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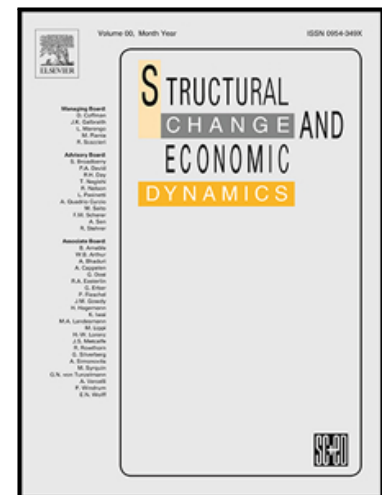
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### Highlights

- We develop a dynamic stochastic general equilibrium (DSGE) model featuring the role of social capital.
- We estimate the model with Bayesian techniques using Italian data.
- Results suggest that social capital improves total factor productivity.

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# Does social capital explain the Solow residual? A DSGE approach

Amedeo Argentiero\*, Roy Cerqueti†, Fabio Sabatini ‡

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## Abstract

The literature has credited social capital with playing a role in many desirable economic outcomes. We analyze how these potentially beneficial effects translate into the performance of economies by developing a dynamic stochastic general equilibrium (DSGE) model featuring the role of social capital in explaining the Solow residual. We then simulate and estimate the model with Bayesian techniques using Italian data. Our framework fits actual data better than a standard DSGE model, suggesting that social capital may improve the economic performance via its impact on total factor productivity. Including human capital in the model further raises social capital's ability to explain the Solow residual.

**Keywords:** social capital; total factor productivity; Solow residual; DSGE models.

**JEL Classification:** E12, E22, O11, Z1, Z13.

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## 1 Introduction

The literature has credited social capital with playing a role in many desirable economic outcomes such as loan repayment and access to credit (Karlan et al., 2009), financial development (Guiso et al., 2004), investments in education (Coleman, 1988) and innovation (Knack and Keefer, 1997), political accountability (Nannicini et al., 2013), and productivity in organizations (Costa and Kahn, 2003; Guiso et al., 2015), just to name a few.

How do these effects translate into the performance of economies? Empirical studies found evidence of a positive relationship between aspects of social capital - such as trust, networks, and manifestations of prosocial attitudes - and growth across countries (e.g. Knack and Keefer, 1997; Algan and Cahuc, 2010) or regions (e.g. Tabellini, 2010; Guiso et al., 2016). However, our knowledge of the mechanisms allowing the effects of social capital to result in better economic performance and, in the long run, growth is still limited.

In line with seminal studies (Bourdieu, 1986; Coleman, 1988), we assume that social capital is an asset that allows agents to internalize the benefits of cooperation. Social capital can be created as a by-product of disinterested activities such as prosocial behaviors like blood donation, or rational investment decisions taken to pursue particular goals. These decisions incidentally create a cooperative environment, a shared resource that has a public good feature. This resource is multidimensional, as it can take many forms, productive, as it makes possible the achievement of specific ends that would not be possible in its absence, and not completely fungible, as it is specific to certain activities (Coleman, 1988). The multidimensionality and “situationality” (Coleman, 1988) of social capital led many authors to consider it as an umbrella concept that captures those societal features helping people to better work together for shared purposes (Putnam, 1995)<sup>1</sup>. In this paper, we study how this multifaceted resource contributes to the economic performance by developing a dynamic stochastic general equilibrium (DSGE) model that features the role of social capital in a

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<sup>1</sup>See Sabatini (2007) and Guiso et al. (2010) for a review of the literature.

constant returns to scale production function. The model is simulated and estimated using Bayesian techniques to match Italian data for total factor productivity over 1950-2014. We then compare the actual pattern of total factor productivity with the same time series simulated through the DSGE model in a benchmark case, not including social capital, and our framework explicitly modeling the role of social capital. This exercise aims at improving our understanding of whether the accumulation of social capital supports the economic performance. Moreover, we assess whether the simultaneous inclusion of social capital and human capital (see Glaeser et al., 2002) raises the ability to explain Solow residual respect to a standard DSGE model, a DSGE model with social capital and a DSGE model with human capital.

The empirical analysis shows that accounting for social capital allows an otherwise standard DSGE model to fit actual data in the long run better. Jointly accounting for social and human capital allows the corresponding DSGE model to match total factor productivity data better than a DSGE model with only social capital, a DSGE model with only human capital, and a standard DSGE model. These results suggest that the macroeconomic outcomes of social capital may help to explain the Solow residual.

Our paper bridges two strands of literature. The first broadly studies the aggregate returns to social capital by empirically analyzing its correlation with growth (Algan and Cahuc, 2010; Guiso et al., 2016), and other macroeconomic outcomes, such as innovation (Knack and Keefer, 1997; Akçomak and ter Weel, 2009), financial development (Guiso et al., 2004), welfare spending (Bjørnskov and Svendsen, 2013), the quality of government (Putnam et al., 1993; Alesina and Zhuravskaya, 2011).

The second strand encompasses studies investigating the drivers of growth, such as innovation (Castellacci, 2008; Castellacci and Natera, 2016), access to credit (Skott and Gómez-Ramírez, 2018), trade (Sasaki, 2017), technological progress (Antoci et al., 2011b; Fiaschi and Fioroni, 2019), employment (Compagnucci et al., 2018), the quality of institutions (Acemoglu et al., 2001; Dias and

Tebaldi, 2012), and the depletion of natural resources (Antoci et al., 2009a; Antoci et al., 2011a).

We contribute to these fields by developing and empirically testing the first DSGE model that captures social capital's macroeconomic effects.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature about social capital's definition, measurement, and relationship with the economic performance. Section 3 describes the theoretical model. In Section 4, we describe our data, the methodology employed to estimate the parameters, the model's dynamics through the impulse response functions, and the related results. The analysis comparing the considered models is presented and implemented in Section 5. We discuss our findings and their possible policy implications in Section 6 and conclude in Section 6. Two appendices address some technical aspects.

## **2 Social capital: definition, measurement, and outcomes**

In this section, we first discuss the multidimensional nature of social capital (subsection 2.1). Then, we address measurement issues and briefly summarize the extant literature on social capital and the economic performance (2.2).

### **2.1 Definition**

In his early work on social capital, Bourdieu (1986) blamed neoclassical economics for substantially failing to understand that society's structure depends on the distribution of the various forms of capital across social classes and groups. In Bourdieu's work, capital's property rights ultimately ground the immanent structure of the social world, i.e., the set of constraints that durably govern its functioning, determining the chances of success for individuals, social groups, and practices. These structures are persistent, as capital takes time to accumulate and has the potential to reproduce itself "in identical or expanded form" (Bourdieu, 1986, pp. 260), and persistently shape society's

structure. Bourdieu and Wacquant (1992) stress the impossibility of adequately understanding the functioning of societies and individual behavior without accounting for the role of the distribution of the various capital forms. Economic theory's neglect of the inner features of the social structure resulted in a limited understanding of individual behavior.

As a consequence, mainstream models long relied on an "under-socialized" characterization of the representative agent. "By reducing the universe of exchanges to mercantile exchange, which is objectively and subjectively oriented towards the maximization of profit, i.e., self-interested, the discipline has implicitly defined the other forms of exchange as noneconomic, and therefore disinterested" (Bourdieu, 1986, pp. 105-106). Such a weakness led economics to claim that immaterial forms of capital such as cultural and social capital result from disinterested interactions and do not affect self-interested exchanges. Bourdieu concluded urging economic theory to fully grasp the role of social capital in the economic action. The author defined social capital as the aggregate of social obligations and the actual or potential resources linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition.

In his elaboration of Bourdieu's thought, Coleman (1988) proposed a definition of social capital as fundamentally depending on the purposes it serves: "Social capital is defined by its function. It is not a single entity but a variety of different entities, with two elements in common: they all consist of some aspects of the social structure, and they facilitate certain actions of actors within the structure" (Coleman, 1988, p. 98). Putnam (1995) referred to social capital as all the features of social life - networks, norms, civic engagement, and trust - that enable individuals to act together more effectively to pursue shared objectives. Such goals may, or may not, be compatible with the welfare of the community as a whole. In their pioneering work on the Italian regions, Putnam et al. (1993) stressed the multidimensional nature of social capital, with each dimension potentially having different macroeconomic outcomes. For example, members of a network may use their ties as a means for the pursuit of narrow sectarian interests, and organizations may lobby against the

interest of other groups. The conventional distinction between bonding and bridging social capital reflects the different roles that social capital may play in shaping the economic development of a society (Sabatini, 2004; 2007; 2008; 2009).

The term ‘bonding’ holds a negative connotation. It refers to relationships between people who know each other well, i.e., family members, close friends, and neighbors (Gittel and Vidal, 1998). These relationships correspond to what Granovetter (1973) defined as ‘strong ties’. Instead, bridging social capital consists of horizontal ties shaping heterogeneous groups of people with different backgrounds. The term ‘bridging’ refers to the ability of such networks to create ‘bridges’ connecting sectors of society that, otherwise, would have never come into contact. The common claim is that bridging social capital positively affects the diffusion of information and trust, thus fostering transactions and economic growth. Bonding social capital, instead, is mainly viewed as a potential obstacle to cooperation and development.

To account for the double-sided role of social capital, Guiso et al. (2010) operationalize social capital as “those persistent and shared beliefs and values that help a group overcome the free-rider problem in the pursuit of socially valuable activities” (p. 419). This approach provides the theoretical justification for focusing exclusively on the constructive dimensions of social capital, i.e., those that positively contribute to society’s development by helping to overcome free-riding and rent-seeking problems. These dimensions partially overlap with what Putnam referred to as “bridging social capital”, though shifting the focus to a further distinction between “structural” and “cognitive” social capital<sup>2</sup>. The adoption of such a “positive” definition of social capital (overlapping with the concept of bridging social capital) helps explaining why economic theory ended up viewing social capital as an enabler of cooperation and development by definition (Fine, 2001). Coleman (1988)

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<sup>2</sup>Cognitive social capital derives from individuals’ perceptions and mental processes resulting in norms, values, and beliefs that promote cooperation. Structural social capital concerns aspects of social organization, such as rules and procedures, and formal and informal networks that enable cooperation (Uphoff, 1999). Economic research has typically investigated how cognitive social capital, mainly in the form of social trust, relates to outcomes such as economic growth or public spending (Fiorillo and Sabatini, 2015).



suggests that people create social capital as an incidental by-product of disinterested activities (e.g., blood donation) or as rational investment decisions to reach the shared goals of a group, as in the case of parents' associations in schools. Blood donation, in particular, has the potential to strengthen the perception that most people are trustworthy, which provides the building blocks for the diffusion of social trust and the development of cooperative interactions (Guiso et al., 2006; 2010).

## 2.2 Measurement and outcomes

The social capital definitions used in economics stress its role in supporting communities or groups to solve coordination issues. However, they also share the weakness inherent in a vague and multidimensional concept. As summarized by Solow (2005) in his critique to Fukuyama (1995): "If 'social capital' is to be more than a buzzword, the stock of social capital should somehow be measurable, even inexactly". The literature has proposed many different measures of social capital, which capture its many dimensions. A strategy to synthesize them all in a single indicator is to focus on their hypothetical outcomes, such as those behaviors that reveal individuals' propensity for cooperation. One problem with these measures is that they can be contaminated by other factors (Guiso et al., 2010). For example, tax compliance is strictly linked to civic-mindedness. However, it may also depend on the tightness of tax surveillance and the design of the tax system (Argentiero and Cerqueti, 2019; Cerqueti et al., 2019). However, there are cases in which the relationship between social capital and its hypothetical outcomes is not affected by confounding factors. Several authors suggest this is the case of blood donation (e.g. Guiso et al., 2004; Akçomak and ter Weel, 2012; Nannicini et al., 2013; Guriev and Melnikov, 2016). Guiso et al. (2010) explain that the decision to donate can be seen as a direct measure of how much people internalize the common good. In fact, there is neither an economic payoff to donation nor a legal obligation to donate. This aspect is particularly true for Italy, where blood donation infrastructures are widespread and supervised by a unique organization,

the Association of Voluntary Blood Donors (AVIS, acronym for *Associazione Volontari Italiani del Sangue*). AVIS is responsible for 90 percent of all blood donations in Italy and has branches in virtually every Italian municipality.

Measures of cooperative behaviors such as blood donation allow empirical research to operationalize the concept of social capital. However, they also have the weakness of accounting for only one of its multiple dimensions and possibly confounding the core of social capital's concept with one of its possible, but not necessary, outcomes. Trust-intensive networks may support or hinder cooperative behaviors depending on the circumstances (Coleman, 1990). The use of "indirect indicators" of social capital has led to confusion about what social capital is, as distinct from its outcomes, and what the relationship between social capital and its outcomes may be (Fine, 2001). Following the economics literature, in this paper we relied on a measure of blood donation to operationalize the concept of social capital. This approach is a second-best option motivated by the lack of comparably long and frequent time-series measures of social capital's dimensions. However, we are aware of the potential weakness of this approach, and we highlight how it could weaken the external validity of our findings in the discussion of results in Section 6.

