RETURNS TO SPECIALIZATION AND ECONOMIC GROWTH UNDER HUMAN CAPITAL ACCUMULATION

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OUTLINE OF THE TALK

- Why Do We Need to Discuss about PMC and Economic Growth in Endogenous Growth Theory?
- The *Schumpeterian Hypothesis* (PMC, Innovation and Economic Growth)
- The *Population-Push Hypothesis* (Population, Innovation and Economic Growth)
- Aim of the paper
- Methodology
- The Model: Broad Description, BGP Analysis, Main Results, and Extensions
- Summary and Future Research

WHY DO WE NEED TO DISCUSS ABOUT PMC AND ECONOMIC GROWTH IN ENDOGENOUS GROWTH THEORY?

- *Technological change is the result of an intentional economic activity (R&D) carried out by forward-looking, rational agents in search for higher rewards (profits)*
- *Technological knowledge is a* ***NONRIVAL*** *input that can be accumulated without bounds on a per-capita basis* (**Romer, 1990**)

Non-rivalry introduces non-convexities, therefore a decentralized equilibrium with price-taking competition can no longer be sustained (**Arrow, 1962** and **Shell, 1966**)

"…The institutions of complete property rights and perfect competition that work so well in a world consisting solely of rival goods no longer deliver the optimal allocation of resources in a world containing ideas. Efficiency in use dictates price equal to marginal cost. But with increasing returns, there is insufficient output to pay each input its marginal product…Price must exceed marginal cost somewhere to provide the incentive for profit maximizing private firms to create new ideas" (**JONES and ROMER, 2009, p. 7**)

"…The only way to accept all **[these]** *premises…is to return to the suggestion of Schumpeter (1942) and explicitly introduce market power"* **(Romer, 1990, p. S78)**

THE "*SCHUMPETERIAN HYPOTHESIS*"

- Schumpeter (1942) was among the first to recognize that **MORE MARKET POWER**, by increasing the rents that can be appropriated by successful innovators, **SPURS R&D**, so accelerating the pace of technical progress and economic growth in the long-run [same argument as in Aghion and Howitt, 1992]

- Contrary to this view, more recent THEORETICAL RESEARCH (both IO and macro-based) finds **MIXED RESULTS** in the relationship between PMC and innovation/growth [Aghion and Griffith, 2005]

- EMPIRICAL ANALYSES confirm the ambiguity of this relationship:

    - Blundell *et al.* (1995 and 1999) and Nickell (1996) find that **COMPETITIVE PRESSURES ENCOURAGE INNOVATION** and, thus, may have a positive effect on productivity growth in the long term

    - Aghion *et al.* (2005) find that the **RELATIONSHIP BETWEEN PMC AND INNOVATION/GROWTH IS *INVERTED U-SHAPED***

THE "*SCHUMPETERIAN HYPOTHESIS*" REVISITED

In order to account for the existing evidence, the basic theoretical Schumpeterian growth paradigm (Aghion and Howitt, 1992) has been extended along different directions

Aghion *et al.* (1997 and **1999):** Emphasize the importance of ***AGENCY ISSUES***. Intensified PMC can force managers to speed up the adoption of new technologies in order to avoid loss of control rights due to bankruptcy

Aghion and Howitt (1996): More competition between new and old production lines (parameterized by ***INCREASED SUBSTITUTABILITY*** between them) makes workers more adaptable in switching to newer ones. This increases the flow of workers into newly discovered products, which enhances the profitability of R&D (and, hence, economic growth)

In these papers there is a **POSITIVE** relationship between PMC and innovation/growth

THE "*SCHUMPETERIAN HYPOTHESIS*" REVISITED

Aghion, Harris and Vickers (1997),
Aghion *et al.* (2001),
Aghion *et al.* (2005)

allow incumbent firms to innovate and obtain an **AMBIGUOUS** relation between PMC and innovation/growth.

- When competition is low, an increase will raise innovation through the ***ESCAPE COMPETITION EFFECT*** on neck-and-neck firms;
- When it becomes intense enough it may lower innovation through the traditional ***SCHUMPETERIAN EFFECT*** on laggards

In these papers PMC is measured by either a GREATER ELASTICITY OF DEMAND, or as a SWITCH FROM COURNOT TO BERTRAND RIVALRY, or else in terms of the LERNER INDEX

IN SUM, THERE ARE MANY DIFFERENT AND CONVINCING (THEORETICAL, AS WELL AS EMPIRICAL) ARGUMENTS SHOWING THAT THE SIGN OF THE CORRELATION BETWEEN PMC AND INNOVATION/GROWTH MAY BE EITHER ALWAYS NEGATIVE, OR ALWAYS POSITIVE, OR ELSE AMBIGUOUS

THE "*POPULATION-PUSH*" HYPOTHESIS

Innovation and economic growth are influenced not only by the degree of competition in the product market, but also by demographic forces:

"…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" **(Kuznets, 1960, p. 328)**

"…One can hardly imagine, I think, how poor we would be today were it not for the rapid population growth of the past to which we owe the enormous number of technological advances enjoyed today... If I could re-do the history of the world, halving population size each year from the beginning of time on some random basis, I would not do it for fear of losing Mozart in the process" **(Phelps, 1968, pp. 511-512)**

"More people means more Isaac Newtons and therefore more ideas" **(Jones, 2003, p. 505)**

POPULATION, INNOVATION AND ECONOMIC GROWTH: SOME FURTHER LITERATURE

ENDOGENOUS TECHNOLOGICAL CHANGE WITH NO *INVESTMENT IN HUMAN CAPITAL*

1. Romer (1990); Grossman and Helpman (1991); Aghion and Howitt (1992):

$$\gamma_y = f\left(\underset{+}{L}\right)$$

   Empirical evidence does not support this kind of **STRONG SCALE EFFECT**

2. Jones (1995); Kortum (1997); Segerstrom (1998):

$$\gamma_y = f\left(\underset{+}{n}\right), \qquad \gamma_y = f\left(0\right) = 0$$

   The evidence does not support the prediction that income growth is unambiguously and positively correlated with population growth (*semi-endogenous* growth models - **WEAK SCALE EFFECT**)

3. Young (1998); Peretto (1998); Dinopoulos and Thompson (1998); Howitt (1999):
   Explain why we can observe positive growth in per-capita incomes even in the absence of any population change: $\gamma_y = a + b \cdot n, \qquad a, b > 0$

POPULATION, INNOVATION AND ECONOMIC GROWTH: SOME FURTHER LITERATURE

ENDOGENOUS TECHNOLOGICAL CHANGE <u>WITH</u> *HUMAN CAPITAL INVESTMENT*

- **DALGAARD AND KREINER (2001)**
- **STRULIK (2005)**
- **BUCCI (2008)**

➢ Population growth has a non-positive impact on economic growth; economic growth is compatible with a stable population (Dalgaard and Kreiner, 2001);

➢ Economic growth is ambiguously correlated with population growth (Strulik, 2005; Bucci, 2008)

Empirical research confirms this ambiguity:

"…Though countries with rapidly growing populations tend to have more slowly growing economies…, this negative correlation typically disappears (or even reverses direction) once other factors …are taken into account. …In other words, when controlling for other factors, there is little cross-country evidence that population growth impedes or promotes economic growth. This result seems to justify a third view: population neutralism" **(Bloom et al., 2003, p. 17)**

POPULATION, INNOVATION AND ECONOMIC GROWTH: SOME EMPIRICAL RESULTS

- Brander and Dowrick (1994)
- Kelley and Schmidt (1995)
- Ahituv (2001)
- Bernanke and Gürkaynak (2001)

Find a **negative correlation** between population and economic growth rates (with slower population growth having a positive impact on economic growth)

- More recent scenario–analyses conducted in a growth–accounting framework for the Euro-area (Maddaloni *et al.*, 2006)

Reveal a **positive correlation** between the two variables (so that a slower population growth can have a negative impact on economic growth)

- According to Kelley and Schmidt (2003):

*"[…]No empirical finding has been more important to conditioning the 'population debate' than the widely-obtained statistical result showing **a general lack of correlation between the growth rates of population and per capita output**"*.

