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Production complexity, adaptability and economic growth

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ABSTRACT

This paper analyzes the impact of production complexity and its adaptability on the level of output and on its rate of growth. We develop an endogenous growth model where increased complexity raises the rate of economic growth but has an ambiguous effect on the level of output. Our empirical measure of production adaptability captures the proximity of production sectors within the product space, which we modify to reflect intra-industry trade and the international fragmentation of production. We test the model against a sample of 89 countries over the two decades to 2009 and find that its main predictions are validated.

1. Introduction

A country's ability to develop and expand a set of complex production structures requires the availability of a broad skill set, or capabilities, that are adaptable to changing technology. The recognition of a causal link between the efficient division of labor and the gains from specialization goes back to Smith (1776) and has found broad recognition since. For example, the role of capabilities as a precondition for long-term growth is central to the work of Hirschman (1958), where capabilities consist of backward and forward linkages across economic sectors. Similarly, Lewis (1955), Rostow (1959) and Kaldor (1967) portrayed economic development essentially as a process of structural transformation and increasing productivity that is driven by the progressive strengthening of productive capabilities, as well as by the reallocation of resources. Later, Lall (1992) and Kremer (1993) linked capabilities to economic growth and development through their impact on innovation. At the firm level of analysis, Sutton (2001) showed that modern economies' ability to exploit scarce capabilities is at the root of their development success.

Introducing the concept of product space, which maps and links products according to country characteristics necessary for their production, Hausmann et al., 2007 initiated an influential line of research that has sought to explain the relationship between country incomes, growth and a broad measure of production capacity or capabilities. They find evidence that a positive relationship exists between a country's set of capabilities and its rate of

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economic growth, and suggest that some goods have higher spillover effects than others. Expanding on this finding, Hidalgo and Hausmann (2009) suggest that economic complexity spurs growth in countries that are below the income expected from their capability endowment and have yet to venture into developing the full range of products that is within their technological reach. Spillovers and potential growth are highest for countries producing the more complex goods, which are more tightly linked within the product space and facilitate expansion into a broader range of product lines and industries. Governments can address this market failure by tilting resource allocation toward more complex or sophisticated goods. Wang et al. (2010) question the proposition that governments should pursue such a "leapfrogging growth strategy". They argue that empirical evidence in favor of government intervention is too scant, as various measures of export sophistication in their panel growth regressions are estimated to be statistically insignificant. However, subsequent analyses, such as in Felipe et al. (2012) and Poncet and de Waldemar (2013), are at odds with this conclusion and find that complexity exerts a positive impact on economic growth.

Such track record notwithstanding, the concept of capabilities has not entered the mainstream literature of economic growth. Indeed, the neoclassical growth model (Solow, 1956) treats technology and its complexity as exogenous, and the endogenous growth models either account for technological change (Romer, 1989) or human capital (Lucas, 1988), but not for production complexity and capabilities as such, which are ignored. In view of this gap, in this paper we set out a growth model that is driven by human capital accumulation as well as by trade specialization and complexity, building on Costinot (2009). We gauge complexity through an aggregate measure of production adaptability derived from a modified (net trade) Hausmann and Klinger (2006, 2007) product space. In this approach, economic development involves countries striving to upgrade their complex set of capabilities in order to expand production into the newly attainable sectors associated with higher productivity. This process in turn enhances their set of capabilities so that the next tier of proximate sectors will become attainable over time (Hidalgo et al., 2007; Hidalgo and Hausmann, 2009; Hidalgo, 2009; Ferrarini and Scaramozzino, 2015).

In our model, an increase in production complexity plays a dual role. On the one hand, it enhances human capital accumulation through the advancement of skills and the promotion of learning (Lucas, 1988, 1993). On the other, it heightens the risk of production failure through an increase in the number of tasks that need be executed correctly for the product to finalize. Consistent with Kremer's (1993) O-ring theory, a more complex technology entails a higher risk of failure because it lowers the probability that all of the required tasks are performed correctly.

Our theoretical framework thus implies that complexity impacts the level of output and its rate of growth through two separate channels, and possibly in opposite directions. While increased complexity is always associated with a higher long-run rate of growth, at any given time it may either increase or decrease the level of output, depending on whether or not the gains from specialization will outweigh the losses associated with production failures.

We test these predictions against a data set spanning 89 countries from 1990 to 2009. The focus of our empirical investigation is the relation between production adaptability and output. To do so, we devise a measure of average country density that proxies for production adaptability and complexity to an extent. Controlling for human capital and the other key drivers of economic growth identified in the literature, our findings suggest that countries with more adaptable production systems experience higher output growth. Moreover, country density is found to yield a negative impact on economic output, which suggests that, in levels, the losses outweigh the gains from greater specialization.

The remainder of the paper defines, in Section 2, the endogenous growth model with human capital accumulation and complexity. Section 3 derives our trade-based measure of complexity and adaptability and extends the empirical framework to account also for the role of international production networks and vertical trade. Section 4 turns to the regressions of country density on output level and growth. Section 5 concludes.

2. Complexity, human capital and growth

Technological complexity and economic capabilities can play a crucial role for the economic performance of a country. The way they interact can be explained with the aid of an endogenous growth model with human capital accumulation, heterogeneous industries, and complementarities in the production technology. The main motivation for the analysis is that technological complexity can be critical for the development of new skills and for human capital formation, which are the fundamental drivers of growth in the long run. We set out a very flexible specification, which makes it possible to consider the multiple potential effects of complexity both on the level and on the rate of growth of output.

Accumulation of human capital is modeled following Lucas (1998, 1993). Workers decide how much of their time should be allocated to current production and to the formation of human capital, which would increase their future productivity. Differently from the original model by Lucas, industries are not identical but each is characterized by a different level of complexity in its production technology. Greater complexity could be associated with a reduction in industry output: production requires the execution of a certain number of complementary tasks, and a greater degree of complexity increases the risk of failure in the production process (as in the O-ring production function: Kremer, 1993). On the other hand, it could have a positive effect on output because it can be associated with a more advanced region in the product space (Hidalgo et al., 2007; Ferrarini and Scaramozzino, 2015). A higher average level of complexity would always have a beneficial effect on the rate of growth of the economy, because it enhances the accumulation of human capital. Hence, whilst the consequence of greater complexity on the level of output could be ambiguous, its effect on the rate of growth of the economy is always positive.