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Working Papers SMART - LERECO

# Exploring the effect of crisis on cooperatives: A Bayesian performance analysis of French craftsmen cooperatives

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**Working Paper SMART – LERECO** N°18-07

October 2018

UMR INRA-Agrocampus Ouest **SMART - LERECO**

(Laboratoires d'Etudes et de Recherches en Economie sur les Structures et Marchés Agricoles, Ressources et Territoires)

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# Exploring the effect of crisis on cooperatives: A Bayesian performance analysis of French craftsmen cooperatives

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**Acknowledgements**

*We acknowledge a grant from the Scientific Council of the University of Angers for the project CODESOL. Data access to the Orbis database has been provided thanks to the project "Diversification des métiers des coopératives agricoles et agro-alimentaires" (SHRC Insights Grant), headed by Martine Vézina (HEC Montréal). We are indebted to Angela Cheptea and Laure Latruffe for their insightful suggestions and editorial assistance on a previous version.*

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**Exploring the effect of crisis on cooperatives: A Bayesian performance analysis of French craftsmen cooperatives**

**Abstract**

This paper aims at understanding the economic performance of craftsmen cooperatives during the crisis period. These cooperatives have the distinctive feature of being supply cooperatives. We use an exhaustive dataset for the French craftsmen cooperatives (2004-2014). We estimate Bayesian Translog econometric models in order to underline the impact of the 2008 crisis on these cooperatives. On the one hand, cooperatives' turnover contracts during the crisis, the effect is lower for elder cooperatives and varies across sectors. On the other hand, there is convergence towards the mean for the various generations of cooperatives. Theses findings are robust to alternative econometric specifications.

**Keywords:** Crisis, cooperatives, performance, production function

**JEL Classification:** C11, D22, L25, P13

**Etudier l'effet de la crise sur les coopératives : Une analyse bayésienne de la performance des coopératives artisanales françaises.**

**Résumé**

Cet article propose une analyse de la performance économique des coopératives artisanales pendant la période de crise. Ces coopératives ont comme caractéristiques particulières d'être des coopératives d'approvisionnement. Nous utilisons une base de données exhaustives des coopératives artisanales françaises (2004-2014). Nous estimons des modèles économétriques bayésiens translog afin de mettre en évidence l'impact de la crise sur les coopératives: D'une part la crise a un faible effet négatif sur le chiffre d'affaires, avec un effet atténuant du secteur et de l'âge. D'autre part il y a une convergence à la moyenne pour les différentes générations de coopératives. Ces résultats sont robustes à des spécifications économétriques alternatives.

**Mots-clés:** Crise, coopératives, performance, fonction de production

**Classification JEL:** C11, D22, L25, P13

**Exploring the effect of crisis on cooperatives: A Bayesian performance analysis of French craftsmen cooperatives**

## 1. Introduction

Due to their organization that promotes democracy and transparent management, cooperatives play an important role in building a more balanced economy (Stiglitz, 2009; Birchall, 2013). Hannan (2014) explains that cooperatives "are part of the market economy but possess a multi-dimensionality that enables them to perform in market economies while providing members with a range of tangible and intangible benefits that have the potential to enhance their socio-economic position and voice". The resilience of cooperatives has been challenged during the recent economic crisis (Carini and Costa, 2013; Vieta, 2010).

Identifying the comparative advantages and disadvantages of *member-owned businesses*, Birchall (2013) states that the cooperative model may potentially be stronger than other businesses during economic recession. Several studies show better social and economic performances of cooperatives relative to other businesses (Cheney *et al.*, 2014; Lambru and Petrescu, 2014; Bentivogli and Viviano, 2012; Zamagni, 2012; Costa and Carini, 2016; Carini and Carpita, 2014), but there are counter-examples and the crisis effect may vary by sector and with the market context (Birchall, 2013). According to Nunez-Nickel and Moyano-Fuentes (2004); Simons and Ingram (2003, 2004), agricultural cooperatives and kibbutzim are more sensitive to changes in the regulatory environment, but have a greater ability to adapt to macroeconomic fluctuations. Staber (1992) pointed out that agricultural marketing cooperatives are highly resistant to recessions.