Despite the ambiguity in its definition and measurement, the concept of social capital has gained wide attention among economists for its ability to improve the understanding of the intangible factors of development. The stronger propensity for cooperation stemming from social capital can be beneficial for development in many ways. Cooperation reinforces trust and trustworthiness (Dasgupta, 2009), thereby improving the environment in which individuals and firms make their investment decisions, resulting in a more efficient allocation of resources and a higher total factor productivity. For example, since trust enhances access to credit (Karlan, 2005; Feigenberg et al., 2013), enrollment in higher education may be more accessible. At the firm level, higher credit opportunities might simplify the financing of innovative projects (Akçomak and ter Weel, 2009). The mitigation of agency problems typical of a more cooperative and trusting society improves the management of

human resources and lowers monitoring costs both in the workplace and in inter-firm relationships (La Porta et al., 1997; Costa and Kahn, 2003). In high trust societies, hiring decisions are more likely to be influenced by talent and effort instead of the personal attributes of applicants, such as blood ties and personal knowledge - which are common surrogates of trustworthiness in low-trusting societies (Knack and Keefer, 1997; Alesina et al., 2015). As a result, social capital also increases the return to specialized and vocational education, resulting in more substantial incentives to invest in human capital (Knack and Keefer, 1997; Guiso et al., 2010).

Overall, these mechanisms create a social infrastructure more favorable to high levels of output per worker, which, to use the words of Hall and Jones (1999): “Gets the prices right so that individuals capture the social returns to their actions as private returns” (p. 84).

The empirical literature on the drivers of economic development suggests that the private returns to social capital lead actors - whether individual or corporate - to create a cooperative environment that supports growth. Knack and Keefer (1997) and Zak and Knack (2001) find that the share of people declaring to trust others is significantly associated with economic growth across countries. Guiso et al. (2004) show that in areas with more social capital - measured as voter turnout and the number of blood bags collected per inhabitant - households are more likely to use checks, invest less in cash and more in stock, have higher access to institutional credit, and make less use of informal credit. Algan and Cahuc (2010) find that changes in the level of inherited trust explain a substantial part of the differences in economic development across countries over 1935–2000. Nannicini et al. (2013) show that political accountability, a key determinant of the institutions’ performance, is stronger in provinces with higher social capital, measured as average per-capita blood donations. Guiso et al. (2016) show that the Italian cities that experienced independence as free city-states in the Middle Ages have a higher density of non-profit organizations and host an organ donation association. These indicators of social capital predict economic development across municipalities.

Our contribution to this literature consists of a DSGE model that assesses social capital’s ability

to explain the Solow residual, thus explaining the correlation between social capital and the economic performance. To simulate and estimate the model using Italian data, we measure social capital as the volume of blood donations per inhabitants, as suggested in Guiso et al. (2004) and Guiso et al. (2010). This indicator of social capital has been adopted in many other studies (see for example Akçomak and ter Weel, 2009; De Blasio and Nuzzo, 2010; Durante et al., 2011; Nannicini et al., 2013; Guriev and Melnikov, 2016).

### 3 The model

The economy is populated by infinitely living households, who maximize the expected discounted value of an inter-temporal utility function, i.e.:

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t, N_t) \quad (1)$$

with  $\beta^t$  corresponding to the subjective discount factor,  $C_t$  is private consumption and  $N_t$  are the hours worked,  $E_0$  is the expected value operator given the information at time 0, under the following inter-temporal budget constraint:

$$P_t C_t + K_t^p + K_t^s \leq R_t^p K_{t-1}^p + R_t^s K_{t-1}^s + W_t N_t \quad (2)$$

where  $K_{t-1}^p$  and  $K_{t-1}^s$  are the endowments of physical and social capital respectively at time  $t-1$ ,  $P_t$  is the consumer price index,  $W_t$  are nominal wages, and  $R_t^i$  ( $i = s, p$ ) are the gross rates of return

$$R_t^i = r_t^i + 1 - \delta^i \quad (3)$$

with  $r_t^i$  ( $i = s, p$ ) representing the net capital rentals and  $\delta^i$  ( $i = s, p$ ) the capital depreciation rates<sup>3</sup>.

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<sup>3</sup>The analytical derivation of the equilibrium characterization for the households and firms is reported in the

Social capital is in part accumulated through rational investment decisions (Becker, 1974; Bourdieu, 1986). Agents invest in the creation of connections and social obligations, and in building a reputation of trustworthiness, to the purpose of pursuing particular or general goals that could not be achieved without coordination and cooperation. The stock resulting from these decisions is a shared resource having the nature of a public good. In line with the extensive literature on social capital and growth (see for example Francois and Zabojnik, 2005 and Antoci et al., 2011b), we assume this resource being an input of production. As suggested by Bourdieu (1986), agents can appropriate the outcomes of production to the extent of their personal or corporate wealth of social capital, which therefore determines the rental rate of this factor of production. Social capital, however, requires an endless and costly effort to produce and reproduce lasting relationships (Bourdieu, 1982; 1986). Like the other forms of capital, it is therefore subject to depreciation, as relationships, networks, trust and the individuals' propensity for cooperation can slacken over time as a result, for example, of the decline in social participation (Antoci et al., 2011b) and of negative shocks (Guriev and Melnikov, 2016).

Both physical and social capital,  $K_t^i$  ( $i = s, p$ ), evolve according to the standard law of motion, i.e.:

$$K_t^i - K_{t-1}^i = I_t^i - \delta^i K_{t-1}^i \quad (4)$$

where  $I_t^i$  ( $i = s, p$ ) are the incidental investments in physical and social capital for  $i$  at time  $t$ , achieved through behaviors involving a contribution to the common good or promoting reciprocal trust and cooperation, such as blood donation.

Private consumption  $C_t$  is defined as follows

$$C_t = \left[ \int_0^1 C_t(j)^{1-\frac{1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (5)$$

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Appendix A.

with  $j$  representing the variety of goods produced by each firm acting as a monopolistic competitor,  $C_t(j)$  is the consumption of the good  $j \in [0; 1]$  and  $\varepsilon > 1$  indicating the elasticity of substitution between differentiated goods.

The optimal allocation of expenditures across the households reads as

$$C_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\varepsilon} C_t \quad (6)$$

with  $P_t(j)$  representing the price of the good  $j$  at time  $t$  implying that

$$\int_0^1 P_t(j) C_t(j) dj = P_t C_t \quad (7)$$

and

$$P_t = \left[ \int_0^1 P_t(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \quad (8)$$

We assume that the period utility function follows a semi-logarithmic form:

$$U(C_t, N_t) = \log(C_t) - \frac{N_t^{1+\gamma}}{1+\gamma} \quad (9)$$

where  $\gamma$  is the inverse of the Frisch elasticity of labor supply.

The aggregate output is defined as follows:

$$Y_t = \left( \int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (10)$$

where  $j \in [0; 1]$  is a continuum of firms, each one producing a different variety of final good with the same constant returns to scale technology:

$$Y_t(j) = A_t [N_t(j)]^\zeta [K_{t-1}^p(j)]^\nu [K_{t-1}^s(j)]^{1-\zeta-\nu} \quad (11)$$

where  $Y_t(j)$  is the production function of good  $j$ ,  $N_t(j)$ ,  $K_{t-1}^p(j)$  and  $K_{t-1}^s(j)$  are labor, physical and social capital employed in the productive process of good  $j$ , whereas  $A_t$  is a productivity shifter common to all firms whose law of motion in logs reads as

$$a_t = \rho a_{t-1} + \epsilon_t^a \quad (12)$$

where  $a_t = \log A_t$ ,  $\rho \in [0, 1]$  is a persistence coefficient and  $\epsilon_t^a$  is a white noise.

Moreover, each firm has a probability of resetting prices in any given period,  $1 - \theta$ , independent across firms (staggered price setting, Calvo, 1983), with  $\theta \in [0; 1]$ , indicating an index of price stickiness.

The aggregate price level reads as

$$P_t = \left[ \theta (P_{t-1})^{1-\varepsilon} + (1-\theta) (P_t^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \quad (13)$$

with  $P_t^*$  indicating the identical prices reset in period  $t$ . The expression (13) states that the aggregate level is a weighted average of reset and non reset prices across firms.

The (13) can be rewritten as:

$$(P_t)^{1-\varepsilon} = \left[ \theta (P_{t-1})^{1-\varepsilon} + (1-\theta) (P_t^*)^{1-\varepsilon} \right] \quad (14)$$

Then, dividing each member of (14) by  $(P_{t-1})^{1-\varepsilon}$  the following expression for the price dynamics  $\left( \Pi_t = \frac{P_t}{P_{t-1}} \right)$  is obtained:

$$\Pi_t^{1-\varepsilon} = \theta + (1-\theta) \left( \frac{P_t^*}{P_{t-1}} \right)^{1-\varepsilon} \quad (15)$$

Inflation rate is only determined by the share  $(1 - \theta)$  of firms resetting their prices at a level  $P_t^*$ . The log-linearization of (15) around zero inflation steady state produces the following equivalent

results

$$\pi_t = (1 - \theta) (p_t^* - p_{t-1}) \quad (16)$$

$$p_t = \theta p_{t-1} + (1 - \theta) p_t^* \quad (17)$$

But how the firms choose the optimal price level  $P_t^*$ ?

A firm in period  $t$  chooses a price  $P_t^*$  that maximizes the current market value of the profits  $\Upsilon_t$ ,

i.e.

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k E_t \{ Q_{t,t+k} (P_t^* Y_{t+k|t} - \Psi_{t+k} (Y_{t+k|t})) \} \quad (18)$$

subject to the sequence of demand constraints

$$Y_{t+k|t} = \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} C_{t+k} \quad (19)$$

for  $k = 0, 1, 2, \dots$  and where  $Q_{t,t+k} = \beta^k (C_{t+k}/C_t) (P_t/P_{t+k})$  is the discount factor,  $\Psi_t(\cdot)$  is the cost function of the firm, whereas  $Y_{t+k|t}$  represents output in period  $t+k$  for a firm resetting its price in period  $t$ . Next, the first order condition associated with the problem (18) is given by:

$$\sum_{k=0}^{\infty} \theta^k E_t \{ Q_{t,t+k} Y_{t+k|t} (P_t^* - M \psi_{t+k|t}) \} = 0 \quad (20)$$

where  $\psi_{t+k|t} = \Psi'_{t+k}(Y_{t+k|t})$  indicates the nominal marginal cost in period  $t+k$  for a firm resetting its price in period  $t$  and  $M = \frac{\varepsilon}{\varepsilon-1}$  that is the desired markup in the absence of constraints on the frequency of price adjustment. Note that in the absence of price rigidities ( $\theta = 0$ ) the previous condition collapses to the optimal price setting condition under flexible prices:

$$P_t^* = M \psi_{t|t} \quad (21)$$



according to which the optimal price is a mark-up over the marginal costs. Then, the division of both the members of (20) by  $P_{t-1}^i$  reads as:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} Y_{t+k|t} \left( \frac{P_t^*}{P_{t-1}} - M \times MC_{t+k|t} \Pi_{t-1,t+k} \right) \right\} = 0 \quad (22)$$

where  $MC_{t+k|t} = \frac{\psi_{t+k|t}}{P_{t+k}}$  is the real marginal cost in period  $t+k$  for firms whose last price set is in period  $t$ .

Finally, the log-linearization of (22) around the zero inflation steady state with a first-order Taylor expansion reads as

$$p_t^* - p_{t-1} = (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t [\widehat{mc}_{t+k|t} + (p_{t+k} - p_{t-1})] \quad (23)$$

where  $\widehat{mc}_{t+k|t} = mc_{t+k|t} - \overline{mc}$  is the log-deviation of marginal cost from its steady state value.

The optimal price setting strategy for the typical firm resetting its price in period  $t$  can be derived from (23), after some algebra:

$$p_t^* = \mu + (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t [mc_{t+k|t} + p_{t+k}] \quad (24)$$

with  $\mu = \log \frac{\varepsilon}{\varepsilon-1}$  representing the optimal markup in the absence of constraints on the frequency of price adjustment ( $\theta = 0$ ).

Hence, the price setting rule for the firms resetting their prices is represented by a charge over the optimal markup in the presence of fully flexible prices, given by a weighted average of their current and expected nominal marginal costs, with the weights being proportional to the probability of the price remaining effective  $(\theta)^k$ .

Note that, under the hypothesis of constant returns to scale, implicit in the production function of our model, the marginal cost is independent from the level of production, i.e.  $mc_{t+k|t} = mc_{t+k}$

and, hence, common across firms; so, the expression (24) can be rewritten in the following way:

$$p_t^* - p_{t-1} = (1 - \beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k E_t [mc_{t+k}] + \sum_{k=0}^{\infty} (\beta\theta)^k E_t [p_{t+k}] \quad (25)$$

Moreover, the equation (25) can be expressed in the following recursive form:

$$p_t^* - p_{t-1} = \beta\theta E_t [p_{t+1}^*] - (1 - \beta\theta) p_t + (1 - \beta\theta) \widehat{mc}_t \quad (26)$$

and combined with (16) in a log-linear form in order to obtain the domestic inflation equation:

$$\pi_t = \beta\pi_{t+1}^e + \frac{(1 - \theta)(1 - \beta\theta)}{\theta} \widehat{mc}_t \quad (27)$$

with  $\pi_{t+1}^e = E_t [\pi_{t+1}]$ .