AIM OF THIS PAPER

The main aim of this paper is to account simultaneously and within the same semi-endogenous growth framework with horizontal R&D activity and human capital accumulation for the ambiguous correlations between

- PMC and ECONOMIC GROWTH

and between

- POPULATION GROWTH and ECONOMIC GROWTH

Unlike the existing literature, our explanation of the ambiguity in the sign of both relations is based on the notion of ***'RETURNS TO SPECIALIZATION'***, that is the extent

"…To which society benefits from 'specializing' production between a larger number of intermediates"
(Benassy, 1998, p. 63)

METHODOLOGY

In order to reach this aim, the present work extends two previous papers (Bucci, 2008 and 2012)

The first one (Bucci, 2008), using a horizontal innovation-driven growth model with purposive human capital investment, demonstrates that the ambiguous relation between population growth and the growth rate of real per capita income may also be related to the nature (‘*skill-biased’*, ‘*eroding’*, or ‘*neutral’*) of technical change

Differently from Bucci (2008), the present paper accounts for an ambiguous correlation not only between population and per-capita income growth rates, but also between PMC and economic growth, regardless of the type of technological progress

METHODOLOGY

With respect to Bucci (2012), the present article introduces four major novelties.

1. I use a more general aggregate production function that is able to replicate the production functions of Ethier (1982), Benassy (1998), and Bucci (2012) as particular cases

2. I follow Ethier (1982) and Benassy (1998) in postulating explicitly that the degree of returns to specialization is non – negative

3. I take into account the possibility that there might be no (negative and linear) *dilution effect* of population growth on per-capita human capital investment

4. I study what happens with a different (*Mincerian-type*) equation for education

THE MODEL: A BROAD DESCRIPTION (THE PRODUCTION-SIDE OF THE ECONOMY)

Imagine an economy where three sectors of activity are vertically integrated:

- In the R&D sector, firms use skilled labor (human capital) and, eventually, ideas (knowledge capital) to engage in innovative activity. This sector is competitive

- The intermediate sector is composed of monopolistically competitive firms, each producing a differentiated variety *i* of durables. The only input in the production of each variety of capital goods is human capital, a reproducible factor-input

- In the competitive final output sector firms produce a homogeneous consumption good by employing human capital and the existing set of varieties of intermediate inputs

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtreqless 1 \tag{1}$$

The *Elasticity of Substitution* between any generic pair of varieties of differentiated intermediates is:

$$\frac{1}{1-\beta} > 1$$

$\uparrow \beta$ $\uparrow$ *Elasticity of Substitution* $\uparrow$ Degree of PMC between capital–good producers

- I disentangle the measure of PMC (β) from the factor–shares in GDP (Z)
- The aggregate production function displays constant returns to H_Y and x_i together

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtreqless 1 \qquad (1)$$

- When $Z \in (0;1)$, final output production takes place by using simultaneously human capital and intermediates

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtreqless 1 \qquad (1)$$

- When $Z = \varepsilon = 1$ and $\bar{\alpha} > 1$, the aggregate production function (1) writes as:

$$Y_t = n_t^{\bar{\alpha}} \left[\int_0^{n_t} \frac{\left(x_{it} \right)^{\beta}}{n_t} di \right]^{\frac{1}{\beta}}, \qquad \bar{\alpha} > 1, \qquad 0 < \beta < 1. \qquad (1a)$$

With a continuous variety-space, Eq. (1a) coincides with the production function of the so-called *"output of finished manufactures"* (**Ethier, 1982**, Eq. 2', p. 391)

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

- When $Z = \varepsilon = 1$ and $\bar{\alpha} > 1$, we have the same aggregate production function of **Ethier (1982)**

$$Y_t = n_t^{\bar{\alpha}} \left[\int_0^{n_t} \frac{\left(x_{it}\right)^{\beta}}{n_t} di \right]^{\frac{1}{\beta}}, \qquad \bar{\alpha} > 1, \qquad 0 < \beta < 1. \tag{1a}$$

It is evident that in Ethier (1982): $\bar{\alpha} > Z$

In a symmetric equilibrium (in which $x_i = x,\ \forall i$), Eq. (1a) becomes:

$$Y_t = n_t^{\bar{\alpha}} x_t = n_t^{\bar{\alpha}} \left(\frac{n_t x_t}{n_t} \right) = n_t^{\bar{\alpha}-1} \underbrace{\left(n_t x_t \right)}_{\equiv X_t} = n_t^{\bar{\alpha}-1} X_t, \qquad \bar{\alpha} > 1 \tag{1b}$$

The term $n^{\bar{\alpha}-1}$ is an externality that ultimately shapes the gains from the division of labor, and summarizes, for given X, the role of horizontal product differentiation in GDP

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

Bucci (2012) uses a different technology:

$$Y_t = H_{Yt}^{1-\alpha} \underbrace{\left[\frac{1}{N_t^{\varepsilon}} \int_0^{N_t} \left(x_{it} \right)^{1/m} di \right]^{\alpha m}}_{\equiv X^{\alpha}}, \qquad 0<\alpha<1, \qquad m>1 \qquad (1c)$$

Ethier (1982):

$$Y_t = n_t^{\bar{\alpha}} x_t = n_t^{\bar{\alpha}} \left(\frac{n_t x_t}{n_t} \right) = n_t^{\bar{\alpha}-1} \underbrace{\left(n_t x_t \right)}_{\equiv X_t} = n_t^{\bar{\alpha}-1} X_t, \qquad \bar{\alpha}>1,$$

The modeling-strategy in Eq. (1c) reflects the idea that:

- *No externality from "horizontal" innovation* is at work;
- All possible aggregate effects of a change in the number of available intermediate varieties stem just from the technology of aggregation, $\Sigma \equiv X^{\alpha} = \left[\underbrace{\left(\int_0^N \frac{\left(x_i \right)^{1/m}}{N^{\varepsilon}} di \right)^m}_{\equiv X} \right]^{\alpha}$

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

Indeed, Eq. (1c) – **Bucci (2012)**:

$$Y_t = H_{Yt}^{1-\alpha}\left[\frac{1}{N_t^{\varepsilon}}\int_0^{N_t}\left(x_{it}\right)^{1/m} di\right]^{\alpha m}, \qquad 0<\alpha<1, \qquad m>1, \qquad \varepsilon \gtreqless 1 \tag{1c}$$

can be easily obtained from Eq. (1) – **present paper**:

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z}\left[\frac{1}{n_t^{\varepsilon}}\int_0^{n_t}\left(x_{it}\right)^{\beta} di\right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha}\geq 0, \qquad 0<Z\leq 1, \qquad 0<\beta<1, \qquad \varepsilon \gtreqless 1 \tag{1}$$

by assuming:

- $\bar{\alpha}=0$, $\mathrm{Z}\equiv\alpha\in\left(0;1\right)$, and defining: $n\equiv N$, $m\equiv 1/\beta$
- It is clear that, with respect to Eq. (1), Bucci (2012) implicitly assumes: $\bar{\alpha}<\mathrm{Z}$

IN THE PRESENT ARTICLE I FOLLOW ETHIER (1982) IN POSTULATING $\bar{\alpha}>\mathrm{Z}$

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtrless 1 \tag{1}$$

In normalizing the integral within the square brackets by n_t^{ε}, Eq. (1) formalizes the idea that

"[…]THE PRODUCTIVITY-ENHANCING EFFECTS OF HORIZONTAL INNOVATIONS ARE NOT…OBVIOUS… FOR WHILE HAVING MORE PRODUCTS DEFINITELY OPENS UP MORE POSSIBILITIES FOR SPECIALIZATION, AND OF HAVING INSTRUMENTS MORE CLOSELY MATCHED WITH A VARIETY OF NEEDS, IT ALSO MAKES LIFE MORE COMPLICATED AND CREATES GREATER CHANCES OF ERROR…" (Aghion and Howitt, 1998, p. 407)

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtreqless 1 \qquad (1)$$

- When positive, ε is meant to capture the detrimental effect on aggregate productivity of having a larger number of intermediate–input varieties available to be assembled in the same production process. In absolute terms, ε captures some *(production-)complexity effect*