While most of the literature focuses on the agricultural and financial sectors, as well as worker cooperatives, we study here the case of French craftsmen cooperatives, which have the distinctive feature of being supply cooperatives. This paper aims at understanding the economic performance of these cooperatives during crise periods. Particular attention is paid to the age of the cooperative and the differences between sectors of activity. We are particularly interested in the resilience of French craftsmen cooperatives, namely how effective they are at surviving economic recession. We use exhaustive accounting data from the AMADEUS data base over the years 2004-2014. We show that the negative effect of the crisis depends on the sector and the date of creation of the cooperative. Economies of scale, estimated with elasticities, also present differences depending on the sector, the experience, and the size of craftsmen cooperatives. These analyses are important for public policy design since they indicate whether cooperatives need support on investment or labor expenses to improve their resilience. We use Bayesian analysis to compare different models underlying the impact of cooperatives characteristics, such as their location. State-of-the-art Bayesian regression techniques allow us to perform sensitivity

analyses, robustness checks (following Leamer (1983, 1985)), and to ensure the transparency of results. The present paper is the first study addressing this issue for craftsmen cooperatives, a type of cooperatives largely understudied in the literature.

The remainder of the article is organized as follows. The next section describes briefly the literature on the growth and resilience of cooperatives. Section 3 presents the empirical analysis, section 4 – the context and the data. In section 5, we report our main results, that show a low impact of the crisis on the economic performance of cooperatives, which diminishes with age and is smaller in some sectors, and a convergence toward the mean of effects specific to various generations of cooperatives. Alternative estimations and robustness checks are reported in appendix A. Finally, in section 6 we discuss the implications of our empirical findings.

## 2. Growth and resilience of cooperatives

It is interesting to note that the literature on craftsmen cooperatives in developed economies is sparse, while at the same time there is an extensive literature on the benefits of horizontal cooperation between SME (Small and Medium Enterprises) (Villa and Bruno, 2012). Ohnemus (1994) provides some empirical evidence on plumbing cooperatives in the USA; Lee and Mulford (1990) andRawwas and Iyer (2013) document the activity of small business cooperatives in the Japanese retail and wholesale sector. In the context of transitional economies, cooperation may be a convenient strategy for small businesses to survive economy transformation and shocks (Cordell, 1993; Surubaru, 2012). Richomme (2001) and Lapayre *et al.* (2016) study various cases of French craftsmen cooperatives in the construction sector. Auvolat (2008) provides a comprehensive overview of the development of craftsmen cooperatives in France.

Supply cooperatives, that provide their members with intermediate inputs, emerged when investor-owned firms had a substantial monopoly power over small business enterprises (including farmers) in the supply of these inputs (Mikami, 2003). According to Rawwas and Iyer (2013) and Richomme (2001), these cooperatives have established trust among members, which has improved their overall performance.

One of the main objectives of the cooperative is social performance. Therefore, the way to measure the economic performance of cooperatives is subject to debate (Carini and Costa, 2013). Soboh *et al.* (2009) review the empirical studies on the performance of agricultural marketing cooperatives in different industries and countries, and list the employed performance measurements (pp. 458-459). They state that due to the inaccessibility of data, empirical studies failed to address globally all cooperatives' objectives, as well as to represent stakeholders' performance. The empirical literature uses mostly financial ratios, mathematical and statistical tools, and surveys to evaluate cooperatives' efficiency.[1] The economic performance of cooperatives

[1]Table A1 of appendix A.2, lists the variables and ratios used in recent works to apprehend, measure the

can be measured by comparing their turnover, total assets, profits, raw materials, output, or sales – in levels or in terms of evolution over a specific time period – against other firms (Carini and Carpita, 2014; Costa and Carini, 2016; Delboni and Reggiani, 2013; Jones and Mygind, 2002; Lambru and Petrescu, 2014; Soboh *et al.*, 2012, 2014). Many studies measure social performance using employment data on the number of workers (Jones and Mygind, 2002; Lambru and Petrescu, 2014; Delboni and Reggiani, 2013; Costa and Carini, 2016), on the number of full-time equivalent workers (Arando *et al.*, 2015), or on the number of employees by types of work contract (Carini and Carpita, 2014). Financial ratios characterize the performance of cooperatives by evaluating the efficiency of assets, the ability to invest or to face shocks. Soboh *et al.* (2011) uses financial ratios to show that while cooperatives are less profitable than investor-owned firms, they operate more efficiently and have a stronger financial position. Regarding marginal productivity and elasticities, Liu and Bailey (2013) found that large cooperatives have an advantage over small cooperatives in terms of economies of scale. Soboh *et al.* (2014) observe decreasing returns to scale for dairy processing cooperatives, as well as for investor-owned firms. Similarly, Fakhfakh *et al.* (2013) found that labor-managed firms use their inputs as efficiently as other firms.