Note that from (27) it emerges that the inflation rate of this economy depends on the discounted future expected inflation rate,  $\beta\pi_{t+1}^e$  and the log deviation of real marginal costs from their steady state value  $\widehat{mc}_t$  according to  $\frac{(1-\theta)(1-\beta\theta)}{\theta}$ , which is a strictly decreasing function in the index of price stickiness  $\theta$ .

Solving (27) forward, inflation is expressed as the discounted sum of current and future log deviations of real marginal costs from their steady state level:

$$\pi_t = \frac{(1 - \theta)(1 - \beta\theta)}{\theta} \sum_{k=0}^{\infty} \beta^k E_t (\widehat{mc}_{t+k}) \quad (28)$$

The expression (28) shows that the fluctuations of inflation in this monopolistically competitive model with sticky prices á la Calvo result from price-setting decision of the firms linked to their expectations on marginal costs.

The level of output associated to a fully-flexible price scenario is  $\bar{y}_t$  with the following corre-

spending log-linear definition of output gap

$$\tilde{y}_t = y_t - \bar{y}_t \quad (29)$$

The market clearing conditions for the good  $j$  can be expressed as follows:

$$Y_t(j) = C_t(j) + I_t^s(j) + I_t^p(j) \quad (30)$$

The previous relationship states that production of good  $j$  is allocated to private consumption, investments in social capital and physical capital.

Then, using the definitions of  $C_t(j)$ , equation (30) can be rewritten as follows:

$$Y_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\varepsilon} C_t + I_t^s(j) + I_t^p(j) \quad (31)$$

By plugging (31) into the definition of the aggregate output (10), the aggregate market clearing condition is obtained:

$$Y_t = C_t + I_t^s + I_t^p \quad (32)$$

Finally, in order to deal with the complementary effect of social capital with human capital (Glaeser et al., 2002), we also consider a standard DSGE model (see Maffezzoli, 2000; King and Rebelo, 1999; Goessling et al., 2018; Smith and Thoenissen, 2019, among the others) incorporating social capital and human capital as well.

In this case, the utility function (9) and the resource constraint (2) assume the following forms:

$$U_t(C_t, N_t, M_t) = \log(C_t) - \frac{N_t^{1+\gamma}}{1+\gamma} - \phi M_t \quad (33)$$

$$P_t C_t + K_t^p + K_t^s \leq R_t^p K_{t-1}^p + R_t^s K_{t-1}^s + W_t N_t H_{t-1} \quad (34)$$

where  $C_t$  is private consumption,  $N_t$  and  $M_t$  are the hours available to the consumer and used respectively in goods production and in human capital investment,  $H_{t-1}$  is the stock of human capital at the beginning of period  $t$ ,  $\phi$  is the disutility in investing in human capital and  $N_t H_{t-1}$  represents the “effective labour input”. The remaining hours of time endowment,  $T$ , for the representative household are allocated to leisure ( $L_t$ )

$$N_t + L_t + M_t = T \quad (35)$$

As a consequence, the stock of human capital evolves according to the following process:

$$H_t = (1 - \delta^h) H_{t-1} + \bar{S} (M_t H_{t-1}) \quad (36)$$

$$H_t = (1 - \delta^h + \bar{S} M_t) H_{t-1} \quad (37)$$

with  $\delta^h$  indicating the depreciation rate of human capital and  $\bar{S}$  is a constant productivity shifter – normalized to one – measuring the efficiency of human capital production technology.

The utility function (33) has to be maximized under the constraints (34), (35) and (36).

The production function (11) is modified as follows

$$Y_t(j) = A_t [N_t H_{t-1}(j)]^\zeta [K_{t-1}^p(j)]^\nu [K_{t-1}^s(j)]^{1-\zeta-\nu} \quad (38)$$

where  $H_{t-1}(j)$  is stock of human capital at the beginning of period  $t$  for the sector  $j$ .

In the case of absence of social capital, but with human capital, the model collapses to the

following equations:

$$\begin{aligned}
 U(C_t, N_t, M_t) &= \log(C_t) - \frac{N_t^{1+\gamma}}{1+\gamma} - \phi M_t & (39) \\
 P_t C_t + K_t^p &\leq R_t^p K_{t-1}^p + W_t N_t H_{t-1} \\
 K_t^p &= (1 - \delta^p) K_{t-1}^p + I_t^p \\
 N_t + L_t + M_t &= T \\
 H_t &= (1 - \delta^h) H_{t-1} + \bar{S}(M_t H_{t-1}) \\
 \int_0^1 P_t(j) C_t(j) dj &= P_t C_t \\
 Y_t(j) &= A_t [N_t H_{t-1}(j)]^\epsilon [K_{t-1}^p(j)]^{1-\epsilon} \\
 a_t &= \rho a_{t-1} + \epsilon_t^a \\
 Y_t &= \left( \int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \\
 \pi_t &= \beta \pi_{t+1}^e + \frac{(1-\theta)(1-\beta\theta)}{\theta} \widehat{m}c_t \\
 Y_t &= C_t + I_t^p
 \end{aligned}$$

whereas in the case of absence of both social and human capital (i.e. the benchmark case), the

model structure reads as follows:

$$\begin{aligned}
 U(C_t, N_t) &= \log(C_t) - \frac{N_t^{1+\gamma}}{1+\gamma} & (40) \\
 P_t C_t + K_t^p &\leq R_t^p K_{t-1}^p + W_t N_t \\
 K_t^p &= (1 - \delta^p) K_{t-1}^p + I_t^p \\
 \int_0^1 P_t(j) C_t(j) dj &= P_t C_t \\
 Y_t(j) &= A_t [N_t(j)]^\zeta [K_{t-1}^p(j)]^{1-\zeta} \\
 a_t &= \rho a_{t-1} + \epsilon_t^a \\
 Y_t &= \left( \int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \\
 \pi_t &= \beta \pi_{t+1}^e + \frac{(1-\theta)(1-\beta\theta)}{\theta} \widehat{m} c_t \\
 Y_t &= C_t + I_t^p
 \end{aligned}$$

#### 4 Methodology, data and model dynamics

We empirically test the model using Italian annual data. Italy is a typical case study in the social capital literature since the pioneering study of Banfield (1958), in which the author shows in which the author shows how the lack of civic spirit can explain the backwardness of the Italian Mezzogiorno.

In order to estimate the parameters, simulate the time series, and evaluate their dynamic responses in the presence of the total factor productivity shock, we adopt the inferential procedure based on the Monte Carlo Markow Chains (MCMC) methods and, in particular, on the Metropolis-Hastings algorithm, which belongs to the family of Bayesian estimation methods (see among others Canova, 2007, and Smets and Wouters, 2007). In particular, we build a multi-chain MCMC procedure based on four chains of size 100,000. The algorithm converges within 45,000 iterations to its

expected value. Therefore, to remove any dependence from the initial conditions, we remove the first 45,000 observations from each chain. This high number of iterations, together with the 90% highest posterior density (HPD) credible interval for the estimates, ensures the robustness of our results<sup>4</sup>. All the calculations have been performed through the software DYNARE.

Below, we summarize the measurement equation considered, i.e. the relationship between the data (left side) and the model variables (right side):

$$[\Delta \ln Y_t] = [\Xi] + 100 \times [y_t - y_{t-1}] \quad (41)$$

where  $\Delta \ln Y_t$  is the real GDP annual growth rate for Italy expressed in percentage terms from 1950 to 2014 drawn from Fred Economic Data, and  $\Xi = 100 \times \ln(v)$  is the annual real GDP trend growth rate, expressed in percentage terms.

We choose the real GDP growth rate as the observable variable due to its essential informative role: real GDP growth encompasses both Solow residual and the contribution to growth linked to the productive factors.

The parameters and their definitions are shown in Table 1.

The prior densities are consistent with the domain of the parameters. Following Del Negro and Schorfheide (2008), in the prior elicitation process, we divided the parameters into three groups based on the information used to calibrate the priors.

The first group of parameters consists of those that determine the steady state  $[\zeta, \nu, \delta^p, \delta^s, \delta^h]$  and whose calibration derives from macroeconomic ‘great ratios’ mainly referred to the sample information. In the second group, some parameters are related to policy, households, production

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<sup>4</sup>In detail, the estimation procedure is based on two steps. First, we have estimated the mode of the posterior distribution by maximizing the log posterior density function, which is a combination of the prior information on the structural parameters with the likelihood of the data. In the second, we have used the Metropolis-Hastings algorithm to draw a complete picture of the posterior distribution and compute the log marginal likelihood of the model. Moreover, following Brooks and Gelman (1998), we carried out the univariate convergence diagnostic based on a comparison between pooled and within MCMC moments, whose results are available upon request.

Table 1: Definitions of the parameters

Parameters	Definitions
$\zeta$	output elasticity of labor
$\nu$	output elasticity of private capital
$\delta^p$	depreciation rate of private capital
$\delta^s$	depreciation rate of social capital
$\delta^h$	depreciation rate of human capital
$\gamma$	Frisch elasticity of labor supply
$\beta$	Inter-temporal discount factor
$\theta$	Price stickiness
$\phi$	Disutility of human capital investment
$\Xi$	Annual real GDP growth rate
$\rho$	Persistence of total factor productivity
$\sigma$	Standard deviation of total factor productivity shock

$[\gamma, \beta, \theta, \phi, \Xi]$ , taken either from micro-level data or from the literature or from out-of-the-sample information. The third group includes parameters describing the propagation mechanism of the stochastic shocks, such as their standard deviations and autocorrelations  $[\rho, \sigma]$ . These last parameters are calibrated based on the second moments of the observable variables, consistent with the results found in the literature.

The calibrated values compared with the posterior ones are shown in Table 2 for the model with only social capital and Table 3 for the model with social capital and human capital<sup>5</sup>.

The posterior values of the parameters are estimated using the observable variable (the real GDP annual growth rate) conditionally to the model. The posterior estimates of the parameters are composed of the posterior means together with the 90% HPD (Highest Posterior Density) credible interval for the estimated parameters obtained by the Metropolis-Hastings algorithm<sup>6</sup>.

The elasticities of the production function ( $\zeta, \nu$ ) are calibrated considering the average share

<sup>5</sup>To save space, we do not report the parametrization for the model without social capital and human capital and for the model with only human capital. This information is available upon request.

<sup>6</sup>We have increased the standard deviations of the prior distributions of the parameters by 50 percent to evaluate the sensitivity of the estimation results with the assumptions on prior estimates (Smets and Wouters, 2007). Overall, the estimation results are quite the same (results are available upon request).



Table 2: Prior and posterior distributions of the parameters for the model with only social capital

Parameters	Prior distribution			Posterior distribution		
	Distribution	Mean	St. Dev.	Mean	90% HPD interval	
$\zeta$	beta	0.40	0.10	0.60	0.45	0.73
$\nu$	beta	0.30	0.10	0.32	0.15	0.50
$\delta^p$	beta	0.10	0.10	0.16	0.00	0.38
$\delta^s$	beta	0.09	0.10	0.14	0.00	0.38
$\gamma$	gamma	3.00	0.75	2.55	1.32	3.67
$\beta$	beta	0.80	0.1	0.78	0.63	0.93
$\theta$	beta	0.75	0.1	0.95	0.92	0.98
$\Xi$	normal	1.55	0.1	1.53	1.36	1.68
$\rho$	beta	0.90	0.10	0.98	0.95	1.00
$\sigma$	inv. gamma	0.10	2.00	0.04	0.02	0.06

of wages and capital rentals on Italy's GDP from 1980 to 2011 (provided by the Italian National Institute of Statistics, ISTAT) with a slight standard deviation. The posterior value of labor share is higher than the prior one, showing the relative importance of labor input in the Italian production function, whereas the posterior estimate of physical capital is almost the same as the calibrated value. The initial value of the depreciation rates for private, social and human capital is measured through the steady state ratio  $\left(\delta^i = \frac{\bar{I}^i}{K^i}\right)$  ( $i = s, p, h$ ): for physical capital, we use Italian data on investments and capital stocks from 1980 to 2011. To measure social capital, we follow the approach to use an indicator of its hypothetical outcomes that summarizes individuals' propensity for cooperation: blood donation. As explained in Guiso et al. (2004) and Guiso et al. (2010), the relationship between social capital and blood donation is unlikely to be affected by confounding factors, especially for the Italian case. Blood donation in Italy is supervised by a unique association, the AVIS, which collects the totality of anonymous blood donations and manages a collection center in almost every Italian municipality.

