The results in equation 3 lead to a remarkable result that is central to understanding demand dynamics in this model. The model has a constant steady-state growth rate over time only if aggregate demand grows at the same rate as autonomous demand, that is, if the ratio f_t is constant. *The steady-state rate of growth of output in a demand-constrained system equals the growth rate of autonomous demand.* Assuming a constant growth rate of g^* for autonomous demand and given the structural

[8] See Sen (1970), Harris (1978, p. 27), and Fazzari (1985) for an interpretation of Harrod's warranted rate in terms of realized expectations of demand growth.

parameters s, v^*, and δ, output growth must also converge to grow at g^* if the system is to have a constant steady-state growth rate.

If the growth rate of autonomous demand is constant and the model is stable, convergence to steady state occurs through the adjustment of f_t.[9] Formally whether f_t adjusts to approach a steady-state growth path depends on the stability of the full model including the dynamics of expectation formation and the supply process, as discussed later. But the law of motion for growth in equation 2 provides some intuition about how adjustment of f_t could restore steady state. Suppose that the system begins in steady state, growing at g^*, and demand growth is exogenously shocked downward to $g' < g^*$. Endogenous dynamics lead to slower growth of both consumption and investment, but autonomous demand continues to grow at g^*. With output growing more slowly than autonomous demand, the final term in equation 2 (the ratio of autonomous demand to lagged output) increases, eventually raising the actual growth rate and pushing it back in the direction of g^*.[10] This intuition drives home the significance of "autonomous" demand in this model: it is a component of demand with dynamics that are independent of the actual evolution of the economy. It plays a fundamental stabilizing role in the dynamics of demand growth.

It is straightforward to solve for the steady-state path of demand-determined output:

$$Y_t^* = \left[\frac{1}{s - v^*(g^* + \delta)}\right] F_t \tag{4}$$

Equation 4 is familiar from static Keynesian models: equilibrium output is autonomous spending times a multiplier that reflects how additional income or output induces additional spending. The denominator of the bracketed multiplier term equation 4 is the marginal propensity to save minus the marginal propensity to invest in steady state ($dI_t/dY_t = v^*(g^* + \delta)$ if investment and output are on

[9] Lavoie (2016, p. 177), following Serrano (1995) makes a similar argument.

[10] In Fazzari et al. (2013) we show that the final term in equation 2 must eventually dominate the growth process when output declines indefinitely because the dynamics of the numerator are independent of the declining level of output in the denominator.

the steady-state growth path). The multiplier implied by equation 4 is what Freitas and Serrano (2016, equation 5) define as the "supermultiplier." This concept goes back to Hicks (1950, pages 61-62) and was further developed in in Serrano (1995). Cesaratto et al. (2003, equation 7) present an almost identical expression. Details of the specification used by Allain (2015) are somewhat different, but the results are effectively the same. The steady-state growth rate of demand and total output is the exogenously given growth rate of autonomous expenditure.[11]

Let us consider what the steady-state result tell us, and what it does not tell us, about the dynamics of aggregate demand. First, it is important to recognize that while the steady-state path implied by the output solution from equation 4 corresponds to a perfect foresight or a "rational expectations" dynamic equilibrium, the more general law of motion for demand growth (equation 2) does not impose any particular behavior on expectations. Whether reasonable dynamics of learning and expectation formation lead to convergence of the system to the steady-state path depends on the dynamic stability of the full model, which we consider in section 5 below. In this respect, our interpretation of these results differ somewhat from Lavoie's summary of much of the supermultiplier literature (2014, p. 408): "supporters of the supermultiplier … refer to perfect foresight or to correct forward-looking expectations."[12] We impose neither restriction on the dynamics of expectation formation. The steady-state results simply show that *if* the system converges to a path along which expectations are realized, this path must be the one generated by the supermultiplier equation 4 with steady-state growth equal to the growth rate of autonomous expenditure.

Second, on a related topic, we do not assert that the steady-state growth path is necessarily some kind of "fully adjusted" or "long run" equilibrium to which the system converges. Again, a necessary condition for such convergence is the dynamic stability of the model, which is not

[11] Our understanding of these models benefitted from the exposition by Lavoie (2014), section 6.5.7.

