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Economic Growth and Business Cycles: The Labor Supply Decision with Two Types of Technological Progress

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Abstract

An informal model is described that leads to multiple macroeconomic equilibria as a consequence of random variation in the relative amounts of technological change for *new* and existing goods. The novel observation is that the rate of introduction and market penetration of new goods (sometimes called *product innovation*) vis-à-vis technological advance for existing goods (sometimes called *process innovation*) importantly affects the labor supply decision. A relatively rapid influx of new goods will generally increase labor supply, while relatively more technological advance for existing goods will reduce labor supply to the market. These impacts are seen to provide insights into Rostow's stages of growth. Short run variations in the relative importance of the two types of technological change are seen to imply unpredictable business cycle behavior of the type we observe. The welfare implications of national income accounting that fails to consider changes in leisure are discussed.

1. Introduction

Much has been written about the development/growth process, with few economists, from Adam Smith on completely ignoring the issue. The field has, however, always been a murky swirl of many disciplines (anthropology, economics, history, political science, sociology, and others) with frequent strong doses of liberal or conservative ideology stirred in.

Here the impact of goods variety and two types of technological change is examined on household labor supply decisions. Labor supply decisions, in turn, are shown to have important impacts on both growth and the business cycle in a closed economy. The exercise provides an attempt to explain the following central stylized facts: First, some countries have fairly high incomes, yet are not fully "developed" in the broad-based sense of that term (e.g. as expressed in the rationale for the U.N.'s Human Development Index). Second, some countries have experienced virtually no real income growth or development, while others suddenly "take off" in the Rostow sense, and yet others settle into the lower growth rates of the "mature economy" (Rostow [1])[1], Finally,

the development and growth process is not smooth but rather appears to involve irregular cycles about the growth path, regardless of a country's stage on that path.

Early models in the Solow [2] and Swan [3] tradition treated growth in labor, knowledge, and the savings rate as exogenous (see D. Romer [4] for a detailed survey of growth and business cycle models). More sophisticated models in this vein examine the implications of overlapping generations, effects of government purchases and associated financing issues, but most importantly for present purposes, endogenize the savings rate as stemming from the interaction of maximizing households and firms in competitive markets[2]. A problem with these approaches is that "capital accumulation cannot account for a large part of either long-run growth or cross-country income differences" (D. Romer, p. 95). This leaves Romer's so-called "mystery variable", the effectiveness of

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[1]There are, of course many potential reasons for the text phenomena, including security of property rights, infrastructure variation, cultural or religious beliefs, corruption, inflation, and so on. That discussion of these causative factors is suppressed here is not to deny their importance.
[2]See Diamond [5], Cass [6], Koopmans [7] and the early work of Ramsey [8].

labor, "whose exact meaning is not specified and whose behavior is taken as exogenous" (Ibid.).

The "new growth theory" attempts to put structure on the effectiveness of labor variable by a) explicitly attributing it to knowledge and b) modeling its evolution over time. The allocation of resources toward knowledge accumulation (in its public good nature) is endogenized and broader interpretations of capital (to include human capital of a private good nature) are examined[3].

The present effort, unlike existing models that employ homogeneous output, focuses on how labor supply is affected by technological advances that lower the costs of existing goods vis-à-vis those that result in new goods. Section 2 discusses the nature of consumption, arguing that in the dynamic development/growth setting, traditional views of the role of income and interest rates are given undue causative importance, relative to household desires for the ever-increasing variety of goods available that drive consumption and (endogenous) income generation. In Section 3 the role that differential rates of technological advance for existing goods and for new goods play is discussed prior to turning to implications for growth and fluctuations in Section IV. Issues of systematic bias in GDP as a measure of welfare, due to varying relative patterns of technological advance, are also discussed briefly in Section 4. Section 5 summarizes the paper, providing suggestions for further work.