This literature globally shows that cooperatives demonstrate a greater resilience than others types of enterprises. However, cooperatives may be less profitable than investor-owned firms, but operate more efficiently, present a stronger financial position (Soboh *et al.*, 2012, 2014), and have a stabilizing effect on employment with respect to shocks (Alves *et al.*, 2016; Delboni and Reggiani, 2013). The global characteristics of cooperatives' organization are the source of their resilience, since cooperative members join their resources to build collective networks and skills, improve their capability to innovate, and attract government funding (Borda-Rodriguez *et al.*, 2016). However, the cooperatives' resilience capacity differs across the sector of activity, the size and the geographic location of the cooperative (Costa and Carini, 2016; Fakhfakh *et al.*, 2013; Soboh *et al.*, 2014; Borda-Rodriguez *et al.*, 2016).

## 3. Empirical strategy: A Bayesian econometric approach to production function modelling

We estimate a classical translog model, which is a more flexible production function than its special case (cobb-douglas). This production function has already been used for cooperatives: see Fakhfakh *et al.* (2013) for an application to French worker cooperatives, Maietta and Sena (2008, 2010) for an application to Italian producers cooperatives, or Soboh *et al.* (2012) for an application to dairy cooperatives.

For a cooperative $i$ observed at a period $t$, a panel-data translog model is:

multidimensional performance of cooperatives.

$$\ln(O_{i;t}) = \alpha_i + \sum_{k=1}^{K} \beta_k \ln I_{i,t}^k + \sum_{k=1}^{K} \beta_{kk} (\ln I_{i,t}^k)^2 + \sum_{k=1 \neq h}^{K} \beta_{kht} \ln I_{i,t}^k \ln I_{i,t}^h + \mu_i + \epsilon_{i,t} \tag{1}$$

where $O$ is the cooperative's output, $I$ is a vector of $k$ input variables, $\mu$ and $\epsilon$ are errors term, with $\mu \sim N(0, \sigma)$ and $\epsilon \sim N(0, \phi)$.

As we suspect heterogeneous effects of crisis by age and sector, our benchmark model is:

$$\begin{gathered} \ln(O_{i;t}) = \alpha_i + \sum_{k=1}^{K} \beta_k \ln I_{i,t}^k + \sum_{k=1}^{K} \beta_{kk} (\ln I_{i,t}^k)^2 + \sum_{k=1 \neq h}^{K} \beta_{kht} \ln I_{i,t}^k \ln I_{i,t}^h + \\ \gamma_1 A_{i,t} + \gamma_2 C_{i,t} + \gamma_3 S_{i,t} + \gamma_4 A.C_{i,t} + \gamma_5 A.S_{i,t} + \gamma_6 C.S_{i,t} + \gamma_7 A.C.S_{i,t} + \mu_i + \epsilon_{i,t} \end{gathered} \tag{2}$$

with $A$, $C$ and $S$ standing for age, crisis, and, respectively, sector.

There is no consensus in the literature regarding the objective function of a cooperative. It can be, for example, the utility or welfare of its members (as in Fulton and Giannakas (2001) or Giannakas and Fulton (2005)), or its profits with a patronage refunds payed to its members (as in Agbo *et al.* (2015)). Soboh *et al.* (2009) provide a more comprehensive review on the objective functions of cooperatives. As highlighted by the Conceptual Framework for Statistics on Cooperatives of the ILO (International Labor Organization) (Bouchard *et al.*, 2017), value added and profits have to be used with caution for marketing and supply cooperatives. For a marketing cooperative, producers' income is part of value added (patronage refunds or interests on social shares), on one the hand, and reflect a decrease in value added (payments for raw materials), on the other hand. For a supply cooperative, producer expenses may reflected different price strategies (combinations of price and patronage refunds). In our case, the available output is the cooperative's total turnover. The logarithm of total turnover is usually used in the literature as an acceptable proxy for economic performance (Fakhfakh *et al.*, 2013; Maietta and Sena, 2008, 2010; Gagliardi, 2009; Soboh *et al.*, 2012). Interviews with directors suggest also that patronage refunds and price strategies are relatively similar across all craftsmen cooperatives.

We choose a Bayesian modelling approach that takes into account uncertainty, sparse data, and moderate-sized sample (Gelman *et al.*, 2014a), especially with weakly informative priors (Gelman *et al.*, 2008). In order to conduct Bayesian model selection, we use the WAIC (Widely Applicable Information Criterion) and LOO (Leave-One-Out cross-validation) implemented in Vehtari *et al.* (2017). WAIC and LOO (Gelman *et al.*, 2014b) are fully Bayesian methods for estimating pointwise out-of-sample prediction accuracy from a fitted Bayesian model, using the log-likelihood evaluated at the posterior simulations of the parameter values.