[12] Lavoie notes that recent work on this topic, especially Allain (2015), relaxes the perfect foresight interpretation.

guaranteed for all parameter values. Furthermore, long-run convergence would require a long-run constant rate of growth of autonomous demand, which is empirically unlikely. Indeed, there may be different sources of autonomous demand with different growth rates. Hicks (1950) thought of autonomous demand as investment spending. Allain (2015) and Ferri (2016) define autonomous demand as government spending, while Freitas and Serrano (2016) model autonomous demand as consumption. It seems reasonable that autonomous demand would consist of these components, as well as a share of imports and likely most of exports (Thirlwall, 1980; Setterfield, 1997; Lavoie and Nah, 2017). In the realistic case that different components of autonomous demand grow at different rates, total autonomous demand will never grow at a constant rate in finite time. Medium-run dynamics will reflect different growth rates of different autonomous demand components and the relative size of these components.[13]

Third, even if the system does not converge to the steady-state path, the steady state can function as a "center of gravity" for actual dynamics. In Fazzari et al. (2013) we explain how any amount of autonomous demand creates a floor under unstable growth dynamics. The expansion of autonomous demand determines the dynamics of the lower bound of the cyclical path. Furthermore, if autonomous demand grows at rates less than or equal to the growth of supply (as we discuss in the next section) the average growth rate of a cyclical path can be determined by the growth rate of autonomous demand even if the system does not converge to steady state (see the example in Fazzari et al. (2013), figure 2). We will return to further explore the role of autonomous demand growth in different contexts below.

In addition, it is important to recognize that while the steady-state *growth rate* is determined entirely by the growth rate of autonomous demand, the *level* of the steady-state path depends on all

[13] We thank Peter Skott for emphasizing this point in comments on an earlier draft of this paper.

parameters of demand.[14] This result is evident from equation 4. For example, a decline in the saving rate, other things equal, does not change the steady-state growth rate of output (in steady state, the change in s would be offset by a change in the steady-state value of f_t in equation 3). But equation 4 shows that a permanently lower value of s raises the level of steady-state demand. Therefore, the model implies a steady-state "paradox of thrift" result. Also, although we have not modeled income distribution explicitly here, a rising profit share or an increase in the share of income going to the top part of the personal income distribution will reduce the level of the steady-state growth path if the saving parameter depends in the standard way on distribution.[15]

3. Endogenous Dynamics that Adapt Supply to Demand

For any demand path to be realized as actual output the economy must have the capacity to produce at least as much as firms expect to sell. The central contribution of this paper is to explore how supply adapts to demand conditions. In particular, we are interested in how changes in autonomous demand growth could change the overall economic growth beyond the short run by causing an endogenous change in supply growth.

If demand exceeds supply, then output is constrained by the supply side. That is,

$$Y_t = \min\,(Y_t^D, Y_t^S).$$

As is typical in related research, we assume that output is produced with a linear Leontief technology.[16] The capital-output ratio v^* determines the output capacity provided by the current capital stock. The

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[14] Lavoie (2016) presents a similar result and points out that if a lower saving rate increases the long-run level of output, then output growth will be higher on average during the "traverse" between long-run equilibrium paths. Nah and Lavoie (2017) also derive this kind of result in a model with autonomous demand growth determined by exports.

[15] This result is discussed in more detail in Cynamon and Fazzari (2015), along with a quantitative exercise that calibrates the change in s to rising US income inequality.

[16] Tavani and Zamparelli (2017b) in an insightful survey of models of economic growth identify a Leontief technology as a common feature of heterodox growth models that rejects the marginal productivity theory of income distribution and allows for under-utilized capital and labor. This survey provides a useful overview of many of the linkages between the supply side and the demand side discussed in this section along with extensive references.

capital stock is endogenous in the model, that is, capital is produced. We assume that firms target a sufficiently low capacity utilization rate that output is not constrained by an inadequate supply of capital. As described by Freitas and Serrano (2016), among others, this behavior arises because production is profitable at the margin for firms and they wish to have enough capacity to meet unanticipated increases in sales. The assumption also accords well with empirical measures of capacity utilization that stay well below 100 percent.[17]

Labor supply may impose a more meaningful constraint on production over the medium run.[18] Skott (1989 and subsequent work) pioneered the analysis of labor constraints in demand-led growth models. We agree that in modern developed economies, what Skott (2010, p. 109 and 119-122) calls “mature” economies, growth can be limited by the supply of labor. Even if the economy never reaches true full employment, low unemployment rates may trigger fears of runaway inflation (justified or not) and lead to restrictive monetary policy that constrains demand. We leave detailed modeling of monetary policy on demand to later research but, as in Fazzari et al. (2013), we model labor supply constraints by imposing the possibility that labor supply restricts output below the level of expected aggregate demand. Denote labor productivity by A_t so that:

$$Y_t^S = A_t L_t$$

where L_t is the number of hours the labor force is willing to work. If $Y_t^D = Y_t < Y_t^S$ then the unemployment rate $u_t = 1 - Y_t^D / Y_t^S$ is positive.