2. On the Nature of Consumption

What determines desired consumption? With unchanging technology, perfect information, and perfect mobility one would expect the real interest rate to determine the allocation of the representative agent's consumption among periods. In such a classical world, income would not determine consumption, because market clearing would imply that we would always be at full employment income. In a Keynesian setting, and in many growth models, consumption is taken to be a function of income (exogenously in the fixed savings rates of the traditional growth models, endogenously, though in a way unrelated to the present discussion, in the new growth theory).

Yet it should be apparent clear that consumption and income are jointly endogenous—we work to get the things we want, hence the generation of income is de-

pendent on the nature and number of the goods available[4]. Economists have tended, largely as a result of mathematical convenience, to view the number of goods in an economy as principally a mere matter of vector length or the range of an index, i = 1,···, n. To be sure, a difference in going from a two-good world of substitutes to a three-good world has received emphasis. Moreover, it is commonly observed that having a bigger choice set must enable utility to rise or at least stay the same, since people will only buy newly available goods if they "crowd out" goods of lower utility.

But, the nature and number of goods in a society has greater importance than suggested by such formalisms. When comparing a developing country with a developed country, the greater variety of goods in the developed country affects both labor supply in the short run and human capital augmentation in the long run. Households in developed countries will tend to have the same (or quite similar) goods as predominate in a developing country plus a vast amount of other goods that are generally unavailable to households in the developing country[5].

The failure to fully examine the implications of the number of goods available, both within a country over time and in comparisons among countries, omits insights into the development process that are seen here to be potentially important.

Consider first the addition of a desirable new good from a traditional household utility maximization perspective. A new good raises total utility, from the same resources, as people substitute away from now relatively low-value marginal units of pre-existing goods toward marginal units of the new good, until a new, utility-maximizing equilibrium is re-established, at higher marginal utilities for all goods consumed. To clarify the nature of the argument with a simple example, consider a closed economy of homogeneous individuals in an initial two-good world, with X representing the existing good and L representing leisure. All goods are produced, for simplicity, under cost conditions of the usual sort (suppressed in the model discussion). Suppose that utility is

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[3]See Lucas [9], Stokey [10], P. Romer [11], Grossman and Helpman [12], Aghion and Howitt [13], Mankiw, D. Romer and Weil [14], Greenwood and Uysal [15], Bilbiie, Ghironi and Melitz [16], Canova and Lopez-Salido[17], and others for further detail. Most of these do not endogenize labor supply in a way at all related to the present effort, and while the work of Canova and Lopez is most similar, their focus is on neutral and investment-specific technology shocks, rather than upon new goods and existing goods technology shocks.

[4]See Graves [18] (and to a lesser extent Flores and Graves [19] which endogenizes the labor/leisure decision) for papers emphasizing this point in the context of public goods provision. The point, in brief, is that the "given" initial income, from which aggregated marginal willingness to pay is taken to provide the demand side of optimal public goods provision, is itself non-optimally low because the inability to individually buy public goods will result in failure to generate the optimal (larger) level of income. Hence, the traditional benefit-cost approach to optimal public goods provision will under-provide public goods.

[5]It is, of course, possible that the new good will expand (and/or alter the relative values of elements of) the vector of valuable resources in an economy as well (e.g. optical fiber in communications lowering the value of copper).

Cobb-Douglas[6]:

$$U = X^\alpha L^\beta \qquad (1)$$

With a given level of resources in this economy, there will be an initial maximum level of utility, U_0, at the optimal goods-leisure bundle. Now, introduce Z, a new good into this economy:

$$U = X^\alpha L^\beta Z^\gamma \qquad (2)$$

Presuming that the new good does not involve any resource discoveries, resources will be drawn from the original two goods to supply the demand for the new good. Hence, while goods X and L remain as desirable as before, the high marginal values of the new good result in reduced quantities of X and/or L consumed. Hence marginal utilities of all goods consumed become higher than before, at initial income levels, the latter being determined by initial equilibrium labor supply decisions. Integrating over these marginal utilities, total utility is seen to rise, potentially dramatically, in the presence of the new good. Thus, adding "shelter" to a world with "food" and "leisure" might add substantially to utility, if γ is at all large[7].