- This effect contrasts with the positive *specialization effect* that is reflected, for given $n^{\bar{\alpha}}$, by the upper-bound of the integral in Eq. (1)

- With a production function of the type: $Y = n^{\bar{\alpha}} x, \quad \bar{\alpha} > 1$ (Ethier, 1982), there exists no room for modeling the *complexity-effect* induced by the proliferation of intermediate–input varieties:

An expansion of variety ($n > 0$), while holding the quantity employed of each intermediate input ($x > 0$) fixed, is always associated to an increase of aggregate output, Y

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} (x_{it})^{\beta} \, di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtreqless 1 \qquad (1)$$

If $\underline{\varepsilon < 0}$, then: $$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[n_t^{-\varepsilon} \int_0^{n_t} (x_{it})^{\beta} \, di \right]^{\frac{Z}{\beta}} = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[n_t^{\zeta} \int_0^{n_t} (x_{it})^{\beta} \, di \right]^{\frac{Z}{\beta}}, \qquad \zeta \equiv -\varepsilon > 0$$

There is no *increasing (production-)complexity-effect*, since the parameter $\zeta > 0$ now amplifies the *specialization-effect* emerging from the upper-bound of the integral

A fortiori, this is also true when $\varepsilon = 0$ (in this case we end up with the sole, traditional *specialization-effect*)

IN ORDER TO MODEL EXPLICITLY THE *INCREASING (PRODUCTION-)COMPLEXITY-EFFECT*, WE NEED SOME POSITIVE ε !

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

FINAL OUTPUT SECTOR

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtrless 1 \tag{1}$$

If ε (in absolute terms) describes the strength of the *increasing (production-)complexity effect* (a side-effect of horizontal innovation), **<u>when compared to one</u>** the same parameter summarizes the net effect of the ***trade-off* between positive (*specialization*) and negative (*increase in production-complexity*) consequences of having a rising number of specialized intermediates in the same production function**

In a symmetric equilibrium in which $n^{\bar{\alpha}}$ is given and in which : $x_i = x > 0; \quad H_Y > 0; \quad n > 0$, the cases $\varepsilon < 1$, $\varepsilon > 1$ and $\varepsilon = 1$ correspond, respectively, to situations in which the increase of Y (due to the productivity gains resulting from the proliferation of products) exceeds, is lower than, or is exactly offset by the fall of output (caused by the productivity losses owing to the increase in production complexity)

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

INTERMEDIATE-GOODS SECTOR

Each local intermediate monopolist has access to the same one–to–one technology:

$$x_{it} = h_{it}, \qquad \forall i \in [0; n_t], \qquad n_t \in [0; \infty), \tag{3}$$

For given n, Eq. (3) implies:

$$\int_0^{n_t} (x_{it})\, di = \int_0^{n_t} (h_{it})\, di \equiv H_{It}. \tag{4}$$

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

With no strategic interaction across intermediate firms (n large enough):

$$p_{it} = \frac{1}{\beta} w_{It} = \frac{1}{\beta} w_t = p_t, \qquad \forall i \in [0; n_t], \qquad n_t \in [0; \infty). \tag{5}$$

- All human capital (H) is employed across production of consumption goods (H_Y), durables (H_I), and ideas (H_n). Since it is assumed perfectly mobile across these three sectors, human capital will be rewarded according to the same wage rate:

$$w_{Yt} = w_{It} = w_{nt} \equiv w_t.$$

Using the hypothesis of symmetry (x and p are equal across i's) leads to:

$$x_{it} = x_t = \frac{H_{It}}{n_t}, \qquad \forall i \in [0; n_t] \tag{4'}$$

$$\pi_{it} = \left[Z(1-\beta) H_{Yt}^{1-Z} H_{It}^{Z} \right] n_t^{\bar{\alpha}-1+Z\left[\frac{1}{\beta}(1-\varepsilon)-1\right]} = \pi_t, \quad \forall i \in [0; n_t] \tag{6}$$

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

Under symmetry, Eq. (1) can be recast as:

$$Y_t = \left(H_{Yt}^{1-Z} H_{It}^{Z}\right) n_t^R, \qquad R \equiv \overline{\alpha} + \frac{Z}{\beta}\left(1-\varepsilon-\beta\right), \tag{1'}$$

where R measures *"…The degree to which society benefits from 'specializing' production between a larger number of intermediates"* (Benassy, 1998, p. 63).

- In the specification of Ethier (1982) and Benassy (1998), it is immediate to verify that $R \equiv \overline{\alpha} - 1 \geq 0$. In the present paper we postulate $R \geq 0$, as well. Accordingly:

$$\varepsilon \leq \frac{\beta}{Z}\left(\overline{\alpha} - Z\right) + 1, \qquad \overline{\alpha} > Z \tag{1''}$$

- The assumption $R \geq 0$ implies that the impact on aggregate productivity (Y) of having a larger number of intermediate-input varieties ($n > 0$) is always positive (or, at most, equal to zero) for any $H_I > 0$ and $H_Y > 0$ (Eq. 1')

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

Under symmetry, Eq. (1) can be recast as:

$$Y_t = \left(H_{Yt}^{1-Z} H_{It}^{Z}\right) n_t^R, \qquad R \equiv \overline{\alpha} + \frac{Z}{\beta}\left(1-\varepsilon-\beta\right) \tag{1'}$$

According to Eq. (1'), the aggregate production function exhibits:

- Constant returns to H_Y and H_I together,

but …

- Either increasing ($R>1$), or decreasing ($0 \le R < 1$), or else constant ($R=1$) returns to an expansion of variety, while holding the quantity employed of each other input fixed

IN EQ. (1') IT IS APPARENT THAT, WITH $\overline{\alpha}$, Z AND β GIVEN, THE DEGREE OF RETURNS TO SPECIALIZATION IS CRUCIALLY GOVERNED BY THE MAGNITUDE OF ε

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

$$Y_t = \left(H_{Yt}^{1-Z} H_{It}^{Z}\right) n_t^R, \qquad R \equiv \overline{\alpha} + \frac{Z}{\beta}\left(1-\varepsilon-\beta\right), \tag{1'}$$

With respect to other settings, the present paper introduces some important novelties.

- Unlike Devereux *et al.* (1996a; 1996b; 2000) where, if all intermediates are hired in the same quantity x the returns to specialization are either unambiguously increasing or at most constant, **I allow for the possibility that**, depending on the size of ε, the degree of **returns to specialization might also be smaller than one**

- Unlike Bucci (2012), I explicitly rule out the possibility that the returns to specialization R may be negative

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

$$Y_t = \left(H_{Yt}^{1-Z} H_{It}^{Z} \right) n_t^R, \qquad R \equiv \overline{\alpha} + \frac{Z}{\beta}(1-\varepsilon-\beta), \qquad (1')$$

In an influential paper, Benassy (1998) has shown the importance of disentangling the degree of returns to specialization from the degree of market power in *expanding-product-variety* models

In his model, the degree of returns to specialization ($\nu \geq 0$), is set at a level independent of the markup on the marginal production costs

- **In my model, the returns to specialization are related (although in a contradictory manner, depending on the size of ε) to the markup ratio,** $1/\beta$

THE MODEL: A CLOSER COMPARISON WITH ETHIER (1982) AND BENASSY (1998)

IN MY MODEL: The aggregate production function for goods (Eq. 1) can also be written as

$$Y = n^{\bar{\alpha}}\left(H_Y^{1-Z} D^Z\right), \qquad D \equiv \left[\int_0^n \frac{x_i^{\beta}}{n^{\varepsilon}}\, di\right]^{1/\beta}, \qquad \bar{\alpha} \geq 0, \qquad Z \in (0;1), \qquad 0 < \beta < 1 \qquad \text{[A]}$$

Final output (Y) is produced by combining a composite factor input (D) and human capital (H_Y), through an aggregate technology displaying constant returns to scale to H_Y and D together

IN ETHIER (1982): $Y = n^{\bar{\alpha}-1}(nx) = n^{\bar{\alpha}-1} X$, $\quad \bar{\alpha} > 1 \qquad$ [B]