As blood donation is not necessarily a social capital's outcome, it can only approximate the potential impact of social capital's core dimensions on the economic performance. Seminal work in sociology showed that the various forms of social capital could foster or hinder cooperation depend-

Table 3: Prior and posterior distributions of the parameters for the model with social capital and human capital

Parameters	Prior distribution			Posterior distribution		
	Distribution	Mean	St. Dev.	Mean	90% HPD interval	
$\zeta$	beta	0.40	0.10	0.46	0.34	0.57
$\nu$	beta	0.30	0.10	0.30	0.17	0.44
$\delta^p$	beta	0.10	0.10	0.10	0.03	0.17
$\delta^s$	beta	0.09	0.10	0.10	0.02	0.15
$\delta^h$	beta	0.08	0.10	0.10	0.05	0.11
$\gamma$	gamma	3.00	0.75	2.45	2.20	2.68
$\phi$	gamma	1.00	0.75	1.15	0.25	1.45
$\beta$	beta	0.80	0.10	0.71	0.69	0.93
$\theta$	beta	0.75	0.10	0.78	0.63	0.89
$\Xi$	normal	1.55	0.10	1.56	1.45	1.67
$\rho$	beta	0.90	0.10	0.99	0.98	1.00
$\sigma$	inv. gamma	0.10	2.00	0.06	0.03	0.09

ing on the circumstances and the specific goals of their owners (Bourdieu, 1986; Coleman, 1988). Focusing on only one of the multiple facets of social capital, precisely capturing cooperative behaviors, could bias our results by neglecting the potentially concurrent effect of other unobservable dimensions of the concept. This option is driven by the lack of comparably long and frequent time-series data on social capital. Despite these weaknesses, our approach allows us to operationalize the most development-oriented aspect of the concept. Also, it has the advantage of summarizing the tendency to internalize externalities as a matter of civic-mindedness and believe that most people will do the same. This combination of values and beliefs that “help a group overcome the free-rider problem” - leading in this case to the provision of a public good like blood for transfusions - is what Guiso et al. (2010) define as civic capital and Putnam et al. (1993) referred to as social capital.

Our measure of social capital is the volume of blood donations given by the number of 16-ounce blood bags collected per inhabitant. In particular, the parameter  $\delta^s$  is calibrated by considering the yearly blood donations from 1980 to 2011 as a measure of  $I_t^s$ , i.e., the stock of social capital. The calibrated value of the depreciation rate of human capital,  $\delta^h$ , is derived from the available

data (the time span is 2008-2016) provided by the ISTAT for total public and private expenditures for education. In particular, we calculate the stock of human capital as the sum over years of the schooling expenditures, thus following a cost-based approach (see e.g. Kendrick, 1974; 1976; Eisner, 1989), whereas the investment flow has been measured as the per-year average expenditure for education. Despite the small sample size, the calibrated value is almost close to what has been found by the related literature (see Heckman, 1976 and Maffezzoli, 2000 among the others). The posterior values of  $\delta^i$  are higher than prior ones. Following Kim and Lee (2007), we calibrate the relative disutility of human capital investment equal to one loosely. The corresponding posterior value is slightly higher.

The initial value for the inverse of Frisch elasticity of labor supply ( $\gamma$ ) can match four empirical moments for the Italian data from 1980 to 2011 following Cho and Cooley (1994) and Argentiero and Bollino (2015): the ratio of the standard deviation of total output to the standard deviation of total consumption, the correlation between total output and total consumption, the correlation between underground production and total consumption and the correlation between regular production and total consumption. The posterior value for  $\gamma$  is slightly lower than the prior one. The annual real GDP trend growth rate ( $\Xi$ ) is normally distributed and is calibrated on Italian data with a prior mean of 1.55 that is almost the same as the posterior estimated value.

The price stickiness coefficient, i.e., the fraction of firms that do not reset their price in a period, is calibrated to a value of 0.75, following Galí and Monacelli (2008). The posterior value of this parameter is higher than the prior one, thus showing a higher degree of price stickiness for the Italian economy.

Following the real business cycle literature (see for example King and Rebelo, 1999) and the second moments of Italian total factor productivity data (provided by FRED Economic Data), we set a high value for the persistence coefficient of total factor productivity, which has also been confirmed by the estimation procedure, and a loose prior value for the standard deviation of the

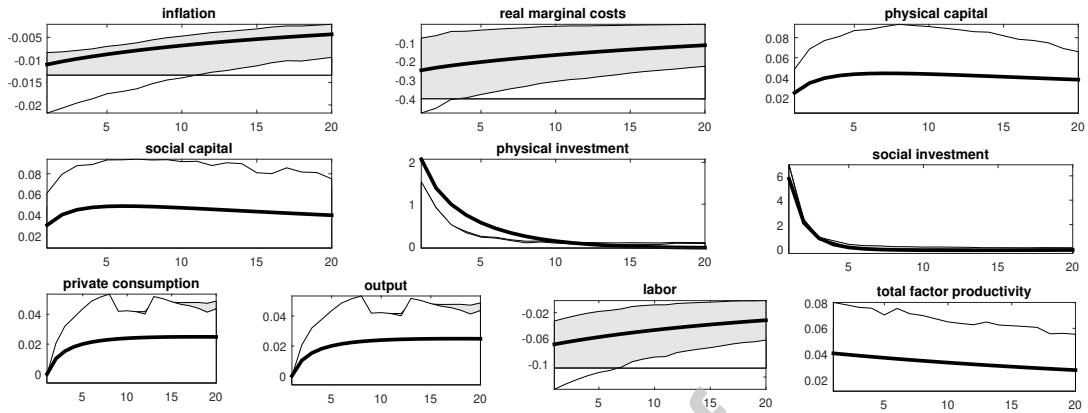


Figure 1: Impulse response functions for a positive productivity shock in the case of only social capital

productivity shifter ( $\sigma$ ).

The dynamic response of the main variables, in log-deviations from their steady state values, to a stochastic shock on total factor productivity is represented by impulse response functions (IRFs) in Figure 1 for the model with only social capital and in Figure 2 for the model with social capital and human capital. The responses are qualitatively similar in both models. Note that for all of the IRFs, the size of the standard deviations of the stochastic shocks and the variables' responses relate to the posterior average of the IRFs for each draw of the MCMC algorithm, together with 90% credible intervals.

In the aftermath of a positive technology shock, output increases but less than the positive growth of total factor productivity. This stylized fact is consistent with the empirical findings of Galì (1999), Smets and Wouters (2003), and Galì and Monacelli (2008), according to which price stickiness determines an increase of aggregate demand (increase in private consumption) lower than the rise in supply. Hence, due to the increased productivity, firms can produce the same quantity of goods with fewer hours worked and less human capital that decreases as well although private and social capital stocks and the corresponding investments increase due to the rise of capital rentals.

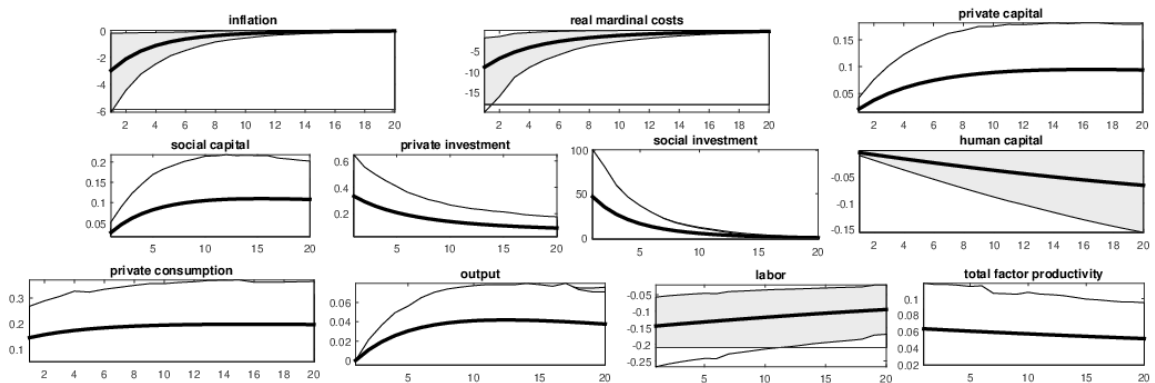


Figure 2: Impulse response functions for a positive productivity shock with social capital and human capital

Real marginal costs ( $mc$ ) fall as well as inflation, but this last variable decrease less than in a fully flexible price scenario.

## 5 Analysis of the performance

In this section, we compare the empirical annual time series of the Italian total factor productivity from 1950 to 2014 with the series obtained by implementing the DSGE model in the benchmark case (40) of absence of social capital (*benchmark series*,  $BS$  hereafter), in presence of social capital (*social capital series*,  $SC$  hereafter), in presence of social capital and human capital (*social and human capital series*,  $SHC$  hereafter) and in presence of only human capital (*human capital series*,  $HC$  hereafter). In doing so, we want to understand if adding social capital to the productivity function allows the model to better fit actual data. In this respect, we also consider the complementary role of human capital.

We use a MCMC method to generate the simulated time series for the  $BS$ ,  $SC$ ,  $SHC$  and  $HC$  models. The simulated series span the same period of the original sample with the same periodicity,

to allow the comparison experiments. Thus, we have 65 years for the period 1950-2014. We consider 100,000 realizations of the random shocks described in the considered DSGE models (see Section 2). Next, the expected value of all the simulations at each time has been taken, and this will be the corresponding values at each year. Therefore, the length of the original sample and of the four simulated series will be  $n = 65$ .

We denote by  $x = (x_i)_{i=1,\dots,n}$ ,  $b = (b_i)_{i=1,\dots,n}$ ,  $s = (s_i)_{i=1,\dots,n}$ ,  $sh = (sh_i)_{i=1,\dots,n}$  and  $h = (h_i)_{i=1,\dots,n}$  the original sample, the series of type BS, SC, SHC and HC, respectively.

To discuss the models, we adopt three strategies. First, the distances between the four simulated series and the original sample  $x$  are compared. The times of the realizations will be included in this part of the analysis, so that the concept of distance between two series will involve the contemporaneous realizations of the series. As we will see, several concepts of distance are used, in order to obtain a satisfactory level of information from this procedure. Second, we adopt a data science perspective and discuss a rank-size analysis of the five series. In so doing, we are able to understand the possible presence of common regularities of the realizations of the five series when they are ranked in descending order. As a side analysis of data science type, the linear trends of the series are also compared. Third, the empirical distributions of the five series are considered and compared under the point of view of the descriptive statistics. In this framework, an entropy between the series distributions is also taken into account.

## 5.1 Time series distance approach

The distances employed in the first approach are the Euclidean one, the maximum, the minimum and the Euclidean one. They are defined, respectively, as follows

$$d_M(x, y) = \max_{i=1,\dots,n} |x_i - y_i|, \quad (42)$$

Distance d	$d(x, s)$	$d(x, b)$	$d(x, sh)$	$d(x, h)$
$d = d_M$	0,524	1,814	0.500	20.409
$d = d_m$	0	0	0	0
$d = d_E$	0,038	0,445	0.036	135.273

Table 4: Distances between the original sample  $x$  and the four competing simulated series  $b$ ,  $s$ ,  $sh$  and  $h$ , according to formulas in (42), (43) and (44).

$$d_m(x, y) = \min_{i=1, \dots, n} |x_i - y_i|, \quad (43)$$

$$d_E(x, y) = \frac{1}{n} \sum_{i=1}^n (x_i - y_i)^2, \quad (44)$$

where  $y \in \{b, s, sh, h\}$ . The three concepts of distance are quite natural and jointly offer a panoramic view on how the original sample is close to the benchmark simulations or to the ones with social capital in a time-wise form.

Results are reported in Table 4.

By looking at Table 4, it is clear that the models with social capital – with or without human capital – have a remarkably smaller distance from the empirical sample than the model without social capital. The model with social and human capital is slightly closer to the original sample than that with only social capital. The average (Euclidean) distance  $d_E(x, b)$  is more than eleven times greater than  $d_E(x, s)$  and  $d_E(x, sh)$ , while the maximum distance is more than three times bigger. Notice the relevance discrepancy between the model with only human capital and the original sample.

## 5.2 Data science approach

Time series are here viewed as collections of numbers. We aim at understanding whenever  $b$ ,  $s$ ,  $sh$  and  $h$  share some regularity properties with  $x$ , and which one is closer to  $x$  in this respect.

