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Dynamic models of R & D, innovation and productivity: Panel data evidence for Dutch and French manufacturing

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ABSTRACT

This paper introduces dynamics in the R&D-to-innovation and innovation-to-productivity relationships, which have mostly been estimated on cross-sectional data. It considers four nonlinear dynamic simultaneous equations models that include individual effects and idiosyncratic errors correlated across equations and that differ in the way innovation enters the conditional mean of labor productivity: through an observed binary indicator, an observed intensity variable or through the continuous latent variables that correspond to the observed occurrence or intensity. It estimates these models by full information maximum likelihood using two unbalanced panels of Dutch and French manufacturing firms from three waves of the Community Innovation Survey. The results provide evidence of robust unidirectional causality from innovation to productivity and of stronger persistence in productivity than in innovation.

1. Introduction

For decades, R&D and innovation have been recognized by scholars and policy makers as major drivers of country, industry and firm economic performance. Many of the early studies, following the lead of Griliches (1979), used an augmented production function with R&D capital to estimate the returns to R&D at the firm level. More recently, many studies relied on innovation survey indicators and on the CDM framework to analyze simultaneously a knowledge production function relating innovation output to R & D, and an augmented production function linking productivity to innovation output (Crépon et al., 1998; Mairesse et al., 2005; Griffith et al., 2006). Both the effects of R&D on innovation output and of innovation output on productivity are usually found to be positive and significant in these studies. Most of them, however, are based on cross-sectional data and cannot take into account the dynamic linkages between innovation

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and economic performance nor unobserved firm heterogeneity. This is where the present study comes into play.[1] More specifically, using data from three waves of the Community Innovation Survey (CIS) for France and The Netherlands, we examine whether there is evidence of persistence in firm innovation and productivity and of bidirectional causality between them.[2] There are several reasons why one should introduce dynamics in the interrelationships between R&D, innovation and productivity. Firstly, the time lag between a firm's decision to invest in R&D, the associated R&D outlays and the resulting innovation success may be substantial because of 'time to build', opportunity cost and uncertainty inherent to the innovation process (Majd and Pindyck, 1987). For example, the studies of knowledge production function using firm panel data, where patents proxy for knowledge, specify a relation of patents to distributed lags of R & D(Pakes and Griliches, 1980; Hall et al., 1986). Secondly, scholars argue that a successfully innovative firm is more likely than a non-innovating firm to experience innovation success in the future, in other words, that 'success breeds success'. Several papers have investigated the persistence of innovation success, measured by the number of granted patents (Geroski et al., 1997), the introduction of new or significantly improved products (Peters, 2009) or production methods (Flaig and Stadler, 1994), or the share in total sales accounted for by sales of these products (henceforth the share of innovative sales) (Raymond et al., 2010). Thirdly, it is also argued that the economic performance of a firm, especially of a repeatedly innovating firm, is likely to exhibit persistence. For instance, Bailey et al. (1992), Bartelsman and Dhrymes (1998), and Fariñas and Ruano (2005) find strong evidence of persistence of firm level productivity differentials using transition probabilities on the quintiles or deciles of the distribution of these differentials over time, or using kernel techniques to estimate the conditional distribution of firm level productivity at period t given productivity at period $t-1$. Finally, because of information asymmetry, firms may be more willing to rely on retained earnings rather than to seek external funding for their future innovations (Bhattacharya and Ritter, 1983), implying a feedback effect from productivity to innovation.

To investigate these dynamic aspects, we study four nonlinear dynamic simultaneous equations models that differ in the way that innovation enters the conditional mean of labor productivity: through an observed binary indicator, an observed intensity variable or through the continuous latent variables that correspond to the observed occurrence or intensity. We describe these models in detail in Section 2.

We show in Section 3 how to derive the full information maximum likelihood estimator assuming random effects that are correlated with sufficiently time-varying explanatory variables. More specifically, we take care of the initial conditions problem due to the autoregressive structure of the models and the presence of firm effects using (Wooldridge, 2005) 'simple solutions' approach, and we handle multiple integration due to the correlations of firm effects and idiosyncratic errors across equations using Gauss–Hermite quadrature sequentially along the lines of Raymond (2007, Chapter 6).

In Section 4, we explain the data on which we base our estimations and provide some descriptive statistics. These data come from three waves of the Dutch and the French Manufacturing Community Innovation Surveys (CIS) for 1994–1996, 1998–2000 and 2002–2004, supplemented by a few firm accounting variables. We work with an unbalanced panel to have a larger sample and thus to weaken possible survivorship biases and to obtain more accurate estimates.

In Section 5 we present our results. For both countries they reveal strong persistence in productivity but weaker persistence in innovation, and they indicate a unidirectional causality running from innovation to labor productivity. Whereas past innovation matters to productivity, the most productive enterprises are not more successful in introducing new or significantly improved products and do not attain larger shares of innovative sales than the least productive ones.

2. Model specifications

Our models consist of a knowledge production function and an augmented production function relating respectively innovation output to R&D and other relevant innovation factors, and productivity to innovation output and other relevant production factors. Four measures of innovation output are considered in the analysis. The first is an *observed* binary variable taking the value one if an enterprise is a product innovator, and zero otherwise. In the innovation survey, a product innovator is a firm that has introduced a new or improved product in the last three years. The second variable is a continuous observed variable, namely the observed innovation intensity, measured by the share of total sales in year t due to products introduced in the last three years, i.e. t, $t-1$ or $t-2$. Although the latter is more informative than the former it is likely to be more affected by important measurement errors. We also consider the two *latent* innovation output variables that underly respectively the propensity to introduce new or improved products on the market and the potential share of innovative sales. Both latent variables are continuous measures that substitute in one case for a binary variable and in the other case for a continuous variable with corner solution. The latent variable specification assumes there is an underlying true variable which is not necessarily zero when it is not observed (e.g. in case of a small incremental innovation) while the observed specification assumes that innovation is well known and possibly equal to zero. As innovation output later enters as an argument in the production function, it is also not clear whether it is the observed ex-post or the expected ex-ante

[1] See also Parisi et al. (2006) and Huergo and Moreno (2011) for two different attempts to go in this direction.

[2] There are important differences between France and The Netherlands, in particular the size of the two countries, the industrial composition, the extent of external trade and institutional and regulatory changes in our study period. It is not clear a priori how these differences impact directly the firm innovation and productivity relationships between the two countries. We consider it interesting and important to compare them for the sake of scientific replication (see Hamermesh, 2007).