Estimations are conducted with package Brms for R (Bürkner, 2017), that called Stan, a C++ program performing Bayesian inference and optimization (Gelman *et al.*, 2015).

## 4. Context and data: Cooperatives in a craft industry under pressure

Since the 2008 crisis, the French craft industry faces a sharp slowdown. This business sector being directly dependent on public and private consumption, the consequences of the economic breakdown came into effect quickly and dramatically. Figure 1 shows the evolution of craft activity since 2009 (in quarterly dynamics). Figure 2 show the evolution of the number of employees of small businesses (less than 20 employees) in two crafts sectors (carpentry and plumbing) that we analyse in this paper.

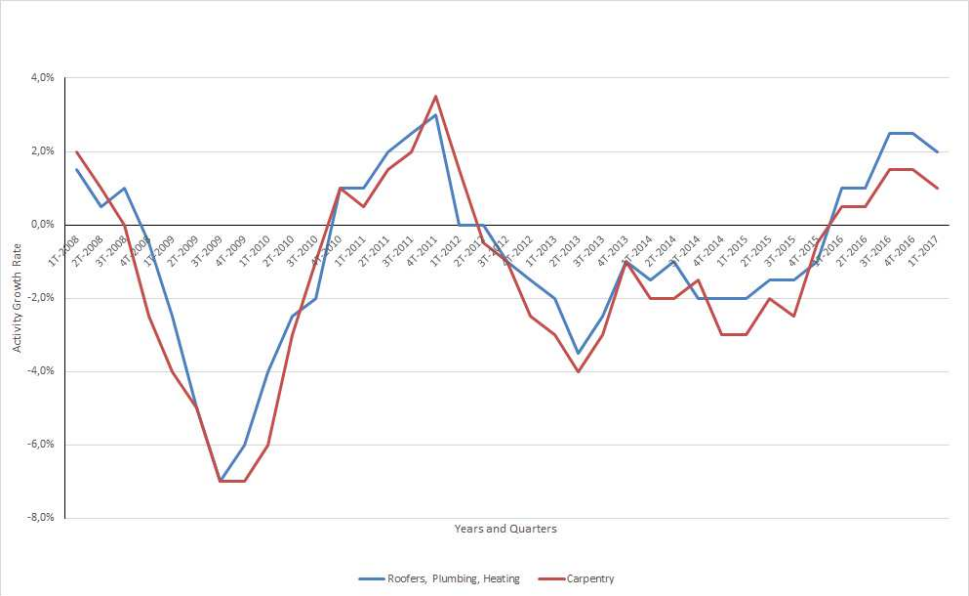
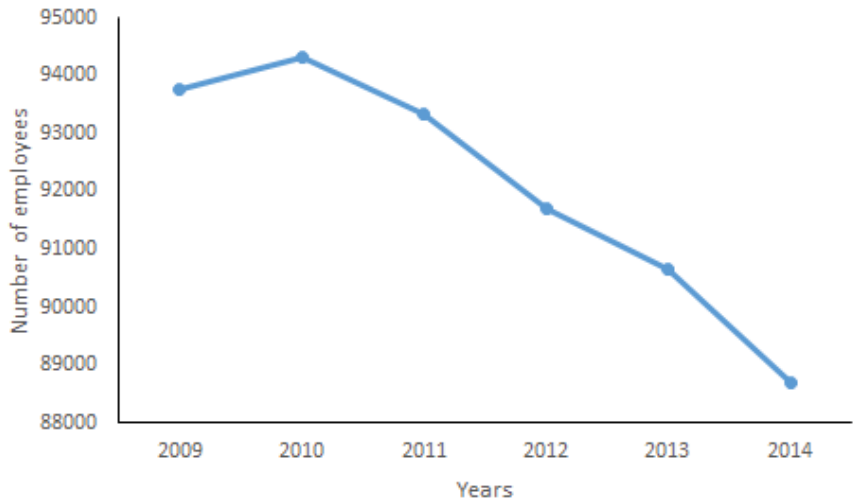