Labor supply growth is related to the unemployment rate:

$$g_t^{LS} = \theta_0 - \theta_1 u_{t-1} \tag{5}$$

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[17] The maximum value of U.S. total industry capacity utilization is 89.4 percent in January, 1967, the first month the series is available. Utilization averaged 79.1 percent from January, 1980 through September, 2016, exceeding 85 percent in just two months during that long period.

[18] In one sense, this approach harkens back to classical political economy in which, as described by Harris (1978, p. 22) “[p]roduction is attributable to labor, that is, to current labor services and to means of production that are themselves reducible to the labor services embodied in them.”

The constant θ_0 captures exogenous demographic factors like the growth of the working age population as well as preferences and social norms, such as the long-term change in female labor force participation in the U.S. The second term in equation 5 posits that a high unemployment rate reduces the growth rate of labor supply. One reason is a decline in labor force participation due to the rising difficulty of finding an acceptable job match as unemployment rises. Phillips curve effects of higher unemployment on wages could also discourage labor force participation and reduce working hours for people with jobs (see Delong and Summers, 2012 and *The Economist*, 2016).[19] High unemployment also tends to reduce immigration (see Setterfield, 2003, who follows Cornwall, 1977). In a simple regression of US labor force growth rate on the unemployment rate, we obtained a statistically significant estimate of 0.19.[20]

We model the growth rate of the labor productivity as a function of two key variables, the unemployment rate and the replacement rate of the capital stock:

$$g_t^A = \rho_0 - \rho_1 u_{t-1} + \rho_2 (g_{t-1}^K + \delta). \tag{6}$$

The constant ρ_0 captures exogenous changes in labor productivity. Labor productivity is usually strongly procyclical, a fact emphasized in the "real business cycle" literature and captured in the second term of equation 6. The incentives for labor-saving innovation also rise in a low-unemployment environment (see Storm, 2017, pp. 17-21 and Tavani and Zamparelli, 2017b, section 5 for discussion and further references). We note that R&D expenditure tends to be procyclical (see Brown et al. 2009). Dutt (2006, p. 325) argues that labor productivity growth depends on the change, rather than the level of unemployment. He refers to Robinson (1956) and summarizes the argument with "the old adage that

[19] These effects are evident in U.S. experience following the Great Recession. Following the spike in unemployment in 2008 and 2009, labor force participation of the working-age population aged 25 to 54 dropped about two percentage points. (Overall labor force participation dropped even further, but this measure is confounded by the aging demographics of the total working-age population.)

[20] The regression includes a time trend. It is estimated from annual data beginning in 1980. The t-statistic for the unemployment rate is 4.9.

necessity is the mother of invention. … The speed of technological change is essentially determined by pressures and bottlenecks in the economy" (also see the related argument in Cornwall and Cornwall, 1994). While this intuition is compelling, it seems more likely to imply that the growth rate of labor productivity depends on the *level* rather than the change in the unemployment rate, as argued persuasively in Palley (2014), and consistent with the specification in equation 6. Flaschel and Skott (2006) discuss how labor shortages (low unemployment levels) could raise incentives for labor-saving innovation (as well as greater immigration, consistent with equation 5 above). Bhaduri (2006) links labor productivity to "labor discipline" by positing that labor productivity grows faster when unemployment is lower to keep real wages from rising due to labor shortages. Hein and Tassarow (2010) and Bivens (2017) provide empirical support for this channel and for the broader implication that a stronger labor market raises productivity growth. Furthermore, as DeLong and Summers (2012) point out, high unemployment leads to "decay" in workers skills, reducing productivity.