WITH RESPECT TO ETHIER (1982) I FIRST ASSUME THAT THERE EXISTS A REPRODUCIBLE FACTOR–INPUT (HUMAN CAPITAL) THAT ENTERS DIRECTLY THE AGGREGATE PRODUCTION FUNCTION AS AN INPUT

THE MODEL: A CLOSER COMPARISON WITH ETHIER (1982) AND BENASSY (1998)

$$Y = n^{\bar{\alpha}}\left(H_Y^{1-Z} D^Z\right), \qquad D \equiv \left[\int_0^n \frac{x_i^\beta}{n^\varepsilon}\, di\right]^{1/\beta}, \qquad \bar{\alpha} \geq 0, \qquad Z \in (0;1), \qquad 0 < \beta < 1 \qquad \text{[A]}$$

IN ETHIER (1982): $Y = n^{\bar{\alpha}-1}(nx) = n^{\bar{\alpha}} x = n^{\bar{\alpha}} \left[\underbrace{\int_0^n \left(\frac{x_i^\beta}{n}\right) di}_{\equiv X}\right]^{\frac{1}{\beta}}, \qquad X \equiv \left[\int_0^n \left(\frac{x_i^\beta}{n}\right) di\right]^{1/\beta}$ [B]

SECONDLY, I DO NOT RESTRICT MY ATTENTION TO THE PECULIAR CASE $\varepsilon = 1$

- Under symmetry ($x_i = x,\ \forall i$) and with $\varepsilon = 1$ $\Rightarrow$ $D = x$

- For this reason both in Ethier, 1982 (and in Benassy, 1998), where $Z = \varepsilon = 1$, so that $Y = n^{\bar{\alpha}} H_Y^{1-Z} D^Z = n^{\bar{\alpha}} D = n^{\bar{\alpha}} x = n^{\bar{\alpha}}\left(\frac{nx}{n}\right) = n^{\bar{\alpha}-1}(nx) = n^{\bar{\alpha}-1} X$, the degree of returns to specialization ($R \equiv \bar{\alpha} - 1$) is totally independent of any other model's parameter (including the monopolistic markup)

THE MODEL: A CLOSER COMPARISON WITH ETHIER (1982) AND BENASSY (1998)

$$Y = n^{\bar{\alpha}}\left(H_Y^{1-Z} D^Z\right), \qquad D \equiv \left[\int_0^n \frac{x_i^\beta}{n^\varepsilon}\, di\right]^{1/\beta}, \qquad \bar{\alpha} \geq 0, \qquad Z \in (0;1), \qquad 0 < \beta < 1 \qquad [A]$$

IN ETHIER (1982): $Y = n^{\bar{\alpha}-1}(nx) = n^{\bar{\alpha}} x = n^{\bar{\alpha}} \left[\underbrace{\int_0^n \left(\frac{x_i^\beta}{n}\right) di}_{\equiv X}\right]^{\frac{1}{\beta}}, \qquad X \equiv \left[\int_0^n \left(\frac{x_i^\beta}{n}\right) di\right]^{1/\beta} \qquad [B]$

- I believe that the assumption $Z = \varepsilon = 1$ (Ethier, 1982; Benassy, 1998) is overly restrictive in a *horizontal differentiation-based* growth model with *Human Capital accumulation* and in which production–complexity related to variety–expansion plays a role !

- Therefore, an unavoidable interaction between β and R would necessarily take place whenever $\varepsilon \neq 1$

$$R \equiv \bar{\alpha} + \frac{Z}{\beta}(1 - \varepsilon - \beta)$$

THE MODEL: A CLOSER COMPARISON WITH ETHIER (1982) AND BENASSY (1998)

$$Y_t = n_t^{\bar{\alpha}} H_{Yt}^{1-Z} \left[\frac{1}{n_t^{\varepsilon}} \int_0^{n_t} \left(x_{it} \right)^{\beta} di \right]^{\frac{Z}{\beta}}, \qquad \bar{\alpha} \geq 0, \qquad 0 < Z \leq 1, \qquad 0 < \beta < 1, \qquad \varepsilon \gtreqless 1 \qquad (1)$$

In sum, with respect to Ethier (1982) and Benassy (1998), my analysis here is explicitly based on the theoretical belief that the possible effects of a change in the number of available intermediate varieties stem:

- Not only from some ***"horizontal" innovation–externality*** (of the form $n^{\bar{\alpha}}$), that plays the role of increasing the productivity of *all* the factors employed in production,…

- …But also (and simultaneously) from **a more general technology of aggregation of the different varieties of durables in the same production process**, $D \equiv \left[\int_0^n \frac{x_i^{\beta}}{n^{\varepsilon}} di \right]^{1/\beta}$

THE MODEL: FORMAL ANALYSIS
(THE PRODUCTION SIDE OF THE ECONOMY)

R&D ACTIVITY

There are many competitive firms undertaking R&D activity, whose production function is:

$$\dot{n}_t = \frac{1}{\chi}\frac{H_{nt}^{\mu}}{H_t^{\Phi}} n_t^{\eta}, \qquad n(0) > 0, \qquad \chi > 0, \qquad \mu > 0, \quad \Phi \geq 0, \quad \mu \neq \Phi, \qquad \eta < 1 \quad (8)$$

In Eq. (8):

- η measures the *inter-temporal spillover* from the existing stock of knowledge
- μ measures the *degree of returns to R&D – Human Capital*

In accordance with Jones (2005, p. 1074, Eq. 16), I keep the analysis as much general as possible and impose no upper bound to μ

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

R&D ACTIVITY

$$\dot{n}_t = \frac{1}{\chi}\frac{H_{nt}^{\mu}}{H_t^{\Phi}} n_t^{\eta}, \qquad n(0)>0, \qquad \chi>0, \qquad \mu>0, \quad \Phi\geq 0, \quad \mu\neq\Phi, \qquad \eta<1 \quad (8)$$

Inventing the latest design for intermediate goods requires a skilled-labor input equal to:

$$H_n = \left(\chi \frac{H^{\Phi}}{n^{\eta}}\right)^{\frac{1}{\mu}}$$

- The fact that population grows at an exogenous and positive rate (g_L), leads in our model to a rise of $H = hL$ and, ultimately, to a decrease of research human capital productivity
- The hypothesis that the productivity of R&D human capital may fall due to an increase of population can be justified by the fact that it becomes **increasingly difficult** to introduce successfully new varieties of goods in a more crowded market (Dinopoulos and Segerstrom, 1999)
- In Eq. (7) Φ measures the strength of this **R&D difficulty-effect**: *ceteris paribus*, the larger Φ and the bigger the decline in the R&D human capital productivity following an increase of population size

THE MODEL: FORMAL ANALYSIS (THE PRODUCTION SIDE OF THE ECONOMY)

R&D ACTIVITY

Because the R&D sector is competitive, there is free entry.

With the total stock of knowledge (n) and the aggregate supply of human capital (H) given, the zero-profit condition implies:

$$w_{nt} = \frac{1}{\chi} \frac{H_{nt}^{\mu-1}}{H_t^{\Phi}} n_t^{\eta} V_{nt} \qquad (9')$$

where:

$$V_{nt} = \int_t^{\infty} \pi_{i\tau} e^{-\int_t^{\tau} r(s) ds} d\tau, \qquad \tau > t \qquad (10)$$

THE MODEL: FORMAL ANALYSIS (THE CONSUMPTION SIDE OF THE ECONOMY)

HOUSEHOLDS

- The economy is closed and consists of a continuum (of total mass 1) of structurally-identical households
- Therefore, we can focus on the choices of a single infinitely-lived family with perfect foresight, whose size coincides with the size of population (L)
- Each member of the household can purposefully invest in human capital
- The aggregate stock of this factor-input, $H = hL$, can rise either because population grows at the exogenous and constant rate $g_L > 0$, or because per capita human capital h endogenously increases over time
- The household uses the income it does not consume to accumulate more assets, taking the form of ownership claims on firms

THE MODEL: FORMAL ANALYSIS (THE CONSUMPTION SIDE OF THE ECONOMY)