Viewed from an input market perspective, the derived demands for inputs have gone up; hence real income will be higher than before, in line with the higher valued output. The competition in input markets from suppliers of the new good raises real wages throughout the economy[8]. There is, under the introduction of an independent good, no ambiguity regarding income versus substitution effects in labor supply—people will want to work more because wages have risen as a result of wanting more combined outputs, the new and the old, considered together. We work to get what we want, and will increase our supply of labor (and in the context of longer-run development, our human capital) to acquire the new goods.

Essentially, introducing the new good (product innovation) increases the value of all goods relative to leisure at initial levels of leisure, hence, we will work more, giving up leisure. Contrast this situation with that in

which we only have a technological advance in the production of existing goods (process innovation), with no new goods becoming available.

One's initial suspicion would be that whether more or less income would be generated depends on the price elasticity of demand for existing goods. That is, if on average existing goods are price elastic, technological progress that lowered existing goods' prices would result in more desired income, hence more work, with reduced leisure. If, conversely, existing goods were inelastically demanded, technological advance would lead to less expenditure and more leisure, with the unitary elastic case (e.g. Cobb-Douglas) seemingly representing the watershed case.

However, these arguments fail to incorporate the wage increases that the productivity gains from the technological advance allow. Existing goods become cheaper and we purchase more of them, but we also would be expected to purchase, at the new optimum, more leisure, a normal good. As we acquire more of the existing goods considered collectively at their lower equilibrium prices, their marginal values will fall, relative to the marginal value of leisure at the latter's initial level.

Thus, technological advance for existing goods lowers their marginal value relative to leisure at initial leisure levels; hence, we would generally be expected to work less, acquiring more leisure[9]. Foreshadowing discussion to follow, the implications of the preceding variations in labor supply will be seen to have dynamic implications for saving as well—implications for business cycles. That is, in periods when there are an unusually large amount of desirable new goods being created, we will not only work more but we will dis-save or reduce the saving rate, depending on how intensely we desire the new goods. Conversely, in periods in which abnormally few desirable new goods are being created we will not only desire fewer work hours, but will also save at above normal rates, in anticipation of greater new goods later[10].

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[6]The Cobb-Douglas formulation, with zero cross-price elasticities, represents an extreme case in that the utility of particular goods in the existing goods vector might either rise (complements) or fall (substitutes) with the introduction certain of the new goods. One may also prefer to think of both original and new goods as vectors, suppressed in the text discussion.

[7]The mathematical convenience of normalizing the coefficients to add to one (implicitly both before and after the introduction of the good), which yields constant marginal utility of income in the individual's LaGrangean maximand, is psychologically misleading, particularly in the development context. While an ordinal treatment would recognize that choices are unaffected by renormalizing the coefficients, the central labor supply message is greatly affected—goods are worth more relative to leisure than before the introduction of the new good(s).

[8]Note that having a higher marginal utility (value) of the combined outputs, implies a higher marginal product of labor in equilibrium, as labor shifts over to the production of the new product, leaving a larger capital/labor ratio in the production of existing goods. And, of course, the labor will not move into the production of the new good unless paid what it could earn in the production of existing goods.

[9]The discussion here represents one way to rationalize the labor supply curve to the market being first upward-sloping as individuals add important new goods, then backward-bending as a higher proportion of goods become "existing" at higher income levels.

[10]The text discussion is thematically related to Leijonhufvud's [20] discussion of liquidity preference versus futures contracts in a world in which we do not know what we will want in the future. This relates to Keynesian notions of "ineffective demand" as underlying the business cycle. Not knowing what goods will exist in the future, as well as how intensely we will want them, implies that savings may not flow meaningfully into investment. This follows from the fact that existing producers will have no valid presumption that observed extra saving now would lead to greater demand for their products in the future. Note further, even if flexible work hours existed, a reduction in those hours would occur concomitantly with an increase in the savings rate (in anticipation of greater new goods in the future). If we are constrained in our work hours when few desirable new goods are coming into existence, layoffs might occur instead of reductions in average work hours. In this case both the disemployed and those continuing to work are forced to have non-optimal goods-leisure combinations (e.g. Clower's [21] "dual decision hypothesis").