Figure 1: Activity growth rate, relative to the past quarter

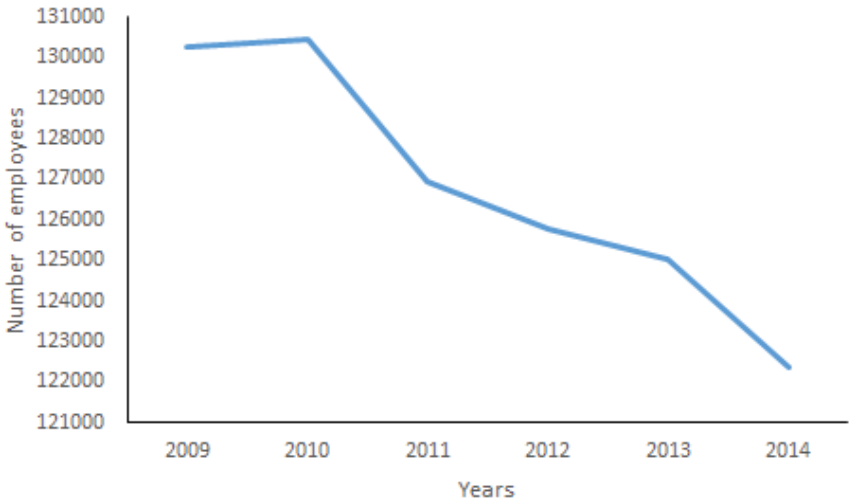
*Source: CAPEB*

The impact of the economic crisis appears dramatically in Figures 1 and 2. The business activity of craftsmen contracted, similarly to sector employment. In this context, we can ask if a craftsmen supply cooperative may be a reliable and efficient backstop for the members, as it was the case in transition economies (Surubaru, 2012). If craftsmen cooperatives are effective at surviving economic recession, it appears necessary to understand how this resilience effect is working.

We use an exhaustive dataset covering the 49 French craftsmen supply cooperatives (2004-2014), based on a matching of the directory of craftsmen cooperatives provided by the French Federation of Craftsmen Cooperatives and accounting data from the Amadeus/Orbis database.




(a) Carpentry sector




(b) Roofing, plumbing, and heating sector

Figure 2: Number of employees

*Source: CAPEB, ACOSS 2014, corrected data, trainees and interns not included. Businesses with 20 employees or less.*

Orbis is often viewed as an inaccurate, imprecise, unreliable source because of missing data. To address this issue, some authors use listwise deletion methods (complete case analysis) (Soboh *et al.*, 2011, 2012; Hirsch and Hartmann, 2014), that may produce biased estimates when there are informative drop-outs or missing not at random data (Seiler and Heumann, 2013).

Our analysis is not affected by these problems, although no comparison can be made with for-profit enterprises, for which no exhaustive directory is available. Note that all cooperatives have survived over the entire period, suggesting the absence of informative drop-outs and of survivor bias. The data was also checked for reliability and consistency using qualitative data responses obtained from ten interviews with cooperatives' directors.