The first step of this analysis is the assessment and the discussion of the linear trend of the five series. Time plays a relevant role, in that trend is intended on a temporal basis and allows to observe

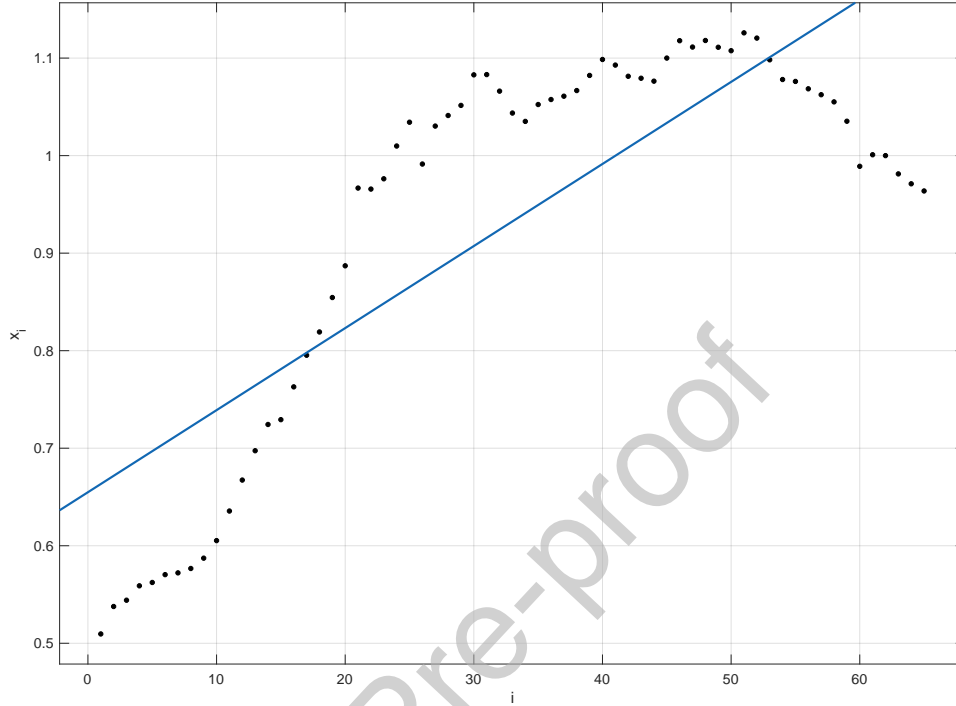


Figure 3: Linear trend for  $x$ . For a better visualization, the scatter plot is also presented.

the overall behavior of the time series. To achieve our aim, a simple linear regression is implemented over the five series, according to equation

$$y = \alpha t + \beta, \quad (45)$$

with  $y \in \{x, b, s, sh, h\}$  and  $t > 0$  represents time.  $\alpha$  and  $\beta$  are the parameters to be calibrated, and represent the slope and the intercept, respectively.

Results can be find in Figures 3, 4, 5, 6, 7 and Table 5.



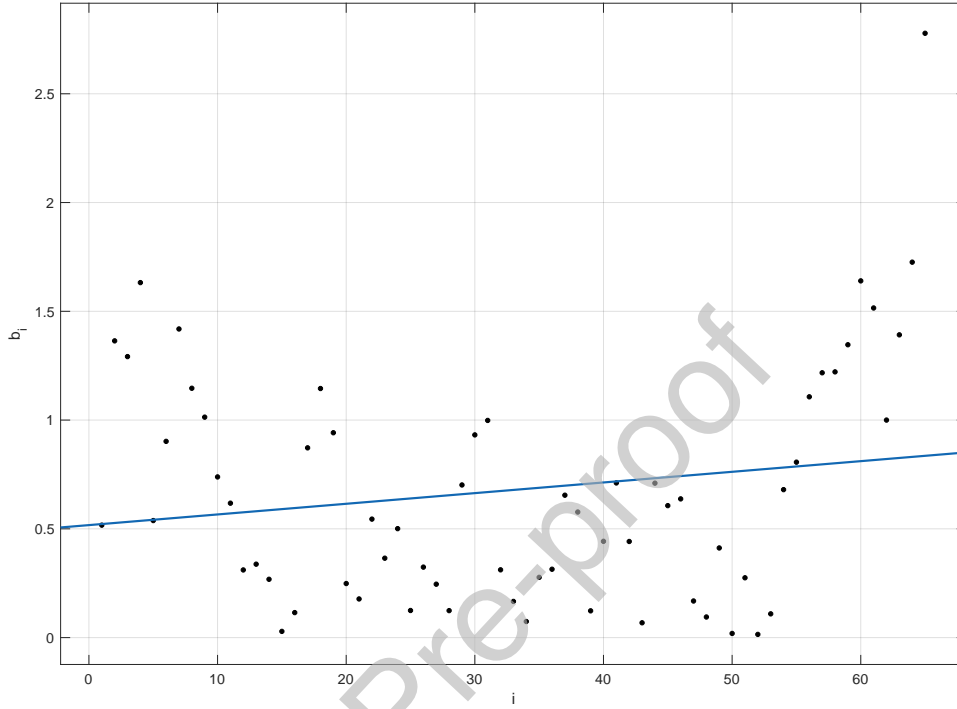


Figure 4: Linear trend for the benchmark series  $b$ . The scatter plot is juxtaposed to the best fit straight line.

Series $y$	$\hat{\alpha}$	$\hat{\beta}$	$R^2$
$y = x$	0.008415 (0.006849, 0.00998)	0.6549 (0.5954, 0.7143)	0.6468
$y = b$	0.0049 (-0.002205, 0.01201)	0.5171 (0.2474, 0.7869)	0.0293
$y = s$	0.01441 (0.01157, 0.01726)	0.3493 (0.2412, 0.4575)	0.6188
$y = sh$	0.01539 (0.01291, 0.01788)	0.3577 (0.2634, 0.4519)	0.7089
$y = h$	-0.2042 (-0.2757, -0.1326)	17.21 (14.5, 19.93)	0.3403

Table 5: The calibrated parameters  $\hat{\alpha}$  and  $\hat{\beta}$  of the linear regression exercise, according to formula (45), for the five cases of original sample, the benchmark series, the one with social capital, the one with human and social capital and the one with human capital. In brackets, the confidence interval at a 95% confidence level.

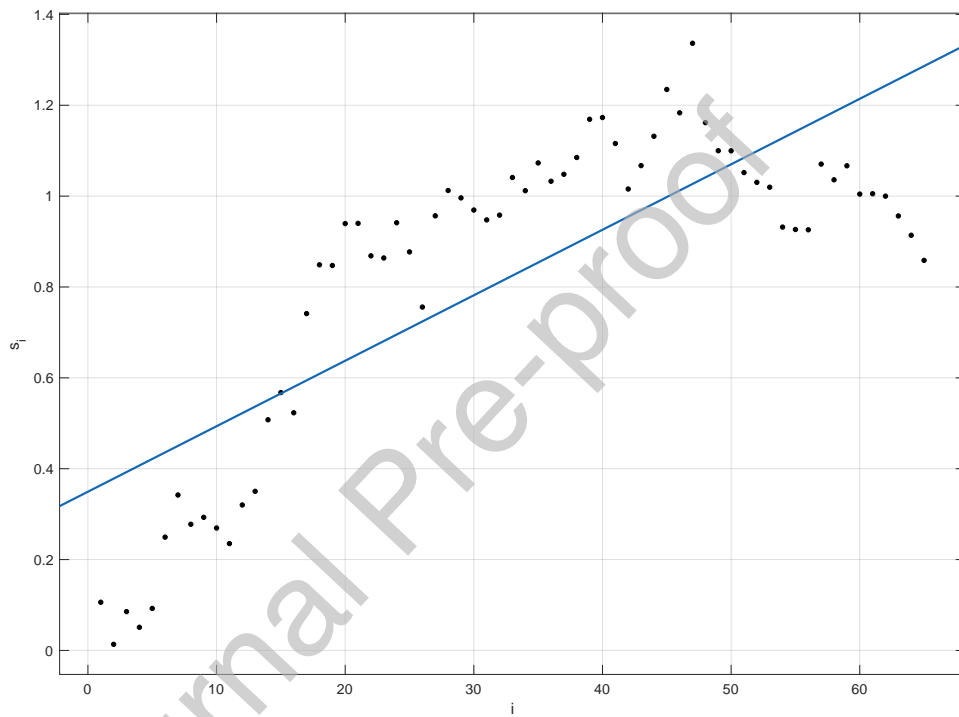


Figure 5: Linear trend for  $s$ . Also in this case, the scatter plot and the calibrated linear function are jointly shown.

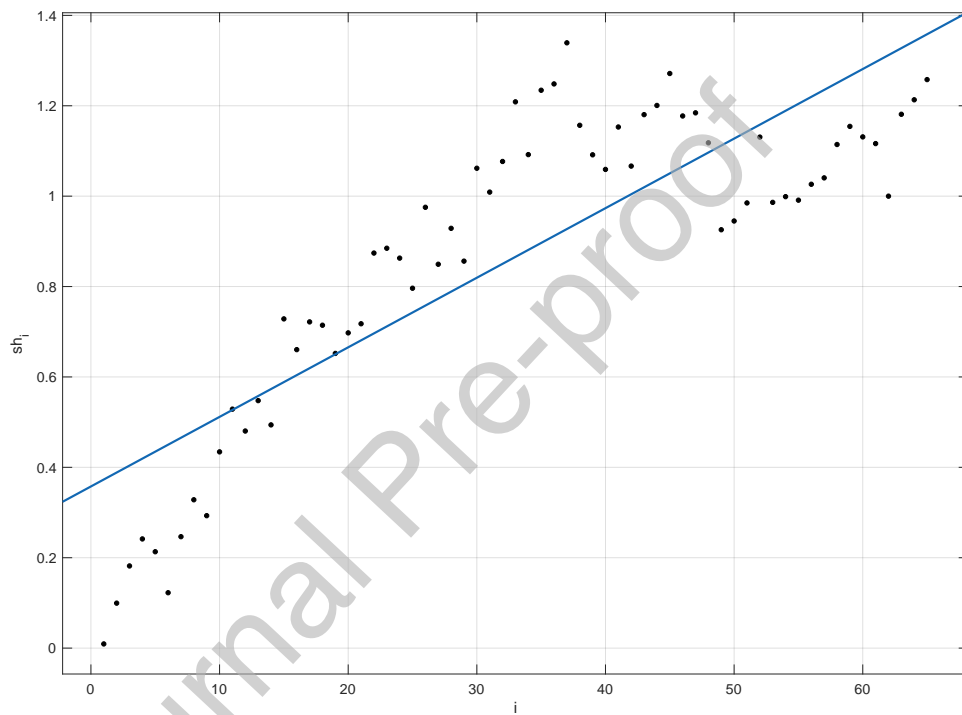


Figure 6: Linear trend for  $sh$ . Also in this case, the scatter plot is juxtaposed.

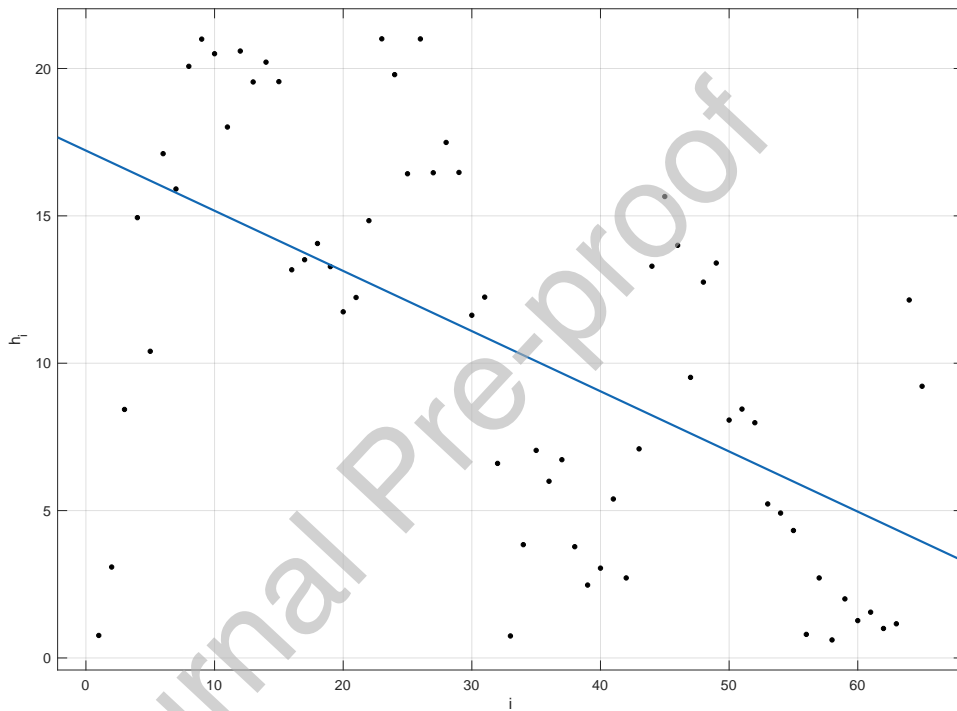


Figure 7: Linear trend for  $h$ . The scatter plot and the calibrated linear function are shown together.

Some insights can be derived from the linear trend exploration. First of all, it is rather evident that one can hardly observe a reliable linear trend for  $b$  and  $h$ , while  $x$ ,  $s$  and  $sh$  exhibit a better looking linear regression. This is confirmed also by the values of  $R^2$ , which are reported in Table 4. Notice also that the  $R^2$  for the empirical case is around 60% and similar to those of SC and SHC, hence suggesting an analogous explanation power of the linear regression of the scatter plot. Moreover, the linear trends for  $x$ ,  $s$  and  $sh$  show an increasing behavior.