HOUSEHOLDS

The representative household solves the following intertemporal optimization problem:

$$\underset{\{c_t, u_t, a_t, h_t\}_{t=0}^{\infty}}{Max} U \equiv \int_0^{\infty} \left(\frac{c_t^{1-\theta} - 1}{1-\theta} \right) e^{-(\rho - \omega g_L)t} dt, \qquad \rho > \omega g_L \geq 0; \qquad \omega \in [0;1]; \qquad \theta > 0 \qquad (13)$$

$$s.t.: \quad \dot{a}_t = (r_t - g_L) a_t + (u_t h_t) w_t - c_t, \qquad u_t \in [0;1], \quad \forall t \geq 0; \qquad \dot{L}_t / L_t \equiv g_L > 0$$

$$\dot{h}_t = \left[\sigma (1 - u_t) - \xi g_L \right] h_t, \qquad \sigma > 0; \qquad \xi \in [0;\, 1]$$

$a(0) > 0$, $\quad h(0) > 0 \quad$ are given

GENERAL EQUILIBRIUM ANALYSIS

CLEARING CONDITIONS FOR THE MARKET OF HUMAN CAPITAL:

$$H_{Et} \equiv u_t H_t = H_{Yt} + H_{It} + H_{nt} \tag{14}$$

$$w_{It} = w_{nt} \tag{15}$$

$$w_{It} = w_{Yt} \tag{16}$$

CLEARING CONDITION FOR THE MARKET OF ASSET HOLDINGS:

$$A_t = n_t V_{nt}, \tag{17}$$

where $V_{nt} = \int_t^{\infty} \pi_{i\tau} e^{-\int_t^{\tau} r(s)ds} d\tau$ and satisfies the usual *no-arbitrage condition*:

$$\dot{V}_{nt} = r_t V_{nt} - \pi_t$$

BGP ANALYSIS

DEFINITION: BGP EQUILIBRIUM

A BGP in this economy is a state where:

(i) *All variables depending on time grow at constant (possibly positive) exponential rates*

(ii) *The sectoral shares of human capital employment* ($s_j \equiv H_j / H$, $j = Y, I, n$) *are constant*

PROPOSITION 1

Along the BGP, the fraction of the aggregate stock of human capital employed in production activities is constant (that is, $u_t = u$, $\forall t \geq 0$).

RESULTS

$$\frac{\dot{H}_{Yt}}{H_{Yt}} = \frac{\dot{H}_{It}}{H_{It}} = \frac{\dot{H}_{nt}}{H_{nt}} = \frac{\dot{H}_t}{H_t} \equiv \gamma_H = \frac{\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta} \tag{18}$$

$$\frac{\dot{n}_t}{n_t} \equiv \gamma_n = \frac{\Upsilon\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta} \tag{19}$$

$$r = \frac{\sigma\theta + \Upsilon R(\sigma\theta-\rho) - \left\{\theta\left[\xi(1+\Upsilon R)-(1+2\Upsilon R)\right]+\Upsilon R(1-\omega)\right\}g_L}{\Upsilon R(\theta-1)+\theta} \tag{20}$$

$$\gamma_a \equiv \frac{\dot{a}_t}{a_t} = \gamma_c \equiv \frac{\dot{c}_t}{c_t} = \frac{1}{\theta}\left[r-\rho-(1-\omega)g_L\right] \tag{21}$$

RESULTS

$$\gamma_y \equiv \frac{\dot{y}_t}{y_t} = \gamma_a = \gamma_c = \frac{(1+\Upsilon R)(\sigma-\rho)-\left[\Upsilon R(\xi-\omega-1)+(\xi-\omega)\right]g_L}{\Upsilon R(\theta-1)+\theta} \tag{22}$$

$$u = 1-\frac{(\sigma-\rho)-\left[\Upsilon R(1-\xi)(\theta-1)+\xi(1-\theta)-\omega\right]g_L}{\sigma\left[\Upsilon R(\theta-1)+\theta\right]} \tag{23}$$

$$s_n \equiv \frac{H_{nt}}{H_t} = \frac{\mathrm{Z}(1-\beta)\gamma_n}{\left[1-\mathrm{Z}(1-\beta)\right]\left[r+(1-R)\gamma_n-\gamma_H\right]+\mathrm{Z}(1-\beta)\gamma_n}u \tag{24}$$

$$s_I \equiv \frac{H_{It}}{H_t} = \left[\frac{\beta \mathrm{Z}}{1-\mathrm{Z}(1-\beta)}\right](u-s_n) \tag{25}$$

$$s_Y \equiv \frac{H_{Yt}}{H_t} = \left[\frac{1-Z}{1-Z(1-\beta)}\right](u-s_n) \tag{26}$$

$$\frac{H_t^{\mu-\Phi}}{n_t^{1-\eta}} = \frac{\chi}{s_n^{\mu}}\gamma_n \tag{27}$$

$$R \equiv \bar{\alpha}+\frac{\mathrm{Z}}{\beta}(1-\varepsilon-\beta), \qquad \Upsilon \equiv \frac{\mu-\Phi}{1-\eta}$$

ASSUMPTION A

Assume:

(i) $\Upsilon > 0$ and $R \geq 0$;

(ii) $\sigma > \text{Max}\left\{0;\ \dfrac{\left[\xi - \Upsilon R(1-\xi)\right] g_L}{(1+\Upsilon R)}\right\}$;

(iii) $\theta > \text{Max}\left\{0;\ \dfrac{\Upsilon R}{1+\Upsilon R};\ \dfrac{\Upsilon R\left[\rho + (1-\omega) g_L\right]}{\sigma(1+\Upsilon R) - \left[\xi(1+\Upsilon R) - (1+2\Upsilon R)\right] g_L};\ \dfrac{\sigma(1+\Upsilon R) - \rho - \left[\xi - \omega - \Upsilon R(1-\xi)\right] g_L}{\sigma(1+\Upsilon R) + \left[\Upsilon R(1-\xi) - \xi\right] g_L};\ \dfrac{(\sigma-\rho)(1-\Upsilon) + \sigma\Upsilon R + \left[(\omega-\xi)(1-\Upsilon) + \Upsilon R(1-\xi)\right] g_L}{(1+\Upsilon R)(\sigma - \xi g_L) + \Upsilon(1+R) g_L}\right\}$;

(iv) $(\sigma - \rho) > \text{Max}\left\{(\xi-\omega) g_L;\ \dfrac{\left[\Upsilon R(\xi-\omega-1) + (\xi-\omega)\right] g_L}{(1+\Upsilon R)};\ \left[\Upsilon R(1-\xi)(\theta-1) + \xi(1-\theta) - \omega\right] g_L\right\}$

JONES (2005, P. 1074, EQ. 16) SETS: $\mu > 0$ $\eta < 1$ $\Phi = 0$

- With this parameterization: $\Upsilon \equiv \dfrac{\mu - \Phi}{1-\eta} = \dfrac{\mu}{1-\eta} > 0$

PROPOSITION 2

If Assumption A is satisfied, then:

- γ_H *and* γ_n *are positive*
- γ_y *is positive*
- $\gamma_y = \dfrac{(\sigma-\rho)-(\xi-\omega)g_L}{\theta}$, *i.e. the growth rate of per-capita income when* $R=0$, *is positive*
- r *is positive*
- $0<u<1$
- $r>\gamma_H-(1-R)\gamma_n$. *This condition allows* V_{nt} *to be positive at any time* $t\geq 0$ *along the BGP*
- *The two transversality conditions:* $\lim_{t\to+\infty}\lambda_{at}a_t=0$ *and* $\lim_{t\to+\infty}\lambda_{ht}h_t=0$ *are simultaneously checked*

PROPOSITION 3

Under Assumption A, the relationship between the degree of returns to specialization (R) *and the growth rate of real per capita income* (γ_y) *is always positive*

PMC AND ECONOMIC GROWTH

THEOREM 1

In this model economy, the sign of the correlation between PMC and economic growth can be either positive, or negative, or equal to zero. In particular, we observe that:

- *PMC and economic growth are positively correlated when* $\varepsilon > 1$
- *PMC and economic growth are negatively correlated when* $\varepsilon < 1$
- *There exists no correlation between PMC and economic growth when* $\varepsilon = 1$