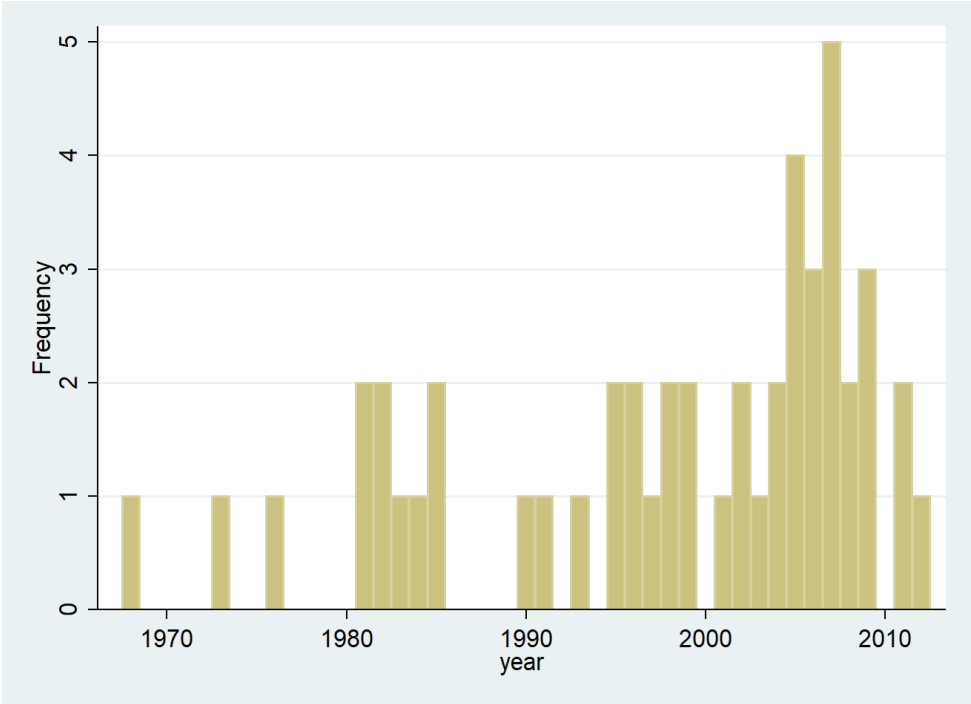



Figure 3: Number of cooperatives created by year

*Source: Authors' computations.*

The population of interest are the 49 craftsmen supply cooperatives. To increase the homogeneity of the analysed population of cooperatives, we do not take into account the bargaining and marketing cooperatives that exist in this industry. As shown in Figure 3, cooperatives in our panel were created between 1968 and 2002.[2] Accordingly, we have a balanced longitudinal database of our population between 2004 and 2014. A first interesting observation is that all the cooperatives survive during that period.

The average size of cooperatives is 8 to 10 millions € of turnover, with an average number of 100 members. These cooperatives are under the umbrella of ORCAB, the French Union of Craftsmen Cooperatives, an association created in 1990. Since its transformation into a consortium of cooperatives (a second level cooperative) in 1998, ORCAB plays an active role in the development of the network: creation of a collective brand, promotion of collective intangible investment, development of human capital (training of elected members), providing (by purchasing) the cooperatives with commodities to sell to their members and, furthermore, support the creation of new cooperatives in a more "top-down" approach (Billaudeau *et al.*, 2016). The success of this cooperation among cooperatives (Fici, 2015) lead to the creation of new cooperatives (half of cooperatives were created since 2000).

As discussed above, the dependent variables is the turnover (T), expressed in thousands of euros. The independent (explanatory) variables are, on one hand, the traditional inputs of the

[2]The 50th cooperative created in 2014 was not included in our study.

production function: intermediate consumption (IC), labor expenditure (LE) (including wages, salaries, and benefits), intangible assets (IA), and tangible assets (TA). All these variables are log-transformed. On the other hand, the following control variables are available: age (A), sector (S) and crisis (C). A is the age of the cooperative in years. Sector is a dummy variable, equal to 1 for the carpentry sector (nace4673: "Wholesale of wood, construction materials and sanitary equipment") and 0 for the plumbing sector (nace4674: "Wholesale of hardware, plumbing and heating equipment and supplies"). The crisis variable is defined as a dummy. It takes the value 1 for 2008 and the following years and 0 otherwise.[3] Note that we can not use the number of members as an explanatory variable, as we have this information only the first year. As revealed by responses to interviews, there is a strong correlation between the number of a cooperative's members and its turnover, as the population of craftsmen is relatively homogeneous. Tables A2 and A3 of appendix A.2 resume the descriptive statistics of the dependent and independent variables.

## 5. Results

### 5.1. Estimation

With weakly informative priors (Cauchy (0, 2.5) prior distributions, Gelman *et al.* (2008)), our benchmark model is based on 4 chains of 5,000 iterations, of which the first 2,500 are used as a warm-up to calibrate the sample, leading to a total of 10,000 posterior samples. Estimations along with all relevant tests are available on the website: `https://cooperatives.shinyapps.io/craftsmen/`. The Stan algorithm is highly efficient as the autocorrelation of Markov chains disappears quickly (see Figure 4 for the estimation of the log Posterior). We have, therefore, a large effective sample size (ESS).