The final term in the productivity growth equation captures the effect of new capital. Even though the capital-output ratio is modeled as a constant, we assume that the dissemination of technical progress as well as learning-by-doing effects are embodied in the new capital stock along the lines described by Kaldor (1978, also see Palley, 1996; Setterfield, 1997; McCombie, 2002; Hein, 2014, page 315; and Bassi and Lang, 2016). McCombie and Spreafico (2015, page 2) summarize Kaldor's perspective as "the act of investment itself generate[s] new and improved methods of production." Palley (1996, page 124) writes "[t]echnical progress is therefore both 'revealed' and 'realized' through investment, so that investment serves simultaneously as the means of (1) expanding the capital stock, (2) feeding technical innovations into the production process, and (3) uncovering further possibilities for innovation" (also see Palley, 1997). Effectively, this specification introduces a version of Verdoorn's Law (a positive relation between output growth and productivity growth) into our model. Note that both net and replacement investment add capital with a newer vintage that embodies improved technology. As DeLong and Summers (2012) and Summers (2014) argue, the recent decline in the investment share in the U.S. economy is linked to slower growth in productivity.

We model the growth rate of aggregate supply (potential output) as the sum of labor supply growth and productivity growth. This approach ignores, for simplicity, the compound term ($g_t^{LS} * g_t^A$) that would arise in a discrete time model. But this term is trivial for reasonable values of the growth rates.

4. Demand-Led Growth of Supply in Steady State

The specifications for supply growth in equations 5 and 6 cause aggregate supply to adapt to the state of demand. Because both the unemployment rate and the gross investment rate depend on the state of the economy, and because the state of the economy depends on the level of aggregate demand, *demand leads supply*. In this section we present the implications of this demand-supply interaction for the steady-state growth path.

The growth of aggregate supply from equations 5 and 6 is:

$$g_t^{LS} + g_t^A = \theta_0 - \theta_1 u_{t-1} + \rho_0 - \rho_1 u_{t-1} + \rho_2 (g_{t-1}^K + \delta).$$

On a steady-state demand path, growth equals the rate of growth of autonomous demand g^*. In steady state, firms will invest so that the capital-output ratio remains at its target v^*. Therefore, in any steady state, $g_{t-1}^K = g^*$. If the growth rate of aggregate supply is in steady state, then the unemployment rate must be constant. Solving the equation above for the unemployment rate that yields a constant rate of supply growth yields:

$$u^* = \frac{\theta_0 + \rho_0 - g^*(1 - \rho_2) + \rho_2 \delta}{\theta_1 + \rho_1} \tag{7}$$

Is supply growth with the unemployment rate at u^* the same as steady-state demand growth? The answer is yes. At any point in time:

$$u_t = 1 - \frac{L_t}{L_t^S} = 1 - \frac{Y_t}{A_t L_t^S} = 1 - \frac{Y_t}{Y_t^S}$$

and $u_t = u^*$ only if demand-determined output grows at the same rate as supply. This result does not necessarily imply that actual supply and demand growth will converge to each other. That result depends on the overall dynamic stability of the model. But if the system is in steady state, demand and supply growth must equal the growth rate of autonomous demand. In other words, if the system starts with expected growth of $g^*$and an unemployment rate of u^*, both aggregate demand and aggregate supply will grow at rate g^*.[21]

What Harrod called the "natural rate" of aggregate supply growth is endogenous in our model. This feature leads to a central result in this paper: changes in the growth rate of autonomous demand can, within bounds, affect the growth rate of aggregate supply. Suppose that g^* increases. Equation 6 shows that u^* will decline. If the dynamics of the model are stable, supply growth will converge to the higher level of g^* driven by a lower level of u^*. The maximum value of g^*, however, is determined by the minimum feasible value for u^*. Suppose this minimum is $\hat{u}$. Then the maximum autonomous growth rate that can be accommodated by steady-state supply growth is:

$$\hat{g} = \frac{\theta_0 + \rho_0 + \rho_2\delta - \hat{u}(\theta_1 + \rho_1)}{(1 - \rho_2)} \tag{8}$$

Demand growth can lead supply growth, but only within limits.[22]

Equations 7 and 8 provide insights into how our model can address the classic "reconciliation problem" posed first by Harrod (1939; also see Setterfield, 2003; Sawyer, 2012; and Allain, 2017) in which the steady-state growth rate of supply (Harrod's "natural rate") need not equal the steady-state

[21] We discuss dynamic stability in the next section for the full system. But there is intuition for why supply growth would converge to demand growth. If supply grows slower (faster) than demand, unemployment will fall (rise), increasing (decreasing) supply growth through both of the channels described by equations 5 and 6.