PMC AND ECONOMIC GROWTH

LEMMA 1

Assume: $\bar{\alpha} > (1+\mathrm{Z}) > 1 \geq \mathrm{Z} > 0$. *This condition ensures that the inequality* $1 < \frac{\beta}{\mathrm{Z}}(\bar{\alpha} - \mathrm{Z} - 1) + 1 < \frac{\beta}{\mathrm{Z}}(\bar{\alpha} - \mathrm{Z}) + 1$ *is checked for any* $\beta \in (0;1)$. *Hence:*

- *With* $\varepsilon < 1$, *the returns to specialization are increasing* ($R > 1$) *and* $\frac{\partial \gamma_y}{\partial \beta} < 0$;
- *With* $\varepsilon = 1$, *the returns to specialization are increasing* ($R > 1$) *and* $\frac{\partial \gamma_y}{\partial \beta} = 0$;
- *With* $1 < \varepsilon < \frac{\beta}{\mathrm{Z}}(\bar{\alpha} - \mathrm{Z} - 1) + 1$, *the returns to specialization are increasing* ($R > 1$) *and* $\frac{\partial \gamma_y}{\partial \beta} > 0$;
- *With* $\varepsilon = \frac{\beta}{\mathrm{Z}}(\bar{\alpha} - \mathrm{Z} - 1) + 1$, *the returns to specialization are constant* ($R = 1$) *and* $\frac{\partial \gamma_y}{\partial \beta} > 0$;
- *With* $\frac{\beta}{\mathrm{Z}}(\bar{\alpha} - \mathrm{Z} - 1) + 1 < \varepsilon \leq \frac{\beta}{\mathrm{Z}}(\bar{\alpha} - \mathrm{Z}) + 1$, *the ret. to spec. are decreasing* ($0 \leq R < 1$) *and* $\frac{\partial \gamma_y}{\partial \beta} > 0$.

Thus, with <u>decreasing/constant returns to specialization</u> ($0 \leq R \leq 1$) *the correlation between PMC and economic growth is always positive, whereas with <u>increasing returns to specialization</u>* ($R > 1$), *a further increase in the degree of PMC can yield either a positive, or a negative, or else no effect on economic growth.*

IN LEMMA 1,

The assumption $\overline{\alpha} > (1+Z) > 1 \geq Z > 0$ is consistent with all the following requirements:

(i) $\overline{\alpha} > 1$

(ii) No upper bound to $\overline{\alpha}$;

(iii) $Z \in (0;1]$

Requirements (*i*) and (*ii*) derive directly from Ethier (1982, p. 391),

who considers the very special case in which $Z = 1$

LEMMA 1: INTUITION

$$\gamma_y = \gamma_H + R\gamma_n - g_L, \qquad \gamma_H \equiv \frac{\dot{H}_t}{H_t} = \frac{\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta}, \qquad \gamma_n \equiv \frac{\dot{n}_t}{n_t} = \frac{\Upsilon\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta}$$

Therefore, the impact of a variation of PMC on economic growth can be decomposed into two separate effects:

- The direct *'RETURNS TO SPECIALIZATION'* EFFECT. An exogenous change in β affects R directly and, hence, γ_y. This effect is a priori ambiguous, since the sign of $\partial R/\partial\beta$ is crucially related to the magnitude of ε (with respect to unity);

- The indirect *'ACCUMULATION'* EFFECT. The variation of R, in turn, influences the accumulation of the two reproducible factor-inputs (H and n). Therefore, the initial change in β is able to affect γ_y also indirectly, *i.e.* through the effect it yields on γ_H and γ_n via the changed R. It is possible to see that $\dfrac{\partial\gamma_n}{\partial R} = \dfrac{\Upsilon^2\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\left[\Upsilon R(\theta-1)+\theta\right]^2}(1-\theta)$ and $\dfrac{\partial\gamma_H}{\partial R} = \dfrac{1}{\Upsilon}\dfrac{\partial\gamma_n}{\partial R} = \dfrac{\Upsilon\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\left[\Upsilon R(\theta-1)+\theta\right]^2}(1-\theta)$. Under the parameter-restrictions of *Assumption A*, the *accumulation* effect is also ambiguous since the two derivatives written above can be positive (if $0<\theta<1$), negative (if $\theta>1$), or else equal to zero (if $\theta=1$)

LEMMA 1: INTUITION

$$\gamma_y = \gamma_H + R\gamma_n - g_L, \qquad \gamma_H \equiv \frac{\dot{H}_t}{H_t} = \frac{\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta}, \qquad \gamma_n \equiv \frac{\dot{n}_t}{n_t} = \frac{\Upsilon\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta}$$

$$\begin{aligned}\frac{\partial\gamma_y}{\partial\beta} &= \frac{\partial R}{\partial\beta}\left(\frac{\partial\gamma_H}{\partial R} + R\frac{\partial\gamma_n}{\partial R} + \gamma_n\right)\\ &= \frac{\partial R}{\partial\beta}\left[\left(\frac{1+\Upsilon R}{\Upsilon}\right)\left(\frac{1}{\gamma_n}\frac{\partial\gamma_n}{\partial R}\right)+1\right]\gamma_n\\ &= \frac{\partial R}{\partial\beta}\underbrace{\left[\frac{1}{\Upsilon R(\theta-1)+\theta}\right]\gamma_n}_{>0 \text{ under } \textit{Assumption A}}\end{aligned}$$

- Although its sign is unclear, the indirect *'accumulation'* effect $(\partial\gamma_n/\partial R)$ does not alter the sign of the whole impact of β on γ_y, which is ultimately determined by the sign of the direct *'returns to specialization'* effect $(\partial R/\partial\beta)$, as long as the requirements of *Assumption A* are satisfied

  (THE *'ACCUMULATION'* EFFECT OPERATES IN RELATIVE RATHER THAN IN ABSOLUTE TERMS!)

LEMMA 1

Suggests **THREE important conclusions**:

1. When the increase in the number of available intermediate-input varieties causes no costs (in terms of aggregate GDP losses) due to an *increase in production-complexity*

$$i.e., \qquad \varepsilon \leq 0,$$

then <u>PMC plays an ambiguously negative role on economic growth</u>, γ_y.

This result may help explaining why **non-OECD, but fast-growing countries such as Brazil, Russia, India, China, and South-Africa** (that we can probably regard as those for which an increase in the number of available intermediate-good varieties brings about almost solely positive consequences, that is an increase in aggregate productivity due to more specialization) have exhibited in recent years a level of PMC which is evidently lower than that one may find in OECD, slow-growing countries

LEMMA 1

2. On the other hand, if we think of the **OECD-countries** as those in which an *increasing-(production-)complexity-effect* plays a role, along with a *specialization-effect*

$$i.e., \quad \varepsilon > 0,$$

then our model seems to provide another explanation (alternative to the one offered by Aghion *et al.*, 2005) of the <u>ambiguous correlation between PMC and growth</u>

Unlike Aghion *et al.* (2005), who explain the *inverted-U* shaped relationship between competition and innovation/growth through the contraposition of the <u>*Escape–Competition*</u> vs. <u>*Schumpeterian*</u> effects, MY EXPLANATION IS BASED ON THE PRESENCE OF INCREASING RETURNS TO SPECIALIZATION ($R > 1$)

LEMMA 1

3. When assembling a larger number of varieties of intermediates using the same technology becomes increasingly difficult in terms of induced *production–complexity*

$$i.e., \qquad \varepsilon > 1$$

then we always observe a <u>positive correlation between PMC and economic growth</u>

This result appears consistent with the fact that, according to OECD statistics, the US (a country whose economic growth rate, and probably whose degree of technological complexity measured in terms of number of intermediate inputs employed in the same production process are among the highest in the world) displayed in 2008 the smallest (largest) degree of product market regulation (PMC)

A RANKING OF COUNTRIES (OECD AND SOME NON-OECD) ACCORDING TO THEIR OWN LEVEL OF *PRODUCT MARKET REGULATION* FOR THREE DIFFERENT YEARS (1998, 2003, 2008)