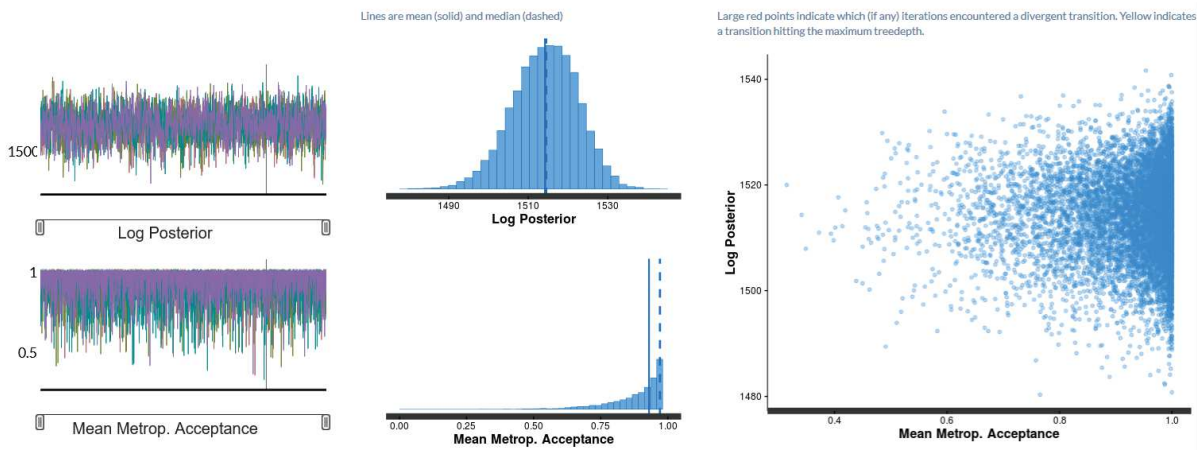



Figure 4: Diagnostics of the Log Posterior

[3]The use of alternative measures for crisis lead to similar results. These estimations can be provided upon request.

The estimation of the benchmark model is reported in Table 1. We estimate also alternative specifications as robustness checks. These estimations account for alternative functional forms, endogeneity, unobserved heterogeneity, and spatial correlations, and are reported in Tables A4 to A13 of appendix A.3. There is a negative effect of the crisis on performance. Note also that this effect decreases with cooperatives' age and is smaller in the carpentry sector. This result is revealed by the positive effect of the interaction of the crisis dummy with cooperative's age and with the carpentry sector dummy. The magnitude of the coefficient of a dummy variable cannot be interpreted directly in a regression with a log dependent variable as a semi-elasticity (Van Garderen and Shah, 2002). Therefore, we choose to interpret these estimates using various prediction of the economies of scale (see section 5.2).

Table 1: Results for the benchmark regression

| Parameter | ESS | mean | s.d. | s.e. mean | 2.5% | 50% | 97.5% |
|---|---|---|---|---|---|---|---|
| $\ln IC$ | 3293 | 1.235 | 0.067 | 0.001 | 1.103 | 1.235 | 1.364 |
| $\ln LE$ | 2773 | -0.165 | 0.060 | 0.001 | -0.280 | -0.165 | -0.048 |
| $\ln IA$ | 4934 | -0.028 | 0.012 | 0.000 | -0.052 | -0.028 | -0.005 |
| $\ln TA$ | 4491 | 0.003 | 0.016 | 0.000 | -0.029 | 0.003 | 0.035 |
| $\ln IC^2$ | 2600 | -0.039 | 0.011 | 0.000 | -0.060 | -0.039 | -0.018 |
| $\ln LE^2$ | 3196 | -0.013 | 0.011 | 0.000 | -0.034 | -0.013 | 0.008 |
| $\ln IA^2$ | 10000 | 0.001 | 0.001 | 0.000 | -0.000 | 0.001 | 0.002 |
| $\ln TA^2$ | 6544 | 0.002 | 0.001 | 0.000 | 0.000 | 0.002 | 0.003 |
| $\ln IC \times \ln LE$ | 2701 | 0.053 | 0.021 | 0.000 | 0.012 | 0.054 | 0.094 |
| $\ln IC \times \ln IA$ | 3548 | 0.004 | 0.003 | 0.000 | -0.003 | 0.004 | 0.011 |
| $\ln IC \times \ln TA$ | 4369 | 0.006 | 0.004 | 0.000 | -0.003 | 0.006 | 0.014 |
| $\ln LE \times \ln IA$ | 4263 | 0.000 | 0.003 | 0.000 | -0.006 | 0.000 | 0.007 |
| $\ln LE \times \ln TA$ | 5223 | -0.011 | 0.004 | 0.000 | -0.018 | -0.011 | -0.004 |
| $\ln IA \times \ln TA$ | 10000 | -0.002 | 0.001 | 0.000 | -0.004 | -0.002 | -0.001 |
| S (carpentry sector) | 2564 | -0.033 | 0.008 | 0.000 | -0.050 | -0.033 | -0.017 |
| C (crisis: 2008-2014) | 5210 | -0.018 | 0.005 | 0.000 | -0.027 | -0.018 | -0.008 |
| A (cooperative age) | 4285 | -0.001 | 0.000 | 0.000 | -0.002 | -0.001 | -0.000 |
| $S \times C$ | 4937 | 0.019 | 0.007 | 0.000 | 0.006 | 0.019 | 0.032 |
| $S \times A$ | 4214 | 0.001 | 0.001 | 0.000 | 0.000 | 0.001 | 0.002 |
| $C \times A$ | 5849 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| $S \times C \times A$ | 5758 | -0.001 | 0.000 | 0.000 | -0.002 | -0.001 | -0.000 |
| Constant | 5370 | -0.190 | 0.150 | 0.002 | -0.482 | -0.189 | 0.107 |
| $\phi$ | 2597 | 0.014 | 0.002 | 0.000 | 0.011 | 0.014 | 0.019 |
| $\sigma$ | 10000 | 0.014 | 0.001 | 0.000 | 0.013 | 0.014 | 0.016 |