[22] This result is somewhat similar to the implications of the model in Palley (1997) according to which different rates of demand growth can shift the economy among a possible multiplicity of supply growth rates.

growth rate of demand (the "warranted rate"). If $g^* < \hat{g}$ then the steady-state growth rates of supply and demand can be reconciled by the adjustment of the unemployment rate to u^*. From equation 7 it is clear that a necessary condition for u^* to exist is for the growth rate of aggregate supply to depend positively on the rate of unemployment ($\theta_1 + \rho_1 > 0$). There must be a structural channel that allows supply to adapt to demand. Note that there is no similar necessary condition for ρ_2, the parameter that connects labor productivity to capital replacement. This outcome arises because the gross investment rate is entirely determined by technology and demand conditions in steady state. The size of ρ_2 affects u^* and $\hat{g}$ (see equations 7 and 8), but a positive ρ_2 is not necessary to reconcile steady-state supply and demand growth.[23]

The model also generates a steady-state version of the Keynesian "paradox of thrift" on both the demand and supply sides. Suppose that the marginal propensity to consume rises. Holding the growth rate of autonomous demand constant, the steady-state growth rates of demand and supply and the steady-state unemployment rate will not change. But equation 4 shows that the steady-state *level* of output will be permanently lower for a given path of the level of autonomous demand (Allain, 2015, Freitas and Serrano, 2016 and Lavoie, 2016 obtain similar results). Because the level of output is lower and the unemployment and utilization rates are the same after the saving shock, we also know that the level of steady-state aggregate supply also declines.[24] In general, persistent effects of demand on output and supply are basic predictions of this model.[25]

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[23] Dutt (2006) presents a model that reconciles demand-led growth with labor supply growth, allowing for endogenous technical change. The key adjustment mechanisms are similar to those in the neoclassical synthesis, but in the Kaleckian growth model these structures produce a continuum of possible growth equilibria. Also see Tavani and Zamparelli (2017a).

[24] A one-time, permanent increase in the level of saving, rather than an increase in the marginal propensity to save, can be modeled as a permanent reduction in the path of autonomous demand in equation 4 with results qualitatively similar to a change in the saving propensity.

[25] In an innovative empirical study, Girardi et al. (2017) find convincing evidence that demand changes have highly persistent effects on output, capital, and labor productivity. These results are motivated with a super-multiplier model and are consistent with the model analyzed here.

Let us further explore the quantitative implications of these results with a simple calibration. Suppose the supply parameters related to unemployment (θ_1 and ρ_1) are both set to 0.2. This means a one percentage point reduction in the unemployment rate would cause an 0.2 percentage point increase in labor force growth (consistent with the empirical evidence presented earlier) and 0.2 percentage point increase in productivity growth. Estimates of Verdoorn's Law coefficients are often much higher, but we will use 0.2 for ρ_2 as well.[26] From equation 7, we have

$$\frac{du^*}{dg^*} = -\frac{1 - \rho_2}{\theta_1 + \rho_1}$$

which equals -2 with the three parameters set at 0.2. Therefore, if autonomous demand growth rises by one percentage point, the steady-state unemployment rate must fall by two percentage points to equate supply growth with the higher demand path. This kind of adjustment seems entirely feasible in a realistic setting. For example, consider an economy with stagnant growth of 1.5 percent and unemployment of 6 percent. A one percentage point increase in autonomous demand growth will raise the overall growth rate to a much more favorable 2.5 percent. To induce supply growth to adapt to the higher demand path, unemployment must decline to 4 percent. Effects of this magnitude seem to be empirically relevant.

5. Dynamic Stability

What conditions are necessary for the steady-state results described in the previous section to attract the actual dynamics of the system? To analyze actual dynamics we must specify expectation formation for sales growth. Fazzari et al. (2013) discuss expectation formation in the context of a similar model (also see Ferri and Variato, 2010). To proceed further, we use a simple adaptive rule

[26] The preferred "demand-side" estimate of the Verdoorn coefficient relating productivity growth to output growth in Angeriz, et al. (2008) is 0.67. Values greater than 0.5 are regularly cited. Michl (1985, table 2) finds Verdoorn coefficients estimated from international panel data that vary from 0.49 to 0.68 for manufacturing industries. Hein (2014, table 8.2, pp. 327-8) surveys a wide range of empirical estimates. While the estimate can be as low as 0.11, the vast majority of estimates for many countries fall between 0.3 and 0.6.