3. Technological Advance and Dynamic Consumption-Income Patterns

Placing the preceding static discussion in a dynamic context requires incorporation of two types of technological progress, progress that brings us existing goods at lower cost and progress that brings us new goods[11]. As indicated in the previous section, technological progress in existing goods will generally result in reduced labor supply (and a reduced marginal incentive to invest in human capital). But, technological progress generating desirable new goods will generally result in an increased labor supply (and an enhanced incentive to invest in human capital).

At any point in time, both types of technological advance will be going on, though the relative importance of the two would be expected to vary over time. Two extreme cases present themselves. Consider first the implications of continual technological advance in the production of existing goods, with no new goods being generated. One would expect, arguing as in Section II, that there would be a continual increase in goods production (income), but that would be accomplished with a continual decrease in labor supply, to balance the falling marginal utility of goods with that of leisure.

The polar extreme case is that of continual introduction of new goods, with fixed technology in the production of existing goods. In this case, one would expect increases in labor supply to obtain the new goods, since they would be "crowding out" marginal amounts of existing goods, resulting in an overall increase in the marginal utility of income.

But, a la Rostow as discussed below, there will also be diminishing marginal utility of new goods provision—that is, the gain in utility from a new good would be expected to be diminishing in the number of existing goods. In the context of the comparison of Equations (1) and (2), there may be a large percentage utility gain in adding the third good, for given γ, when there are only two goods, but this would be unlikely when there are already n, for large n[12]. In actual historical data, technological advance of both types will be occurring at rates with some expectation and some variance about that expectation.

On average, a rough balancing of the two types of technological advance might be expected. If this proves to be the case, one would expect hours of work to appear to be a stationary series. But, the expected random variation in the relative importance in the two types of technological advance will be seen to have implications for growth/development patterns and for business cycle behavior.

4. Growth Patterns and the Business Cycle

Returning to the stylized facts discussed in the introduction, consider first those countries with high incomes that are not "developed" as that word is usually employed. One cannot merely discover oil, for example, and expect that this will lead to meaningful development. Indeed, in a closed economy the discovery of oil would be expected to have little impact on development, because nothing about its discovery allows greater production of new goods, though it might render existing goods production less expensive, resulting in greater leisure demand and reduced incentives to acquire education.

Even with trade, while there might be large demands for the wide variety of newly imported goods in such countries, the local wage rate might not rise much (presuming that the locally-provided labor intensity of oil production, the traded good, is low). Moreover, there will be little incentive to invest in human capital, as the desired goods that incorporate greater human capital in their production are not produced domestically[13].

Other stylized facts are that a) some countries exhibit zero or negligibly positive growth, while b) others "take off" exhibiting high growth rates over a range of income, and c) highly developed countries tend to have the reduced growth rates traditionally associated with "mature" economies. In the context of the present model, this Rostow-like pattern can be explained by very low goods variety in the case of the extremely poor countries; hence there is little reason to work or invest in human capital with a long-term (and uncertain) payoff.

The period of "takeoff" corresponds to a country getting rich enough to begin producing an ever-increasing array of desirable new products, which increase optimal generated household income via labor supply and human capital investments[14]. One might further expect observed

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[11]There might be great practical difficulty in empirically implementing the ideas here; it would not be easy to determine when a quality change is sufficiently important to be viewed as a "new" good. Moreover, a good that is "new" in a poor developing country (e.g. television) might be old in a developed country. There will generally be overlapping market penetration curves of a wide variety of new goods with the net effect on labor supply being an aggregation of effects at the individual level.