INDICATOR		**PRODUCT MARKET REGULATION**		
YEAR		**1998**	**2003**	**2008**
COUNTRY				
AUSTRALIA		1.524	1.156	1.235
AUSTRIA		2.331	1.758	1.452
BELGIUM		2.175	1.590	1.426
CANADA		1.286	1.141	0.954
CHILE		…	…	1.579
CZECH REPUBLIC		2.991	1.975	1.621
DENMARK		1.589	1.184	1.057
ESTONIA		…	…	1.312
FINLAND		2.078	1.297	1.188
FRANCE		2.522	1.746	1.454
GERMANY		2.062	1.598	1.328
GREECE		2.993	2.578	2.374
HUNGARY		2.296	1.911	1.297
ICELAND		1.707	1.199	1.003
IRELAND		1.650	1.349	0.918
ISRAEL		…	…	2.605
ITALY		2.594	1.811	1.377
JAPAN		2.188	1.409	1.112
KOREA		2.348	1.782	1.474

Luxembourg		…	1.477	1.559
Mexico		2.448	2.009	1.850
Netherlands		1.661	1.364	0.969
New Zealand		1.360	1.141	1.255
Norway		1.851	1.416	1.163
Poland		3.970	2.950	2.264
Portugal		2.249	1.644	1.427
Slovak Republic		…	1.841	1.629
Slovenia		…	…	1.458
Spain		2.550	1.682	1.034
Sweden		1.933	1.494	1.302
Switzerland		2.476	1.724	1.179
Turkey		3.301	2.586	2.351
United Kingdom		1.070	0.824	0.842
United States		1.283	1.007	0.841
OECD Member Economies (Average)		**2.160**	**1.621**	**1.4085**
Non-OECD Member Economies	Brazil	…	…	1.945
	China	…	…	3.297
	India	…	…	2.750
	Russian Federation	…	…	3.094
	South Africa	…	…	2.398
	OECD Member Economies (Average)			**2.697**

SOURCE: OECD Statistics - http://stats.oecd.org/Index.aspx

POPULATION GROWTH AND ECONOMIC GROWTH

THEOREM 2

Assume that the parameter-restrictions (i) and (iii) of Assumption A are checked and that $1 \geq \omega > \xi - \frac{\Upsilon}{1+\Upsilon} > \xi - 1$, *for any* $\xi \in [0;1]$. *Then:*

- *In the presence of increasing/constant returns to specialization (*$R \geq 1$*), there exists an unambiguously positive correlation between population growth and economic growth,* $\partial\gamma_y / \partial g_L > 0$;
- *In the presence of decreasing returns to specialization (*$0 \leq R < 1$*), the correlation between population and economic growth rates is ambiguous,* $\partial\gamma_y / \partial g_L \gtrless 0$.

Notice that, with $\Upsilon > 0$, $\xi \in [0;1]$ and $\omega = 1$ (the last one is a standard assumption in exogenous and endogenous growth models with optimizing consumer behavior), inequality

$$1 \geq \omega > \xi - \frac{\Upsilon}{1+\Upsilon} > \xi - 1$$

is trivially checked !

POPULATION GROWTH AND ECONOMIC GROWTH

THEOREM 2 (CONT'D)

We can make a formal distinction among three cases, depending on the magnitude of ω:

1. $\omega = 0$;
2. $\omega = 1$;
3. $0 < \omega < 1$,

and ξ:

1. $\xi = 0$;
2. $\xi = 1$;
3. $0 < \xi < 1$,

respectively.

Results are summarized in the following Table:

	$\omega = 0$	$\omega = \overline{\omega} \in (0;\ 1)$	$\omega = 1$
$\xi = 0$	$\partial\gamma_y / \partial g_L \geq 0$	$\partial\gamma_y / \partial g_L > 0$	$\partial\gamma_y / \partial g_L > 0$
$\xi = \overline{\xi} \in (0;\ 1)$	$\frac{\partial\gamma_y}{\partial g_L} < 0, \quad \forall\ R \in \left[0;\ \frac{\overline{\xi}}{\Upsilon(1-\overline{\xi})}\right)$ $\frac{\partial\gamma_y}{\partial g_L} = 0, \quad R = \frac{\overline{\xi}}{\Upsilon(1-\overline{\xi})} > 0$ $\frac{\partial\gamma_y}{\partial g_L} > 0, \quad \forall\ R > \frac{\overline{\xi}}{\Upsilon(1-\overline{\xi})} > 0$	1. $\forall\ \overline{\xi} \in (0;\overline{\omega})$: $\quad \frac{\partial\gamma_y}{\partial g_L} > 0$ 2. $\forall\ \overline{\xi} = \overline{\omega} \in (0;1)$: $\quad \frac{\partial\gamma_y}{\partial g_L} \geq 0$ 3. $\forall\ \overline{\xi} \in (\overline{\omega};1)$: $\frac{\partial\gamma_y}{\partial g_L} < 0, \quad \forall\ R \in \left[0;\ \frac{\overline{\xi}-\overline{\omega}}{\Upsilon(1+\overline{\omega}-\overline{\xi})}\right)$ $\frac{\partial\gamma_y}{\partial g_L} = 0, \quad R = \frac{\overline{\xi}-\overline{\omega}}{\Upsilon(1+\overline{\omega}-\overline{\xi})} > 0$ $\frac{\partial\gamma_y}{\partial g_L} > 0, \quad \forall\ R > \frac{\overline{\xi}-\overline{\omega}}{\Upsilon(1+\overline{\omega}-\overline{\xi})} > 0$	$\frac{\partial\gamma_y}{\partial g_L} > 0$
$\xi = 1$	$\frac{\partial\gamma_y}{\partial g_L} < 0$	$\partial\gamma_y / \partial g_L < 0, \quad \forall\ R \in \left[0;\ \frac{1-\overline{\omega}}{\Upsilon\overline{\omega}}\right)$ $\partial\gamma_y / \partial g_L = 0, \quad R = (1-\overline{\omega}) / \Upsilon\overline{\omega} > 0$ $\partial\gamma_y / \partial g_L > 0, \quad \forall\ R > (1-\overline{\omega}) / \Upsilon\overline{\omega} > 0$	$\frac{\partial\gamma_y}{\partial g_L} \geq 0$

THE TABLE REVEALS THAT:

- For given ξ, the larger ω and the more likely it is for $\frac{\partial \gamma_y}{\partial g_L}$ to be unambiguously strictly positive

- For given ω, the larger ξ (and the smaller R), and the more likely it is for $\frac{\partial \gamma_y}{\partial g_L}$ to be unambiguously strictly negative

- With *Millian-type* preferences ($\omega = 0$) population growth affects in an unclear way (related to the magnitudes of ξ and R) economic growth. This remains true also when $\omega = \overline{\omega} \in (0;1)$;

- With *Benthamite* preferences ($\omega = 1$), instead, the effect of population growth on economic growth is definitely non–negative.

THE FIRST PART OF THEOREM 2 FOCUSES SOLELY ON THE DEGREE OF RETURNS TO SPECIALIZATION AS THE KEY-VARIABLE AFFECTING THE SIGN OF THE RELATIONSHIP BETWEEN POPULATION AND ECONOMIC GROWTH RATES. THE SECOND PART OF THE THEOREM (*i.e.*, THE TABLE), INSTEAD, LOOKS AT THE IMPORTANT ROLES PLAYED ALSO BY ξ AND ω

INTUITION:

$$\gamma_y = \gamma_H + R\gamma_n - g_L, \qquad \gamma_H = \frac{\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta}, \qquad \gamma_n = \frac{\Upsilon\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta},$$

$$\frac{\partial\gamma_y}{\partial g_L} = \left(\frac{\partial\gamma_H}{\partial g_L} + R\frac{\partial\gamma_n}{\partial g_L}\right) - 1$$

$$= \underbrace{\left(\frac{1+\Upsilon R}{\Upsilon}\right)}_{\substack{>0 \\ \text{under Assumption A}}} \underbrace{\frac{\partial\gamma_n}{\partial g_L}}_{\substack{\text{'ideas'} \\ \text{effect}}} - \underbrace{1}_{\substack{\text{'dilution'} \\ \text{effect}}}$$

The impact of population growth on real per-capita income growth depends on two distinct effects:

- The direct *'dilution'* effect, which is always negative

- The indirect *'ideas'* effect. Unlike the previous one, this effect is always positive provided that:

$$\omega + \theta - \xi > 0$$

The higher the degree of *intratemporal altruism* (ω), the more patient the representative household, and the greater the investment in human capital and ideas (R&D activity) !