here for the growth rate of demand expected between periods *t* and *t*-1 (based on information available at *t*-1):

$$Eg_t = (1-\alpha)g_{t-1} + \alpha Eg_{t-1}.$$

Also, assume partial adjustment of the capital stock period-by-period, similar to the partial adjustment of capacity utilization in Allain (2015, equation 6) and Freitas and Serrano (2016, equation 3):

$$I_t = \hat{v}_t(1 + Eg_t)^2 Y_{t-1} - K_t(1-\delta)$$

$$\hat{v}_t = (1-\lambda)v_{t-1} + \lambda v^*$$

In Fazzari et al. (2013) we assumed $\hat{v}_t = v^*$, that is, that the target capital-output ratio (or equivalently the target utilization rate) is always at the long-run desired level. Serrano and Freitas (2017) present a strong case that immediate adjustment of the capital stock to the long-run target level may induce unrealistic instability and hence they prefer a specification with $\lambda < 1$ along the lines of the traditional "flexible accelerator."

Simulations show that the demand dynamics are cyclical out of steady state with cycles that may be stable or unstable, as in Allain (2015, 2017). The effect of parameters on simulated stability is intuitive (and confirmed by the Jacobian matrix for the linearized model). Changes in parameters that make induced demand less sensitive to the state of the economy, that is parameter changes that lower the value of the supermultiplier, make the model more stable (a decrease in v^*or δ and an increase in s). More persistence in expectation formation (higher value of α) and capital adjustment (lower value of λ) also stabilize the dynamics.[27]

The supply parameters (θ, ρ) have little effect on dynamic stability with the structure of this model. Not surprisingly, supply lags demand since demand is the engine of output growth. Higher

[27] Cesaratto et al. (2003, footnote 19) also model expectations adaptively and identify the speed of adjustment of expectations as central to the dynamic stability of a similar model.

values of the supply parameters make supply more sensitive to demand conditions and therefore reduce the time it takes for supply to catch up with demand in either direction.

Simulations that assess the stability of the model help to address questions raised by Skott (2016) about whether models with autonomous demand like the one developed here can be dynamically stable for plausible parameter values. The results depend strongly on the parameters α and λ in the dynamic adjustment equations above. Assume that half the gaps are closed in two years between actual and expected growth and between the current and steady-state capital-output ratio ($\alpha = 0.75$ and $\lambda = 0.25$). With other plausible parameters values dynamic stability requires a steady-state ratio of autonomous demand to output of about 21% to 24%. An autonomous demand ratio of at least this size seems entirely reasonable.[28]

Of course, if the model is dynamically stable, the system converges to the steady-state results discussed in the previous section. Even in unstable cases, however, the system cycles around the steady state. Ultimately, the peak of unstable cycles will be constrained by the limit imposed by supply, but the extent of unemployment at the trough of unstable cycles, and average unemployment over the cycle, will depend on the steady state. For example, unstable cycles in a model with 2 percent autonomous demand growth will have a less severe trough of unemployment than would be the case with 1 percent autonomous demand growth. It is important to recognize that even if the model does not converge to the steady state, fluctuations are contained in this model.

[28] The ratio of autonomous demand to output in steady state is endogenous in this model, depending on the growth rate of autonomous demand. The figures given in the text assume that autonomous demand growth ranges between zero and 4%. In the US, government consumption and investment in 2016 was 18% of GDP (and used to be higher); exports were 12%. Most of the spending financed by the "social safety net" (Social Security, Medicare, and Medicaid, primarily) is likely also autonomous and accounts for about 15% of GDP. Therefore, the autonomous demand share may well be higher than 40%, although this value is undoubtedly affected by different historical circumstances. Admittedly, the assumed value of v* (0.8), an important parameter in these calculations, is hard to pin down empirically, fraught with questions about how to measure business capital.

6. Implications for Demand-Led Growth

In our model, strong demand causes an increase in supply, unless the constraint imposed by equation 8 is binding. Weak demand growth always reduces supply. These results have important implications that lead to a very different perspective on macroeconomics than what has become conventional wisdom in modern mainstream macro and policy analysis.

Consider first the effect of a positive shock to the exogenous component of labor productivity growth (an increase in ρ_0). What would be considered a positive growth shock from a mainstream supply-driven perspective on growth does not change growth in our model because there has been no change in the growth rate of autonomous demand. Furthermore, from equation 7, a positive shock to labor productivity will *raise unemployment*. The reason is straightforward: demand does not automatically adjust to supply in this model and a more productive economy requires less labor to satisfy given demand.