[12]This provides one explanation for the existence of relatively few menu selections at restaurants. Eventually the diminishing marginal value of variety is offset by the ever-growing marginal costs of ascertaining what is available.

[13]Upon inquiring of a young Kenyan boy what he wanted to be when he grew up, he said, "A driver" (a driver of Land Rovers on safaris). The imagination necessary to think in terms of the goal of being a doctor or engineer requires experience of that possibility…a particular difficulty in a world of "brain-drain" realities.

[14]Traditional discussions of the role of education in growth implicitly presume that people will want to get an education if it is supplied. The present paper recognizes that whether education is pursued involves both benefits and costs; a serious demand for education must be largely predicated on the desire to acquire the income it offers, and that depends on the nature of the goods available.

patterns of rapid urbanization in the take-off period, as economies of scale and agglomeration effects in production emerge.

Finally, the mature economy has a very large number of existing goods implying that introduction of new goods gives a smaller percentage gain in utility than is the case when there are a much smaller number of existing goods. Hence, there is a progressively smaller increase in desired income, hence labor supply, from any given pattern of innovation or invention.

Thus, the impact of the two types of technological advance will vary with a country's position in the development process. The same relative amounts of technological progress in new goods will result in greater desires to generate income in countries where the number of goods is limited (as per the simple Cobb-Douglas example of Section II) than is the case in countries with a plethora of goods in widespread consumption.

To understand the substantial fluctuations about the growth path, regardless of the stage of growth, one might examine more fully the two types of technological advance and their interaction. Take the technological advance of existing goods, T_e, to be normally distributed with a time invariant mean, μ_e, and variance, σ_e. Similarly, let the technological advance of new goods, T_n, be distributed with mean μ_n and variance σ_n.

Under assumed independence between the distributions T_e and T_n, consider various possibilities in the context of standard growth models, as modified to incorporate the fact that consumption and income are jointly endogenous via labor supply decisions. Starting from a random history for the two types of technological advance, there are four general cases: a) both types of technological advance are unusually large, b) both are unusually small, c) T_e is unusually large while T_n is unusually small, and d) T_n is unusually large while T_e is unusually small[15].

The situation when both types of technological advance move up and down together (relative to normal levels) is of interest. For the case where both types of technological advance are unusually large, the technical advances in the production of existing goods would tend to result in reductions in desired hours of work as discussed earlier. However, the demands for the wide range of new products would work oppositely, encouraging greater work effort. Utility will, however, experience cyclically rapid growth as more of both types of goods are obtained at perhaps constant work effort.

The converse case of abnormally low technological advance for both existing and new goods, would similarly lead to approximately constant hours of work, but

[15]More sophisticated treatments might introduce the correlations between the two types of technological change. This is ignored, for simplicity, in the text.

with much lower cyclical growth in utility relative to the norm. GDP as a measure of welfare might not perform too badly in either of these cases, since the opposing impacts on leisure demand might approximately cancel.

Consider, however, a case in which there is abnormally high growth in technological advance for existing goods, but abnormally low such growth for new goods. In this case, there would be increased desire for greater leisure in the presence of the growing real wage. The utility gain from the technological advance would be taken partly from greater quantities of existing goods, and partly in the form of greater leisure, as the marginal value of leisure is equated to the lower marginal values of incremental existing goods.

It is also possible that traditional dynamic macroeconomic processes stemming from revised expectations could exacerbate such real business cycle effects, leading to a recession rather than a mere slowdown. This follows from the fact that people, in efforts to smooth utility over time, will wish to save more for future periods when more new goods are expected to be introduced. This would be particularly the case, if people were constrained to given work hours, since the savings rate might jump substantially in anticipation of the purchase of future new goods not yet introduced.

In any event, with flexible hours GDP would understate the welfare gains from the technological advance in existing goods, since part of the benefits of that technological advance will be taken in the form of greater leisure; income will not be growing as fast as if labor supply were held constant.

