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Driving forces of technological change: The relation between population growth and technological innovation ☆ Analysis of the optimal interaction across countries

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ABSTRACT

Population growth is one of the major problems facing the world today because it affects the patterns of sustainable economic growth. The economic phenomenon to be explained in this study is the relation between population growth and technological outputs (patents), focusing on OECD countries, in order to analyze the range of population growth rates favorable to support higher technological output, *ceteris paribus*. The study seems to show the existence of an inverted-*U* shaped curve between population growth rate and patents, with an optimal intermediate area in which population growth rates tend to be associated to higher technological outputs. The public policy consequences of this vital relation are that, on average, it is difficult to support an optimal level of technological performance with both a low/negative and a high (higher than 1%) population growth rate-annual % in advanced nations. A main consequence is that the estimated relationship of technological outputs *vs.* population growth is likely to be affected by decreasing returns of technological innovation to population growth, because a higher population might decrease research productivity, which is sensitive to the relation between income per capita and population growth.

Societies crystallized in a static demographic distribution, ceteris paribus, tend to survive inadequately and hamper social, technological and economic growth and, as a consequence, their civilization.

1. The problem

Population growth is one of the major problems facing the world today, associated to resource management, environmental conservation and restoration (Austin and Brewer [1], p. 47). Since Thomas Robert Malthus's works in the 1790s, several scholars have investigated the relation between population and economic growth (*see* Coccia [10] for some historical information; [5,7,45,61]; etc. *Cf. also* [43]). Models of endogenous growth show a positive association between per-capita income growth and population size [25]. Population growth is also a key element of semi-endogenous economic growth models

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([33]; *cf.* [24]). 'In its mildest interpretation, semiendogenous growth states that economic growth is correlated with the growth rate of *effort* in research and development' (Jones Charles I. as quoted by Strulik [59], p. 131, original emphasis). The common features of these models are decreasing returns of knowledge in the production of new knowledge and positive population growth [37]. Kremer ([38], p. 688) remarks that, in some models, if research productivity increases with income, technological change will also increase with population. Kuznets [40] claims that research productivity increases are associated to population growth since a larger population generates more intensive intellectual contacts: "high population spurs technological change because it increases the number of potential inventors" (as quoted by Kremer [38], p. 685). In particular, Kuznets ([40], p. 328) states: "Population growth produces an absolutely larger number of geniuses, talented men, and generally gifted contributors to new knowledge whose native ability would be permitted to mature to effective levels when they join the labor force". As quoted by Strulik ([59], p. 130), Jones Charles I. writes: 'More people means more Isaac Newtons and therefore more ideas'. In fact, many inventions and innovations are demand-driven by larger population, associated to active demographic change (*cf.* Boserup [3], p. 5*ff*). LePoire ([42], p. 1303) points out that: "leadership moves from smaller states to larger states because larger states have the flexibility to develop more complex organizational processes and adapt new technology". Instead, Strulik ([59], p. 129) argues that: "long-run growth is compatible with a stable population". In particular, Strulik ([59], p. 131, original emphasis) relaxes the strong tie between population growth and economic growth:

> First, growth in a general two-sector R&D model is no longer semiendogenous (driven by exogenous population growth) but *fully endogenous* (driven by endogenously explained human capital accumulation). Second, growth of an economy is no longer positively tied to population growth. The correlation can be positive or negative; or, as a special intermediate case, economic growth may be independent of population growth. This result corresponds with the empirical findings of a weak, sometimes mixed, and frequently negative correlation between growth rates of population and income per capita.

Some social scientists show that, when population grows, constraints on resources may negatively affect economic growth (*cf.* [63]; [38]). In fact, the contribution of the system dynamics group "Club di Roma" showed negative scenarios for worldwide economic growth due to high population growth rate and limited natural resources ([44]; *cf.* [6] for an interesting discussion concerning peak oil, human population dynamics, and migration pressures). Despite the existence of severe risks for the global environment due to population growth, the typical response to Malthus's pessimistic argument is that technological innovation plays a crucial role, because it can generate larger output from the same resources in order to support sustainable and continuous economic growth.

Modis ([46], p. 998), on the other hand, notices that:

> For decades now, world population increases dramatically but this increase comes from the third world and that is not where most of the innovations are being born. There is no evidence that the number of innovations correlates to the number of world population. On the contrary, it can be seen that Mensch's bunching of innovations does not correlate with any bunching in population number, nor does the discovery of the stable elements.

Huebner ([28], p. 996) disagrees with this statement by Modis [46].

Porter and Stern [49] show a positive relationship between innovative capacity and GDP per capita, which is a main determinant of the patterns of technological performance (*cf.* Kealey [35], p. 240*ff*).

Besides the wealth of nations, why does technological innovation vary across countries? How does innovation depend on population growth?

An interesting *socio-economic problem* arises with respect to how both population and population growth are linked with technological innovation [20]. The objective of this paper is to explain the phenomenon of the interaction between population growth and technological output in Organisation for Economic Co-operation and Development (OECD) countries, and to discuss some evidence. In particular, the purpose is to verify whether the relation between population growth and technological output exhibits an inverted-*U* shaped form, which is important to determine the optimal area where the rates of population growth are likely to be associated with a high level of technological outputs, measured by patent applications by residents. This form can be similar to one of the curves utilized by Kuznets in his analysis of the relation between income inequality and per-capita income [61].

The philosophy of science of my research, and as a consequence of this study, is based on scientific realism: "science aims for and achieves at least approximate truths" (Thagard [60], p. 145; *cf.* [39]).

The results can provide main findings to detect the complex interaction between population growth and technological change, to support adequate public policies of sustainable economic growth for advanced countries.

The paper is laid out as follows: Section 2 describes the theoretical framework of the study and presents the working hypothesis and research design; Section 3 shows the empirical evidence by statistical analysis; Section 4 discusses vital theoretical relationships among the observed facts, some critical consequences, and public policy implications. Then, concluding remarks are drawn.

2. Background and methodology

2.1. Theoretical framework and related works

Scholars [2,3,41] argue that population growth, supported by existing technology, induces people to adopt new technological innovations (*cf.* also Kremer [38], p. 682*ff*). Kuznets [40] and Simon [55] claim that higher populations have a higher probability to create potential inventors: larger populations have proportionally more individuals with new ideas. In particular, Kuznets [40] states that: 'research productivity per capita increases with population since higher population allows more intensive intellectual contact and greater specialization' (as quoted by Kremer [38], p. 690). Some social scholars analyze the interaction between demographic and technological change, focusing on the role of technological