This result seems to support the common "populist" (or perhaps even "Luddite") claim that labor-saving innovation destroys jobs. But the result also suggests the solution to the problem: raise aggregate demand. In one sense, this perspective is similar to the mainstream New Keynesian view that monetary policy provides the key mechanism to reconcile aggregate demand to aggregate supply. Therefore a positive technology shock would justify expansionary monetary policy to boost demand. But our dynamic perspective with endogenous supply pushes the argument further. If labor productivity growth rises above autonomous demand growth the resulting output gap will grow with time. It is far from clear that interest rate adjustment or even unconventional monetary policy ("quantitative easing" for example) will be adequate to fill the demand gap. In addition, since supply adapts to demand, a failure of monetary policy to raise demand growth after a positive shock to labor productivity growth will compromise the supply side.

It is also important to consider whether there actually is a "natural" rate of unemployment or a "natural" rate of growth in this model. Autonomous demand growth can be affected by a variety of private behaviors and policy regimes. In the U.S., we interpret spending growth generated by the recent housing or technology bubbles as shifts in the dynamics of autonomous demand. In both Europe and the U.S., the "pivot to austerity" for fiscal policy in the aftermath of the financial crisis affects the path of autonomous demand. If something like the supply-side mechanisms from our model operate in real-world economies, supply growth will adapt to changes in the dynamics of autonomous demand. There is no "natural" rate of growth of the supply side independent of demand dynamics.

Clearly, the results here also show that a potentially wide range of unemployment rates is consistent with equal rates of growth of aggregate demand and aggregate supply. One might associate a target rate of unemployment with the minimum unemployment rate and maximum rate of autonomous demand growth defined earlier ($\hat{u}$ and $\hat{g}$). But it will be difficult to know what these rates are in practice. Because supply adapts to demand, the economy might follow a lower growth path than feasible but without clear signals of excess supply. Furthermore, while the unemployment rate *in steady state* indicates the degree to which growth is lower than what could be feasible, the actual economy will operate on a cyclical path outside of steady state and the unemployment rate could be a misleading indicator for years about the extent to which the economy falls short of its possible growth path. [29]

This model seems particularly relevant to the concept of secular stagnation (Summers, 2014). The engine of growth is autonomous demand. A significant drop in autonomous demand growth will drag medium-run actual growth along with it. Consider the dynamics of U.S. household demand and its relation to housing finance. In the decades leading up to the financial crisis of 2008 and 2009, rising household debt ratios signaled that a substantial portion of U.S. household demand was financed not

[29] Skott (2005) presents a model with endogenous wage-setting norms in which demand affects equilibrium unemployment and there is no "structurally determined natural rate of unemployment."

by rising incomes but by borrowing. This kind of spending is autonomous in the context of our model; it is driven by factors other than the growth of incomes. When the crisis hit, this powerful source of autonomous demand growth was lost and not replaced by faster autonomous growth of any other demand component. The result has been persistent stagnation of output growth.

This approach also has important implications for fiscal policy. In modern developed economies, government spending has become a significant source of demand. Much of government spending should be classified as autonomous.[30] This conclusion is reinforced by the fact that what are considered government transfer payments for retirement income and health care likely support a large and growing amount of autonomous demand. With so much autonomous demand coming from government fiscal policy, our model implies that acceptable aggregate growth simply may not be feasible in an environment of fiscal austerity that constrains the growth of autonomous demand financed by government. Indeed, a reduction in the rate of autonomous demand growth induced by fiscal austerity will *always* lead to a lower growth path for both demand *and supply* in our model.

Finally, while our model generates demand-led growth, the conditions of supply impose constraints on the extent to which demand can stimulate production in an economy with a limited supply of labor.[31] This outcome is obvious from equation 8 that derives the maximum steady-state demand growth rate that is consistent with the lower bound on the unemployment rate. But the constraints imposed by supply are more nuanced than the simple ceiling on production that we imposed in Fazzari, et al. (2013). The model developed here proposes that there is an empirically relevant range of growth rates of demand that induce supply growth to adapt to demand growth, reversing the direction of causation of mainstream macro growth theory.

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[30] Of course, government spending also includes "automatic stabilizers" that respond explicitly to the state of the economy. These structures could be an important stabilizer, which we intend to explore in further research.

[31] This result differentiates our model from most heterodox research on demand-led growth that usually does not consider constraints imposed by supply.