The opposite pattern would occur if there were abnormally rapid technological advances in new goods combined with abnormally slow technological advance for existing goods. People will desire to work longer hours, giving up leisure to acquire the new goods. Additionally, in smoothing utility, they would want to dissave in this period (a boomtime) to acquire the abnormally large number of new good introductions, anticipating reduced rates of new goods introduction in the future, when they would expect to replace that saving. GDP will overstate the gain in welfare in periods such as this, since leisure is foregone.

5. Summary

The present attempt at understanding economic growth and the business cycle recognizes explicitly that we work to get the goods that we want. The goods that we want can be usefully classified as falling into two broadly defined categories, existing goods and new goods.

By expanding existing notions of technical advance to allow for the differential rates of technological advance

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for existing and for new goods to have an impact on labor supply, a rich tapestry of possible macroeconomic scenarios is woven. A given level of growth could be a result of any of a number of patterns of technological change, with quite different implications for welfare. That is, an "average" growth rate might result from average levels of both types of technological change, in which case both work-leisure decisions and saving decisions might be at normal levels. This would result in a relatively smooth future growth path.

Similarly a given *average* rate of technological progress can result in widely varying levels of economic growth depending on whether the technological progress occurs in existing or new goods. For example, below average growth in technological advance for existing goods, and above average growth in technological advance in new goods, would lead to increased desired hours of work and dis-saving, with resulting near-term "boomtimes".

Alternatively, above average rates of technological advance for existing goods, with a relative dearth of new goods might result in desired hours of work falling and savings increasing, leading to a growth slowdown or recession.

In any of the preceding scenarios, and others that could be constructed, the quantitative value of GDP as even a short-run measure of welfare growth is called into question. Since different combinations of the two types of technological advance lead to different optimal goods/leisure combinations, failing to account for leisure matters[16]. GDP will overstate utility gain when optimal leisure decreases in response to an existing pattern of relative technological advance, and conversely. In no case, of course, does technological advance of either type make us worse off, but in gauging quantitatively how much better off we are, leisure is seen here to matter.

Future work could usefully expand the framework presented here to allow for international trade. It will be seen in that work that the distinction made here between technological advance in existing and in new goods has implications for the optimality of the unwavering pursuit of comparative advantage. That is, if technological advance in new goods results in generalized human capital enhancement (a positive spillover externality to production of all kinds in an economy), pursuing a comparative advantage in existing goods might be a 2nd best policy in a dynamic setting.

Illustrating in a simple two-period setting, a small country might have a comparative advantage in producing, say, bananas, rice, or diamonds. Hence, in period one, welfare would be higher if the country specializes in

the comparative advantage good, as in the usual introductory economics presentations using supply and demand curves or production possibility curves. However, in period two, the country will have a level of human capital that has not been augmented, hence might well find welfare lower than if that country had made itself a bit worse off in period one, in order to reap the public good benefits of human capital enhancement in the later period (s). This could well account for why the Asian "tigers" have been experiencing rapid growth while other countries remain mired in poverty[17].

It should be stressed, in closing, that the hurdles to be cleared prior to implementation of the endogenous growth described here are several. It will be difficult, in practice, to unambiguously categorize technological advance as occurring for "new goods" vis-à-vis "existing goods." Is the technological advance leading to plasma/LCD flat screen TVs progress for an existing good or is that progress such a dramatic departure as to constitute a new good? If one takes the theory sufficiently seriously, it is possible that changes in leisure could be taken as a proxy for the net impact of the two types of technological progress (*i.e.* leisure increases imply a preponderance of progress in existing goods while leisure decreases imply a preponderance of progress in new goods). At any rate, the role of leisure has been largely ignored in existing endogenous growth models and is seen here to have important consequences for growth and business cycle behavior.

6. Acknowledgements

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16Clearly, the duration of such effects discussed in the main text will depend to a significant degree on the extent to which both new and existing goods are durable versus non-durable.

17Of course, the truly poor countries must first survive to the second period. At the lowest stages of development the future might well be discounted greatly.

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