In the second step, a rank-size analysis approach is adopted. The elements of the series are ranked in decreasing order, so that  $rank = 1$  is associated to the largest value of the series while  $rank = n$  is the smallest one. In so doing, the temporal dimension of the considered series is lost. The scatter plot of the series realizations with respect to  $rank$  is then fitted with a decreasing curve  $y = f(rank)$  belonging to a preselected parametric family of functions. The comparison of the calibrated parameters obtained for  $x$ ,  $b$ ,  $s$ ,  $sh$  and  $h$  say much about the similarities of BS, SC, SHC and HC with the empirical sample.

By a preliminary visual inspection of the rank-size scatter plots, we here consider a third degree polynomial of the type

$$f(rank) = \gamma_3 \cdot rank^3 + \gamma_2 \cdot rank^2 + \gamma_1 \cdot rank + \gamma_0 \quad (46)$$

where  $\gamma_0, \gamma_1, \gamma_2, \gamma_3$  are real parameters to be calibrated.

Figures 8, 9, 10, 11 and 12 allows a visual inspection of the best fit, which is rather satisfactory for the five cases. Such an idea is confirmed by looking at the goodness of fit  $R^2$ , which is reported for completeness along with the calibrated parameters in Table 6.

Rank-size analysis provides some information about the closeness of  $b$ ,  $s$ ,  $sh$  and  $h$  to  $x$ . Figures 8, 9, 10, 11 and 12 highlight that  $x$ ,  $s$  and  $sh$  show a similar shape in terms of concavity of the best fitted curve, hence suggesting a common behavior of the elements of the original series and the SC and SHC ones when they are ranked in descending order. Differently with such series, the curve

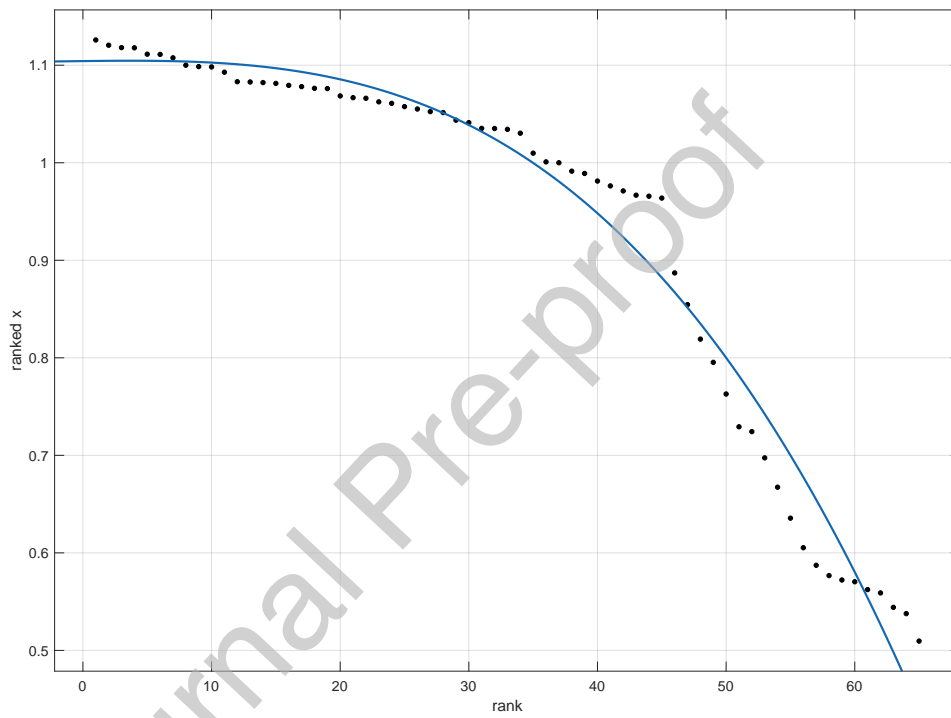


Figure 8: Rank-size best fit for  $x$ , according to formula (46), along with the scatter plot of the real data.

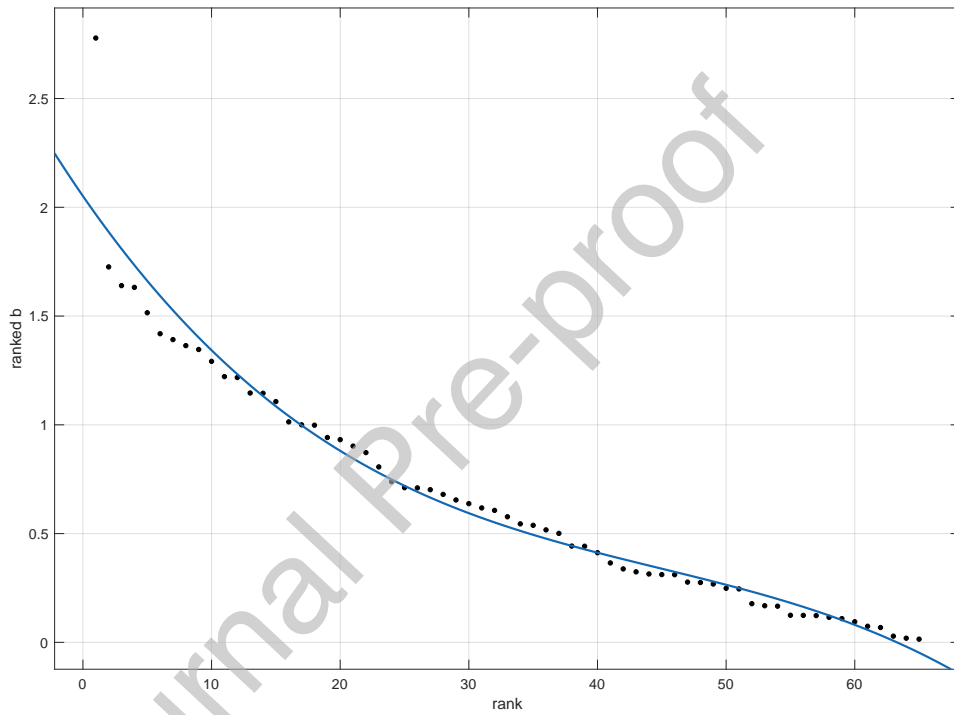


Figure 9: Rank-size best fit for  $b$  through function in (46) and related scatter plot.

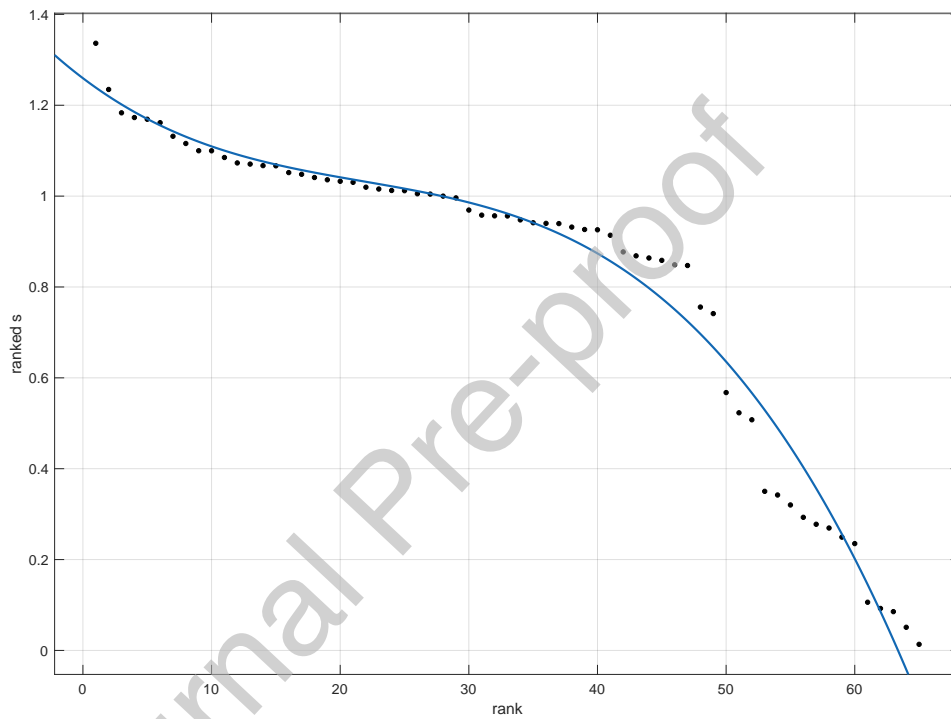


Figure 10: Rank-size best fit for  $s$ , obtained by using formula (46). The scatter plot is also shown for comparison purposes.



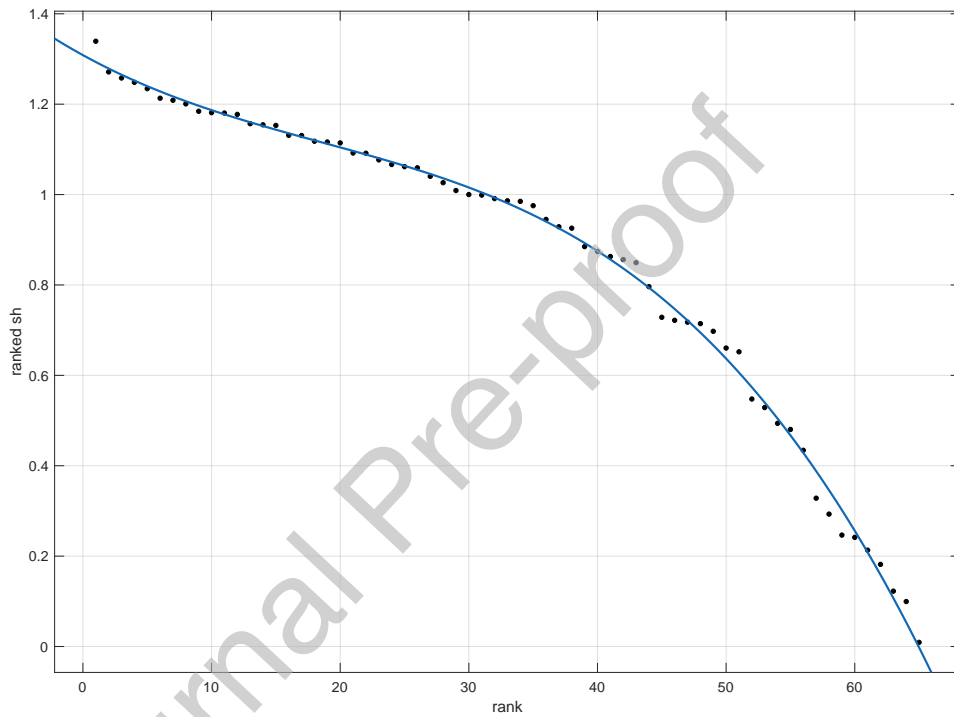


Figure 11: Rank-size best fit for  $sh$  through function in (46). The related scatter plot is also presented.

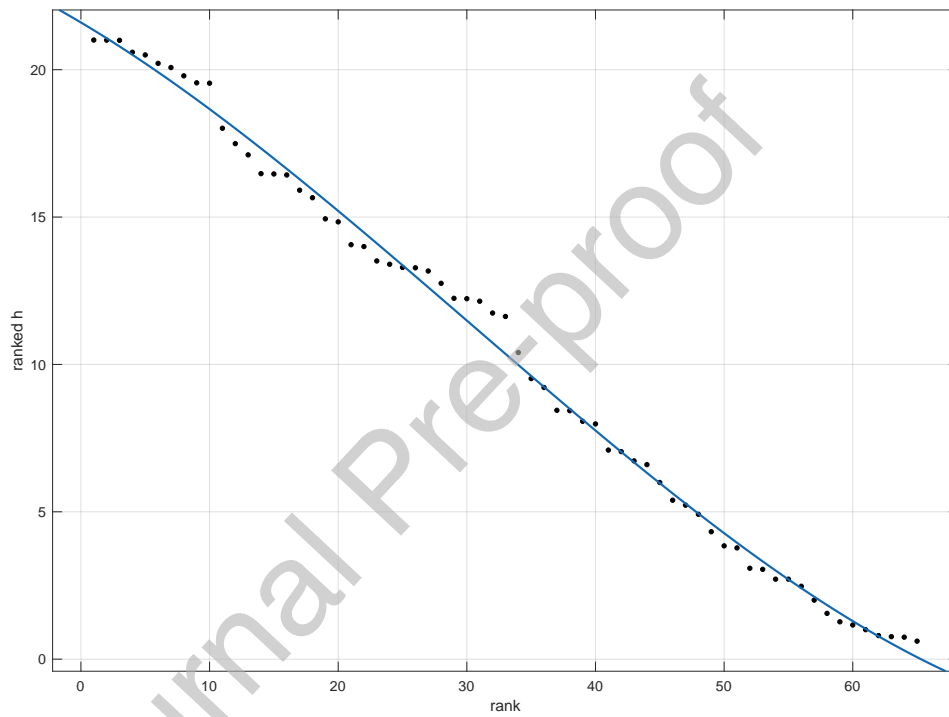


Figure 12: Rank-size best fit for  $h$ , by using formula (46), along with the scatter plot.