7. Conclusion

The main message of this paper is that demand, particularly autonomous demand, can be the engine of economic growth. Of course what is demanded must be feasible to produce, that is, adequate supply is necessary to realize a demand-led growth path. We show that endogenous linkages between the demand-determined state of the economy and both labor supply and labor productivity provide channels through which supply adjusts to demand. This approach reconciles Harrod's warranted and natural rates of growth. The model shows how the demand and supply sides interact with each playing a substantive role in a macroeconomic dance of growth determinants over the medium run (also see Mason, 2017). Clearly our results differ from the mainstream perspective that relegates demand to a short run of a few quarters with supply alone determining growth over multi-year horizons. Yet our results also show that demand-led growth can be limited by supply in ways that often are not analyzed in heterodox Keynesian growth models.

Demand growth in our model cannot generate arbitrarily high rates of actual economic growth because of endogenous limits on the extent to which supply can accommodate demand growth. We believe that this feature is an important and empirically relevant implication of our model. While one can debate whether developed economies can feasibly grow at 2, 3, or 4 percent for a sustained period of time, it seems unreasonable to propose that mature economies could grow at 10 percent or more for an extended period without running hard into supply constraints.[32] That said, although a detailed empirical application of this model is well beyond the scope of this paper, some simple calculations show that it is entirely reasonable that acceleration of demand growth from something like 2 to 3 percent could be accommodated by matching changes in supply constraints. Perhaps more important,

[32] This perspective is consistent with the view of Skott, (2016, p. 15): the "supply side matters, and there is nothing particularly Keynesian about an exclusive focus on the demand side." Dosi et al. (2010) explore the complementarities between Keynesian demand dynamics and Schumpeterian technical change on the supply side.

misguided attempts at demand-side "austerity" will drag supply down with them. The result can be that "output gaps" disappear as supply adjusts to weak demand growth but nonetheless the economy stagnates relative to what it could reach with more robust demand.

The results here are consistent with the idea of hysteresis or "history matters" in the sense that the dynamic path of demand fundamentally affects to economy's productive potential (as in Setterfield, 1997; DeLong and Summers, 2012; Mason, 2017; among many others). Although analytical results often focus on steady states with constant growth rates of autonomous demand, the actual path of autonomous spending in real economies likely evolves over time with history conditioning dynamics. For example, there is little doubt that the institutional changes in US household credit access in the 1970s and 1980s affected the path of autonomous household demand for the decades leading up to the financial crisis of 2008 and 2009. This example illustrates the more general point that "autonomous" need not mean "exogenous" or "constant." Rather autonomous demand refers to spending that is not induced by the state of the economy. To apply the message of our model empirically is to explore how autonomous demand evolves in particular historical periods.

In addition to empirical analysis of the dynamics of autonomous demand, further work is needed on the key structural parameters that link the demand and supply sides of the system. The simple calibration presented earlier is speculative. Research needs to better pin down the relationship between the state of the economy, labor supply, and labor productivity.[33] These parameters are the key determinants of the range of demand-led growth paths that can be accommodated by supply.

The results here, especially if supported by more detailed empirical analysis of the linkages between demand and supply, have critical implications for policy. Most obviously, policy objectives must focus on demand well beyond the mainstream "short run." When private autonomous demand falters public demand can help avoid stagnation. Furthermore, there is the danger of what Palley

[33] Storm (2017) provides an insightful analysis of along these lines.

(2017) describes as policy "lock in," demand-side austerity policy can limit supply growth and cause the appearance of a small traditionally defined output gap even though more aggressive demand growth policies could pull supply with them to generate better medium-term outcomes.[34]

Cornwall and Cornwall (1994, page 238) write that their paper "can be seen as outlining a research strategy for investigators who might wish to put some numbers on programmes designed to better utilize available resources and to reduce unemployment." Our paper is also step in this direction. We show that demand-led reductions in unemployment and greater resource utilization t can be accommodated by the economy's supply side within limits. While our paper is far from a detailed empirical study of these effects, the empirically motivated calibration we present makes the case that the kinds of phenomena that our model highlights could well be empirically important in understanding the growth potential of modern developed economies and guiding policies designed to maximize that potential. We hope, with Cornwall and Cornwall, that this work will spur further research to assess the practical relevance of these results.

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[34] As Mason (2017, p. 10) writes "a belief that hysteresis just reflects the 'new normal' can be self confirming."

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