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Volatility and slow technology diffusion☆

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ABSTRACT

I study the effects of uncertainty on technology adoption and thereby on volatility and growth. I present an analytically-tractable model in which: (i) uncertainty about the returns to adoption delays technology diffusion; and (ii) the mean and volatility of output growth are jointly determined in equilibrium. I then test the key predictions of the model by studying the introduction of three major information and communication technologies (ICTs)—computers, internet, and cell phones. I find that countries with more volatile growth rates of real GDP per capita have higher time adoption lags and lower average growth, as predicted by the model.

1. Introduction

In a seminal paper, Ramey and Ramey (1995) show that countries with higher volatility have lower growth rates of real GDP per capita. This negative volatility-growth link survives for several data sources and samples, and different conditioning variables and estimation strategies (see Acemoglu et al., 2003; Koren and Tenreyro, 2007; Comin and Mulani, 2009; Aghion et al., 2009; 2010; Tabova and Burnside, 2010; Posch, 2011; Posch and Wälde, 2011).

Identifying the determinants of this link is relevant for our understanding of the welfare costs of short-term fluctuations in output and long-term gains from improved stabilization policies. Not surprisingly, several early studies have been exploring potential mechanisms driving the empirical relationship between aggregate uncertainty, volatility and growth (see Bental and Peled, 1996; Acemoglu and Zilibotti, 1997; Matsuyama, 1999; 2001; Francois and Lloyd-Ellis, 2003; Barlevy, 2004; 2007; Wälde, 2005, among others). We have learned a great deal from this body of work. Yet, our understanding remains incomplete.

In this paper, I study the effects of uncertainty on technology diffusion in an analytically-tractable model of technology adoption in which volatility and growth are *jointly* determined in equilibrium. I then show that the key predictions of the model hold in cross-country data. Specifically, I focus on the introduction of three major information and communication

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technologies (ICTs)—computers, internet, and cell phones—which had heterogeneous effects across countries (see Caselli and Coleman, 2001; Caselli and Wilson, 2004; Comin et al., 2006; 2008; Comin and Hobijn, 2010). I find that countries with more volatile growth rates of real GDP per capita have considerably higher time adoption lags and lower average growth, as predicted by the model.[1]

These results provide insights into the economic mechanism, i.e., technology adoption, that links volatility to total factor productivity (TFP), long-run growth, and so cross-country differences in real GDP per capita. Most cross-country differences in output per capita are due to differences in TFP rather than to differences in the levels of factors of production (see Klenow and Rodríguez-Clare, 1997; Hall and Jones, 1999; Jerzmanowski, 2007). These cross-country TFP differences can be attributed to: (i) differences in the technology used; and (ii) non-technological factors that affect the efficiency with which the technology and other factors of production are operated. In this paper, I explore the importance of uncertainty as a determinant of technology diffusion and thereby of volatility and growth.

In Section 2, I present a simple single-agent model of technology adoption, that builds on the real options theory of investment under uncertainty (see Dixit and Pindyck, 1994; Stokey, 2009). I posit the existence of a frontier technology, which unexpectedly becomes available for adoption and dominates the current technology in use in terms of higher risk-adjusted expected growth in output. The replacement of the old technology currently in use with the newly available technology requires payment of a sunk cost and it is irreversible. Sunk costs and investment irreversibilities are arguably key determinants of the diffusion of large-scale technologies such as ICTs. In the model, the technology adoption decision hinges on the risk-return trade-off (akin to portfolio theory): uncertainty (or risk) about the returns to adoption generates a real value of inaction which delays the diffusion of the higher-mean-growth frontier technology. Hence, mean and volatility of output growth are jointly determined and negatively related in equilibrium.

I view the expected return and risk of operating the new technology as determined by features of the economic environment that differ substantially across countries. These cross-country differences result from institutions (see Acemoglu et al., 2001; 2002; Acemoglu and Johnson, 2005), exposure to sizable and frequent domestic and external shocks (see Barro, 2006; Alesina et al., 1996), and governments' policies (see Parente and Prescott, 1994; 1999). Hence, the risk-return trade-off of operating a given technology may substantially vary across countries. This in turn implies that more uncertain (or riskier) countries fall behind the technology frontier: uncertainty effectively acts as a "barrier" impeding technology diffusion, development, and long-run growth.

A negative relationship between uncertainty, embedded in the form of exogenous shocks, and short-run (transitional) output growth emerges as an equilibrium outcome in theories based on investment irreversibility and fixed adjustment costs (see Bernanke, 1983; Pindyck, 1988; 1991; Aizenman, 1993; Bloom, 2009; Bloom et al., 2012). In this paper, I emphasize investment in technology adoption and the effects of uncertainty on technology diffusion and thereby on volatility and long-run growth. Hence, while standard real options theories are concerned with "level effects," this paper is concerned with "growth effects" of uncertainty. In "AK" economies, the link between uncertainty and long-run (steady-state) growth can be either positive or negative depending on the value of the coefficient of relative risk aversion (see Jones et al., 2005) and/or the presence of convex adjustment costs in physical capital (see Barlevy, 2004). In the model of this paper instead, overall uncertainty unambiguously reduces mean output growth through a "wait-and-see" effect on technology adoption.

This paper naturally relates to theories of endogenous volatility and growth (see Bental and Peled, 1996; Matsuyama, 1999; 2001; Francois and Lloyd-Ellis, 2003; Wälde, 2005). In these theories, innovation cycles are self-sustaining and generate long-run growth jointly with recurrent short-run fluctuations in output growth; all in absence of exogenous shocks. In this paper, instead, I consider technology, with the associated expected growth rate and risk, as an exogenous driving force and focus on the endogenous determination of adoption lags.

In addition, the paper relates to early studies on cross-country differences in TFP and real GDP per capita. Such cross-country differences are due to (i) differences in adoption costs (see Chari and Hopenhayn, 1991; Parente and Prescott, 1994; 1999), (ii) mismatch between the skill requirements of new technologies and the skill endowments of the economy (see Basu and Weil, 1998; Acemoglu and Zilibotti, 2001; Jovanovic, 2009), (iii) differences in implementation costs leading to the inefficient use of new technologies (Comin and Hobijn, 2007), and (iv) barriers to trade (see Lucas, 2009; Mutreja et al., 2014). This paper explores instead the role of uncertainty as a determinant of technology diffusion.

In Section 3, I construct the empirical counterpart of the time adoption lag in the model for the three ICTs, based on Comin et al. (2008). The time adoption lag measures how many years before a benchmark year, say 2002, the country leader last had the usage level of an ICT (e.g., number of computers per capita) that another country had in 2002. These time adoption lags are a proxy measure of the distance from the technology frontier. I then test the predictions of the model on volatility, growth, and technology diffusion. To this aim, I calculate country-specific mean growth and volatility as respectively sample average and standard deviation of per capita real GDP annual growth rates based on Ramey and Ramey (1995). As predicted by the model, I find a strong and statistically significant cross-country negative relationship between volatility and the diffusion of the three ICTs: countries with more volatile growth rates of real GDP per capita take considerably more time to adopt new technologies. That is, they have higher time diffusion lags. This relationship is rather robust and holds after controlling for cross-country differences in average growth rates of real GDP per capita. Controlling

[1] I refer to the lag between the time a new technology is introduced and the time at which it is widely adopted as time adoption or time diffusion lag.