Table 6: The calibrated parameters  $\hat{\gamma}$  and  $\hat{\delta}$  of formula (46), for the three series. In brackets, the confidence bounds at 95%. The  $R^2$  is also shown (last column).

Series $y$	$\hat{\gamma}_3$	$\hat{\gamma}_2$	$\hat{\gamma}_1$	$\hat{\gamma}_0$	$R^2$
$y = x$	-2.334e-06 (-3.948e-06, -7.198e-07)	-8.21e-06 (-0.0001702, 0.0001538)	0.0001615 (-0.004458, 0.004781)	1.104 (1.069, 1.14)	0.9723
$y = b$	-1.18e-05 (-1.754e-05, -6.069e-06)	0.001587 (0.001011, 0.002163)	-0.08558 (-0.102, -0.06917)	2.052 (1.926, 2.178)	0.9534
$y = s$	-1.156e-05 (-1.435e-05, -8.779e-06)	0.0007569 (0.0004776, 0.001036)	-0.02142 (-0.02939, -0.01345)	1.26 (1.198, 1.321)	0.9732
$y = sh$	-7.591e-06 (-8.595e-06, -6.586e-06)	0.0004239 (0.0003231, 0.0005247)	-0.01565 (-0.01853, -0.01278)	1.309 (1.286, 1.331)	0.9965
$y = h$	4.242e-05 (2.042e-05, 6.441e-05)	-0.003863 (-0.00607, -0.001656)	-0.2594 (-0.3224, -0.1965)	21.6 (21.12, 22.09)	0.9954

Table 7: Main statistical indicators associated to the three series  $x$ ,  $b$ ,  $s$ ,  $sh$  and  $h$ .

Statistical indicator	$x$	$s$	$b$	$sh$	$h$
Mean $\mu$	0.93	0.83	0.68	0.86	10.48
Variance $\sigma^2$	0.04	0.12	0.29	0.12	43.79
Standard deviation $\sigma$	0.20	0.35	0.54	0.35	6.62
Skewness	-1.01	-1.09	1.18	-0.93	0.04
Kurtosis	-0.55	-0.09	2.07	-0.19	-1.29
Median	1.03	0.96	0.58	0.99	11.63
Max	1.13	1.34	2.78	1.34	21.01
Min	0.51	0.01	0.01	0.01	0.61

associated to BS is convex at high rank and exhibits an inflection point at a middle rank, while the curve related to HC is approximately a straight line.

### 5.3 Empirical distribution approach

Time series are here discussed on the basis of their empirical distributions. As in the case of rank-size analysis, the time dimension is lost but a meaningful analysis of the macroscopic properties of the realizations can be carried out.

The main descriptive statistics are presented in Table 7.

By looking at Table 7, one can immediately argue that the series with social capital – with or without human capital – are much closer to the empirical sample than the series without social capital. Also in this case, it is confirmed that the model with social and human capital together is slightly better than the one with only social capital. Notice the huge deviation between the model with human capital and the original sample. Remarkably, skewness is negative and with very similar values for  $x$ ,  $s$  and  $sh$  while it is positive for  $b$  and  $h$  – with a value larger for the former case rather than for the latter one. Hence, there is an evident violation of the symmetry property of the distributions when social capital does not intervene in the DSGE model. Kurtosis is negative for  $x$ ,  $s$ ,  $sh$  and  $h$  and it is positive with a value close to three for  $b$ . However,  $sh$  and  $s$  are closer to  $x$

than  $h$ . This means that we are in presence of an original sample of platykurtic type – confirmed also for all the considered models with the exclusion of BS – while the case without social capital and/or human capital leads to a leptokurtic distribution. Values of  $x$ ,  $s$  and  $sh$  are much closer to the mean than the one of  $b$  and  $h$  – i.e. they have smaller standard deviations – and  $s$  and  $sh$  show the same value of the standard deviations. Moreover,  $x$ ,  $s$  and  $sh$  seem to span analogous intervals – the same maximum and minimum for  $s$  and  $sh$ , quite the same of  $x$  – while the maximum between  $x$  and  $b$  are noticeably different. In this respect, we also confirm the huge difference between  $h$  and the other considered series.

The distance between the distribution of  $x$  and those of  $b$ ,  $s$ ,  $sh$  and  $h$  has been also measured by using entropy. Such a measure is suitable for our scopes, because it is able to capture the overall features of the distribution of the data under investigation. In this respect, entropy summarize in a unified setting the position and variability indicators given by the descriptive statistics.

The considered entropy is given by:

$$\mathcal{E}(y) = - \sum_{i=1}^n \frac{|y_i|}{\sum_{k=1}^n |y_k|} \cdot \log \left( \frac{|y_i|}{\sum_{k=1}^n |y_k|} \right), \quad (47)$$

where  $y = [y_i]_{i=1, \dots, n}$ . We use formula (47) for the original sample  $y = x$  and when  $y = b, s, sh, h$ . The reference entropy is the one associated to the original sample  $x$ . The model – BS, SC, SHC and HC – which fits the empirical data in a more convincing way is the one whose entropy is closer to the one of  $x$ . The reasoning behind this evidence lies in the thermodynamic definition of entropy, which is nothing but the disorder associated to the series. Basically, the value of the entropy can be associated to the distance of the distribution from the uniform case. This suggests that similar entropies are associated to analogous macroscopic properties of the probabilistic structure of the data, hence leading to similar series.

Results are reported in Table 8.

The comparison between the entropies gives that all the simulated series underestimate the

Table 8: Computation of the entropy for the three series  $x$ ,  $b$  and  $s$ , according to formula (47).

	$x$	$s$	$b$	$sh$	$h$
Entropy	4,15	4,06	3,87	4,07	3,95

reference entropy of the original sample  $x$ . However, the entropy of  $sh$  and  $s$  are much closer to the reference one than the entropy of  $b$  and  $h$ , with  $sh$  slightly closer than  $s$ .

This outcome goes in the same direction of what said by the analysis of the descriptive statistics, hence stating the supremacy of the DSGE model with social capital – with a small predominance of the case with also human capital – in capturing the real data with respect to the benchmark model without social capital and the one with only human capital. In Appendix B, we provide a detailed explanation of how the ISTAT measures TFP and we quantify the contributions of social and human capital to its determination.

## 6 Discussion

Our study provides the first evidence that social capital supports the economic performance in a DSGE framework. This result is reinforced when social capital is coupled with human capital. Several economic mechanisms may explain why the inclusion of social capital allows the model to explain the residual total factor productivity and to fit actual data better. There is evidence that social capital fosters a better allocation of human and financial resources. The mitigation of agency problems typical of a more cooperative and trusting society improves the management of human resources (La Porta et al., 1997; Costa and Kahn, 2003) and lets hiring decisions be driven by the human capital of applicants instead of personal attributes such as blood ties and personal knowledge, which are common surrogates of trustworthiness in low-trusting societies. This mechanism makes investments in human capital more profitable and allows workers to exploit their potential fully, possibly resulting in higher labor productivity (Knack and Keefer, 1997; Guiso et al., 2010; Alesina

et al., 2015). According to several authors, social capital also fosters the accumulation of human capital with a further beneficial effect on labor productivity. For example, since trust enhances access to credit (Karlan, 2005; Feigenberg et al., 2013), enrollment in higher education may be more accessible. People may exploit their networks of contacts to exploit better opportunities for the education of their children (Coleman, 1988). Parents with solid relational skills may create associations advocating for improved teaching at their children's schools (Coleman, 1988). Overall, the empirical literature in economics suggests that societies rich in social capital provide stronger incentives for investing in human capital, making workers more productive.

The higher financial development (Guiso et al., 2004) and improved access to credit (McMillan and Woodruff, 1999; Karlan, 2005; Karlan et al., 2009) connected to social capital also stimulate the entrepreneurial activity possibly conducting to the creation of new firms and a more competitive and efficient allocation of financial resources across firms (Dasgupta, 2001). More dense networks imply a higher probability of repeating economic interactions that raise the importance of reputation. This makes the behavior of agents easier to foresee, reducing monitoring and transaction costs (Nahapiet and Ghoshal, 1998; Antoci et al., 2011b).

The literature has also credited social capital with a beneficial role in reducing litigiousness in industrial relations (Westlund, 2006), fostering knowledge transfer (Inkpen and Tsang, 2005) and the adoption of new technologies (Fafchamps and Minten, 2001), improving search for investment opportunities (Lindner and Strulik, 2014), enhancing the assignment of workers to tasks (Fafchamps, 2011), acquiring competitive capabilities (McEvily and Zaheer, 1999), facilitating the development of industry networks (Walker et al., 1997) and strategic alliances (Koza and Lewin, 1998; Kale et al., 2000).

Overall, higher levels of cooperation (the specific dimension of social capital we measure in our empirical analysis) reinforce trust and trustworthiness and improve the environment in which workers and firms make their investment decisions, being them in human, financial, or physical

capital (Dasgupta, 2009).

Our framework does not allow us to identify which mechanism, among the ones mentioned above, is crucial in making social capital able to improve the fit of the model. Instead, the outcomes of the empirical analysis call for a more profound effort in the retrieval of time-series measures for the various social capital dimensions and the assessment of their role in explaining total factor productivity in a DSGE framework. Social capital, however, is not the only addendum that may improve the model's fit. Other factors could well be missing from the picture, and future research should address their possible role. Technology-skill mismatches can lead to sizable differences in total factor productivity and output per worker (Acemoglu and Zilibotti, 2001). Hall and Jones (1999) document that institutions and government policies, which they call social infrastructure, drive differences in capital accumulation, productivity, and output per worker across nations. Openness to trade (Edwards, 1998), the quality of institutions (Alcala and Ciccone, 2004), and the level of financial intermediaries development (Beck et al., 2000), are also likely to play a role in explaining the total factor productivity, to name a few examples. We should not consider social capital as a substitute for these factors but rather as a complement. While all forms of capital are essential for growth and development, none of them are sufficient in and of themselves (Ostrom, 2000). Seminal literature stresses the complementarity between human and social capital in particular. Bourdieu (1982; 1986) explains that the individuals' ability to invest in social capital crucially depends on their human capital: "The reproduction of social capital presupposes an unceasing effort of sociability, a continuous series of exchanges in which recognition is endlessly affirmed and reaffirmed. This work ... is not profitable or even conceivable unless one invests in it a specific competence (knowledge of which connections are valuable and skills at using them) and an acquired disposition to acquire and maintain this competence" (Bourdieu and Wacquant, 1992: 119). Such knowledge is a form of human capital that contributes to the creation of social capital. In other words, investments in social capital always require human capital in precise forms, and people who invest in human capital



also invest in social capital (Glaeser et al., 2002).

Although many factors may concur in explaining the Solow residual, we are confident our contribution captures the role of social capital explicitly. The time-series measure we employ in the empirical analysis is unlikely to be affected by confounding factors, especially for our specific case study. Blood donation in Italy is supervised by a unique association, the AVIS, which collects the totality of anonymous blood donations and manages a collection center in almost every Italian municipality. The volume of donations has proved to be uncorrelated with indicators of education, public spending for welfare, health expenditure, health conditions, and indicators of the local economic performance across Italian provinces and regions (Guiso et al., 2004).

There are two significant downsides in measuring social capital through blood donation. The first one lies in the lack of time-series of equivalent indicators in other contexts for cross-country or cross-regional comparisons. The most common source of social capital indicators consists of survey data, which provide short series (starting in the 1990s in the best case scenario), with relatively few observation points and not always comparable indicators. The second downside regards the consistency of social capital's operationalization with how the theoretical literature defines the concept. As we explained in sections 2 and 4, blood donation is an "indirect" indicator that proxies one of the possible, but not necessary, outcomes of only one of the social capital's multiple facets. Cooperative behaviors that overcome free-riding problems can likely stem from bridging social capital but may also be hindered by bonding social capital. On the other hand, bridging social capital can lead, but does not necessarily lead, to cooperation depending on the circumstances and the specific goals of the "owners" (Bourdieu, 1982; 1986; Coleman, 1988; 1990). Research reliant upon an outcome of social capital as an indicator of it will necessarily consider social capital to be related to that outcome (Fine, 2001). This approach makes social capital tautologically present wherever an outcome is observed (Portes, 1998; Durlauf, 1999). Following Putnam (1995), the empirical literature in economics has partially dealt with this issue by clarifying that we can only consider as social capital

the features of the social structure that foster cooperation and enable agents to overcome free-riding and rent-seeking problems (e.g., Knack and Keefer, 1997; Guiso et al., 2004; 2010). In other words, economics has substantially used the term social capital to refer to what the political science literature has defined as “bridging” social capital. However, this approach has not been accompanied by a thorough theoretical reflection on social capital’s definition, classification, and possible outcomes in economics. By contrast, empirical studies often end up focusing on significantly different dimensions of social capital, substantially depending on the availability of data, neglecting to clarify the multidimensional nature of the concept and generally giving it a “positive” connotation by definition (Fine, 2001; Wuthnow, 2002; Sabatini, 2007; 2009). Our results must be handled with caution in light of this (still ongoing) debate and the weaknesses inherent in virtually any measurement approach not accounting for every social capital’s facet.