INTUITION:

- The direct *'dilution'* effect. This effect is always negative

- The indirect *'ideas'* effect. This effect is always positive provided that: $\omega+\theta-\xi>0$

- So, all the rest remaining equal (in particular for some $\theta>0$), the larger ω and the smaller ξ, the more likely it is for the restriction $\omega+\theta-\xi>0$ to be satisfied, for the indirect *'ideas'* effect to be strictly positive and to ultimately outweigh the direct negative *'dilution'* effect, leading as a result to $\frac{\partial\gamma_y}{\partial g_L}>0$

THIS IS WHAT WE OBSERVE BY MOVING FROM SOUTH–WEST ($\omega=0$ AND $\xi=1$) TO NORTH–EAST ($\omega=1$ AND $\xi=0$) ALONG THE DIAGONAL OF THE TABLE

INTUITION:

$$\gamma_y = \gamma_H + R\gamma_n - g_L, \qquad \gamma_H = \frac{\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta}, \qquad \gamma_n = \frac{\Upsilon\left[(\sigma-\rho)-(\xi-\omega-\theta)g_L\right]}{\Upsilon R(\theta-1)+\theta},$$

$$\frac{\partial\gamma_y}{\partial g_L} = \left(\frac{\partial\gamma_H}{\partial g_L} + R\frac{\partial\gamma_n}{\partial g_L}\right) - 1$$

$$= \underbrace{\left(\frac{1+\Upsilon R}{\Upsilon}\right)}_{\substack{>0 \\ \text{under Assumption A}}} \underbrace{\frac{\partial\gamma_n}{\partial g_L}}_{\substack{\text{'ideas'} \\ \text{effect}}} - \underbrace{1}_{\substack{\text{'dilution'} \\ \text{effect}}}$$

- Moreover, we observe that the magnitude of R crucially amplifies the indirect *'ideas'* effect: when this effect is positive, the larger R is and the more likely it is for $\frac{\partial\gamma_y}{\partial g_L}$ to be, *ceteris paribus*, positive

THIS IS WHAT BOTH THE FIRST PART OF THEOREM 2 AND THE TABLE, DO REVEAL

POPULATION GROWTH AND ECONOMIC GROWTH

PROPOSITION 5

Assume $R = \xi = 0$ *and* $\omega = 1$

In this case the economy's growth rate coincides with the "efficient" and "competitive" solutions of the ***Lucas model (1988)*** *without any external effect of human capital in the production of final goods*

This rate is unambiguously increasing in the population growth rat

EXTENSIONS

HOW DO RESULTS OBTAINED UP TO NOW CHANGE WITH A MORE REALISTIC *MINCERIAN* EQUATION FOR THE PRODUCTION OF AN INDIVIDUAL'S HUMAN CAPITAL?

$$h_t = e^{\tau l_{ht}}$$

"…The exponential formulation used here is the most straightforward way of incorporating human capital in a manner that is consistent with the large literature on schooling and wages following Jacob Mincer (1974) and with the substantial growth accounting literature that makes adjustments for education. It is a special case of a formulation suggested by Bils and Klenow (2000)…" **(JONES, 2002, p. 222)**

RESULTS (MINCERIAN SPECIFICATION FOR HC ACCUMULATION)

$$\frac{\dot{H}_{Yt}}{H_{Yt}} = \frac{\dot{H}_{It}}{H_{It}} = \frac{\dot{H}_{nt}}{H_{nt}} = \frac{\dot{H}_{t}}{H_{t}} \equiv \gamma_H = g_L \tag{30}$$

$$\frac{\dot{n}_t}{n_t} \equiv \gamma_n = \Upsilon g_L \tag{31}$$

$$r = \rho + \left(1 - \omega + \theta \Upsilon R\right) g_L \tag{32}$$

$$\gamma_y \equiv \frac{\dot{y}_t}{y_t} = \gamma_a \equiv \frac{\dot{a}_t}{a_t} = \gamma_c \equiv \frac{\dot{c}_t}{c_t} = \left(\Upsilon R\right) g_L \tag{33}$$

$$s_n = \frac{Z(1-\beta)\gamma_n}{\left[1 - Z(1-\beta)\right]\left[r + (1-R)\gamma_n - \gamma_H\right] + Z(1-\beta)\gamma_n} \tag{34}$$

$$s_I = \left[\frac{\beta Z}{1 - Z(1-\beta)}\right](1 - s_n) \qquad (35); \qquad s_Y = \left[\frac{1 - Z}{1 - Z(1-\beta)}\right](1 - s_n) \tag{36}$$

$$R \equiv \overline{\alpha} + \frac{Z}{\beta}(1 - \varepsilon - \beta), \qquad \Upsilon \equiv \frac{\mu - \Phi}{1 - \eta}$$

MINCERIAN SPECIFICATION FOR HC ACCUMULATION

PROPOSITION 6

If individuals accumulate human capital in a manner which is consistent with the Mincerian wage regression evidence (Mincer, 1974), then:

- *For any* $\Upsilon > 0$, $g_L > 0$, $\mathrm{Z} \in (0;1]$ *and* $\beta \in (0;1)$
  - *PMC and economic growth are positively correlated when* $\varepsilon > 1$
  - *PMC and economic growth are negatively correlated when* $\varepsilon < 1$
  - *PMC and economic growth are not correlated at all when* $\varepsilon = 1$
- *For any* $\omega \in [0;1]$, $\Upsilon > 0$ *and* $R \geq 0$
  - *The correlation between population growth and economic growth is always non-negative, i.e.* $\partial\gamma_y / \partial g_L \geq 0$
  - *Ceteris paribus, the larger* R*, the more sizeable the positive impact of a given increase in population growth on the growth rate of real per-capita income*
  - $\gamma_y = 0$ *when* $g_L = 0$

MINCERIAN SPECIFICATION FOR HC ACCUMULATION

Employing a more realistic *Mincerian* equation for education (as opposed to a law of motion of human capital *à la* Lucas) does not lead to any different result concerning the long-run relationship between PMC and economic growth

It, instead, implies some changes in the population growth–economic growth link. Now:

(1) The relationship between population and economic growth rates is always non–negative, for any $R \geq 0$

(2) Population growth becomes, *ceteris paribus*, essential for economic growth (γ_y is zero if $g_L = 0$) – **AS IN TRADITIONAL *SEMI-ENDOGENOUS* GROWTH MODELS!**

SUMMARY

- The main point of this paper was to explain, within the same *semi–endogenous* growth framework with horizontal R&D activity and human capital accumulation, under which conditions one may observe the result of ambiguity (largely predicted by the existing theory and evidence) in the relationship between PMC and economic growth, and between population growth and economic growth

- Unlike the existing literature, our focus was on the notion of RETURNS TO SPECIALIZATION

- Differently from Aghion *et al*. (2005), who account for an ambiguous (*inverted U-shaped*) relation between PMC and Innovation/Growth by the interaction of the *Escape–Competition Effect* with the *Schumpeterian Effect*, our explanation is based on the presence of increasing returns to specialization

- Concerning the link between population and economic growth rates, instead, an ambiguous correlation between the two variables is observed in the presence of decreasing returns to specialization

- Employing a more realistic *Mincerian* equation for education does not lead to any different result in the long-run relationship between PMC and economic growth

- This assumption, however, implies that the relationship between population and economic growth rates is always non–negative, and that economic growth would be zero in the absence of population change

FUTURE RESEARCH

- A thorough empirical analysis of the model's theoretical predictions is certainly needed

  - Because our primary interest in this paper was to examine how the returns to specialization can affect the relationship between PMC and economic growth and between population growth and economic growth, we treated these two variables (PMC and population growth) parametrically

  - It is well known that population growth and market structure are endogenous, rather than exogenous, variables

- Therefore, building a growth theory where market concentration and demographic change are <u>simultaneously</u> endogenized is also at the top of our future research agenda