Despite these weaknesses, our study provides a first attempt to explain productivity dynamics through a DSGE framework featuring the role of social capital. Our results suggest a new possible direction in the study of the Solow residual, thus providing a contribution that advances the literature at the intersection between social capital and productivity studies.

## 7 Conclusions

In this paper, we developed a DSGE model with sticky prices to assess the role of social capital in explaining the Solow residual. We dealt with social capital as a productive factor that directly enters a constant returns to scale production function. We estimated, simulated, and dynamically evaluated the model for Italy through Bayesian techniques. We then compared the annual time series for the Solow residual generated by the DSGE model with social capital coupled with human capital, the model with only human capital, and the model without social capital and human capital from 1950 to 2014 with the Italian TFP empirical data in the same sample.

Our empirical test has some limitations that suggest handling results with caution. The time-series nature of the analysis inhibits any intention to establish causal relationships. By construction, the DSGE models aim at simulating the co-movements of the variables in the presence of stochastic shocks. We employ such a methodological property to identify a hierarchy of dynamic correlations between some meaningful specifications, with no intention of empirically ascertaining the causal impact of social capital on productivity. Our blood donation measure captures only one of the multiple facets of social capital, thereby potentially neglecting the concurring role of other dimensions. Overall, the empirical analysis shows that our models with social capital and with social capital coupled with human capital fit the actual pattern of total factor productivity for the period we study better than a standard DSGE model, not featuring the role of social capital. This result is consistent with the many studies crediting social capital with a role in creating a cooperation-friendly environment that helps to solve coordination issues, thereby supporting a better allocation of resources and, more in general, the economic activity.

The take-home message for policymakers is straightforward. Public policy can improve the environment in which agents make transactions and investment decisions in previously unsuspected ways. Nurturing cooperative behavior, social trust, and trustworthiness strengthen a shared resource that has the feature of a public good. Such a shared asset can improve the allocation of factors and their productivity in many ways, as suggested in Section 2.2. Perhaps most importantly, governments and, in general, policymakers should consider that, like the other factors of production, social capital is “fragile” (Antoci et al., 2009b), in that trust and civic spirit can be eroded by the lack of procedural fairness (Rothstein, 2011) and opportunistic and anti-social behaviors (Guiso et al., 2010). If citizens perceive the political process as unfair, the policy outcomes as illegitimate, and public institutions as untrustworthy, they will adapt to the environment by not trusting anyone and behaving accordingly (Frey et al., 2004; Feld and Frey, 2007; Rothstein, 2011). Several authors suggested that agents project the fairness and trustworthiness they perceive in the state onto their fellow citizens, implying

that the efficiency and fairness of institutions are crucial for the preservation of social capital (Frey et al., 2004; Feld and Frey, 2007; van Dijke and Verboon, 2010; Rothstein, 2011; Gobena and van Dijke, 2017; Cerqueti et al., 2019).

Understanding how any proposed policy intervention will affect social cohesion, trust, trustworthiness, the propensity for cooperation and the perceived fairness of institutions is of vital importance since public policy occurs in a social context characterized by a delicate mix of informal organizations, networks, and institutions (Woolcock and Narayan, 2000). It is also critical to invest in bridges between communities and social groups and to contrast discrimination and segregation associated with gender, ethnicity, religion, or socio-economic status (Antoci and Sabatini, 2018). To this end, Woolcock and Narayan (2000) suggest that participatory processes can facilitate social interaction and convergence among stakeholders with diverse interests or identities: “Finding ways and means by which to transcend social divides and build social cohesion and trust is crucial for economic development” (Woolcock and Narayan, p. 242).

Efficiency in the provision of public services, the inclusiveness of institutions, and the accountability of public actors can strengthen the belief that the political process is fair and the policy outcomes legitimate, which could, in turn, further underpin confidence in institutions and social trust. By contrast, exacerbating divisions across social groups, neglecting the efficiency and accountability of public institutions, and carrying out policy measures that the public may perceive as unfair are likely to erode the social capital of the economy (Frey et al., 2004; Feld and Frey, 2007; Rothstein, 2011; Rothstein and Charron, 2018). For example, a tax pardon, which grants immunity for past tax evasions in exchange for a small fee, can be an intelligent fiscal policy in the short term, since it will increase tax revenues without increasing the marginal tax rates, but it might deteriorate the stock of social capital (Guiso et al., 2010).

Our framework cannot shed light on which policy actions can more effectively strengthen, or preserve, the forms of social capital that enhance total factor productivity. Nonetheless, our results

urge public actors to devote to the strengthening of social capital the same attention and effort they usually pay to the accumulation of the other factors of production.

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## Appendix A

### Equilibrium Characterization

#### Households

The (9) is maximized under (2) by using the method of Lagrange multipliers<sup>7</sup>, i.e.:

$$L = \max_{[C_t, N_t, K_t^p, K_t^s]_{t=0}^{\infty}} E \left[ \begin{aligned} & \sum_{t=0}^{\infty} \beta^t \left( \log(C_t) - \frac{N_t^{1+\gamma}}{1+\gamma} \right) + \\ & + \chi_t (R_t^p K_{t-1}^p + R_t^s K_{t-1}^s + W_t N_t - P_t C_t - K_t^p - K_t^s) \end{aligned} \right] \quad (48)$$

where  $\chi_t$  is the dynamic Lagrange multiplier, with the following three necessary conditions:

$$\frac{\partial L}{\partial C_t} : \frac{1}{(C_t) P_t} = \chi_t \quad (49)$$

$$\frac{\partial L}{\partial N_t} : \frac{N_t^\gamma}{W_t} = \chi_t \quad (50)$$

$$\frac{\partial L}{\partial K_t^p} : -\chi_t + \beta E_t [\chi_{t+1} R_t^p] = 0 \quad (51)$$

$$\frac{\partial L}{\partial K_t^s} : -\chi_t + \beta E_t [\chi_{t+1} R_t^s] = 0 \quad (52)$$

where (51) and (52) state that in equilibrium the value of marginal utility of consumption at time  $t$  is equal to the discounted expected value of marginal utility of consumption at time  $t + 1$ .

The following equation is a result of the combination of (49) and (50), i.e.:

$$N_t^\gamma (C_t) = \frac{W_t}{P_t} \quad (53)$$

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<sup>7</sup>The use of dynamic programming technique would produce the same results.



The combination of (49) with (51) and (52) reads as:

$$\beta R_t^p E_t \left[ \left( \frac{C_t}{C_{t+1}} \right) \left( \frac{P_t}{P_{t+1}} \right) \right] = 1 \quad (54)$$

$$\beta R_t^s E_t \left[ \left( \frac{C_t}{C_{t+1}} \right) \left( \frac{P_t}{P_{t+1}} \right) \right] = 1 \quad (55)$$

The previous equations imply the following non arbitrage condition between the gross rates of return

$$R_t^p = R_t^s \quad (56)$$

that in steady state reads as

$$\bar{R}_t^p = \bar{R}_t^s = \frac{1}{\beta} \quad (57)$$

## Firms

Given  $(W_t, R_t^p, R_t^s)_{t=0}^\infty$ , since the representative final producer faces a common price for the productive factors, each firm faces the following problem:

$$\min_{[N_t(j), K_{t-1}^p(j), K_{t-1}^s(j)]_{t=0}^\infty} - (W_t N_t(j) + R_t^p K_{t-1}^p(j) + R_t^s K_{t-1}^s(j)) + \quad (58)$$

$$+ \varphi(j) \left[ \begin{aligned} & A_t [N_t(j)]^\zeta [K_{t-1}^p(j)]^\nu [K_{t-1}^s(j)]^{1-\zeta-\nu} + \\ & + (1 - \delta^p) K_{t-1}^p(j) + \\ & + (1 - \delta^s) K_{t-1}^s(j) - \left( \frac{P_t(j)}{P_t} \right)^{-\epsilon} Y_t \end{aligned} \right] \quad (59)$$

where the Lagrange multiplier  $\varphi(j)$  is associated to the marginal costs.

The problem (58) yields to the following FOCs:

$$W_t = \varphi(j) \left[ \zeta A_t [N_t(j)]^{\zeta-1} [K_{t-1}^p(j)]^\nu [K_{t-1}^s(j)]^{1-\zeta-\nu} \right] \quad (60)$$

$$R_t^p = \varphi(j) \left[ \nu A_t [N_t(j)]^\zeta [K_{t-1}^p(j)]^{\nu-1} [K_{t-1}^s(j)]^{1-\zeta-\nu} + (1 - \delta^p) \right] \quad (61)$$

$$R_t^s = \varphi(j) \left[ \begin{aligned} &(1 - \zeta - \nu) A_t [N_t(j)]^\zeta [K_{t-1}^p(j)]^\nu \times \\ &\times [K_{t-1}^s(j)]^{-\zeta-\nu} + (1 - \delta^s) \end{aligned} \right] \quad (62)$$

from which an expression for the marginal costs  $MC_t$  can be derived

$$MC_t = \zeta^{-\zeta} \nu^{-\nu} (1 - \zeta - \nu)^{-(1-\zeta-\nu)} (W_t)^\zeta (R_t^p)^\nu (R_t^s)^{1-\zeta-\nu} \frac{1}{A_t} \quad (63)$$

## Appendix B

The Italian National Institute of Statistics (ISTAT) measures TFP through a methodology based on economic growth accounting (see e.g., Barro, 1999) and the Tornqvist index (Morrison and Diewert, 1990 and Kohli, 2004). The technology is described by a production function whose inputs are labor and capital. This latter is broken down into three components: non-ICT capital (all the physical capital goods excluding products related to Information and Communication Technologies), ICT capital (capital goods that incorporate Information and Communication Technologies, i.e., hardware, software, and communications equipment) and non-ICT immaterial capital (intellectual property products other than software, i.e., research and development, mineral and original exploration of artistic, literary or entertainment works). The ISTAT measures productive factors as well as gross domestic product on a sectorial basis. The Solow residual of this production function is assumed with Hicks-neutrality, and any adjustment cost is absent. Social capital, intended as a public good resulting from cooperative behaviors, is not explicitly considered in the measures of capital mentioned

above. Nevertheless, our DSGE model incorporating social capital matches Italian TFP data better than a standard DSGE model with only capital and labor.

We interpret this result in light of the evidence that social capital fosters a better allocation of human and financial resources - through the channels summarized in Section 6 - that improves the productivity of the factors of production accounted for in the ISTAT methodology.

By following ISTAT's procedure and using the data generated by our DSGE model, we can measure the contribution of social capital also combined with human capital to the determination of TFP. In particular, the TFP growth rate is given by

$$\ln\left(\frac{A_t}{A_{t-1}}\right) = \ln\left(\frac{Y_t}{Y_{t-1}}\right) - \ln\left(\frac{ID_t}{ID_{t-1}}\right) \quad (64)$$

where

$$ID_t = \varsigma (sn_t + sn_{t-1}) \times \ln\left(\frac{N_t}{N_{t-1}}\right) + \nu (sk_t^p + sk_{t-1}^p) \times \ln\left(\frac{K_t^p}{K_{t-1}^p}\right) + (1 - \varsigma - \nu) (sk_t^s + sk_{t-1}^s) \times \ln\left(\frac{K_t^s}{K_{t-1}^s}\right) \quad (65)$$

is the composite index of inputs' volume (Tornqvist index) and  $sn_t$ ,  $sk_t^p$  and  $sk_t^s$  are the elasticities of GDP concerning labor<sup>8</sup>, private capital, and social capital, which are assumed to be equal to the shares of the cost of each productive factor of nominal GDP, i.e.

$$\begin{aligned} sn_t &= \frac{W_t N_t}{P_t Y_t} \\ sk_t^p &= \frac{R_t K_t^p}{P_t Y_t} \\ sk_t^s &= \frac{W_t K_t^s}{P_t Y_t} \end{aligned}$$

The average contribution of social capital to TFP growth along the period 1950-2014 is equal

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<sup>8</sup>When also human capital is considered in the production function, then the effective labor input takes into account the role of human capital as described in Section 3.

to (64) measured through the model with social capital minus the value of (64) in the model where social capital is absent, whereas the combined contribution of human capital and social capital is measured through (64) in the model where both social and human capital are present minus the value of (64) of the basic model. The numerical results according to our model with the presence of only social capital indicate an average TFP growth for Italy from 1950 to 2014 of 1.15% (the empirical data feature an average value of 1.02%), whereas the model without social capital indicates a TFP growth of 0.7%. When also human capital is introduced the average TFP growth is around 1.20%. Hence, based on our analysis, the contribution of social capital to the TFP growth, can be quantified around 0.45% in the model with only social capital. In the case where both social capital and human capital are present their combined complimentary contribution to TFP growth is around 0.5%.

CRediT author statement

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