*Note: ESS: Effective Sample Size, s.d.: standard deviation, s.e. mean: standard error of the mean*

### 5.2. Economies of scale before and after the crisis

Economies of scale and elasticites may be calculated at the mean, the median, or at various representative values (see (Kumbhakar *et al.*, 2015)). We estimate additional models on distinct subsets of the population (before and after the crisis).

In Table 2 we report the mean using a Bayesian test, which is just the posterior probability under the hypothesis against its alternative (Gelman *et al.*, 2014a). Economies of scale are equal to 1.66, with a high contribution of intermediate consumption (1.52) and a non significant effect of assets. This estimation is higher than in previous studies on cooperatives. For example, Maietta and Sena (2008) found constant economies of scale and an elasticity of intermediate consumption equal to 0.82 for producer cooperatives. The economies of scale are decreasing (0.62) in the case of European dairy cooperatives (Soboh *et al.*, 2014). Finally, we can see that the economies of scale decreased dramatically after the crisis.

Table 2: Economies of scale and elasticies

| | Full sample | | Before the crisis | | After the crisis | |
|---|---|---|---|---|---|---|
| | estimates | s.e. | estimates | s.e. | estimates | s.e. |
| *Elasticities* | | | | | | |
| IC (Intermediary Consumption) | 1.520 | 0.125 | 1.988 | 0.199 | 0.807 | 0.240 |
| LE (Labor Expenditure) | 0.153 | 0.068 | 0.325 | 0.114 | -0.106 | 0.119 |
| IA (Intangible Assets) | -0.002 | 0.001 | -0.002 | 0.003 | 0.000 | 0.001 |
| TA (Tangible Assets) | -0.013 | 0.005 | -0.033 | 0.009 | -0.009 | 0.006 |
| *Economies of Scale* | 1.658 | 0.173 | 2.278 | 0.276 | 0.691 | 0.324 |

In Table 3, we estimate the impact of the 2008 crisis on performance for cooperatives of different ages from the two sectors, with other independent variables fixed at the mean. The marginal impact of crisis is relatively low in all cases, suggesting a high resilience of cooperatives during crise periods. Carpentry sector cooperatives suffer less from the crisis than plumbing cooperatives.

Although the impact of the crisis is small, we note that younger cooperatives seem to be more affected than their older counterparts (Table 2). Accordingly, there is a *convergence towards the mean* for cooperatives of different age during the crisis, as illustrated in Figure 5, where we report the predictions by cooperatives' age and sector of activity. This result holds especially for cooperatives from the plumbing sector. As discussed in section 5.1, this empirical finding may be linked to the different dynamic of the creation of various generations of cooperatives.

Table 3: Impact of age, sector and crisis on cooperatives' performance

| | | Plumbing sector | | | | Carpentry sector | | | |
|---|---|---|---|---|---|---|---|---|---|
| Age of the cooperative | C | Median | 5 % quantile | 90 % quantile | Crisis impact | Median | 5 % quantile | 90 % quantile | Crisis impact |
| $\bar{A}$ - 1 s.d. | 0 | 8901.78 | 8664.97 | 9093.35 | ref | 8475.67 | 8255.52 | 8649.59 | ref |
| $\bar{A}$ - 1 s.d. | 1 | 8678.04 | 8443.75 | 8865.29 | -2.51% | 8614.31 | 8393.45 | 8784.08 | 1.64% |
| $\bar{A}$ - 5 years | 0 | 8892.85 | 8660.34 | 9075.85 | ref | 8530.59 | 8316.58 | 8698.38 | ref |
| $\bar{A}$ - 5 years | 1 | 8644.04 | 8416.32 | 8827.25 | -2.80% | 8565.81 | 8339.01 | 8748.46 | 0.41% |
| $\bar{A}$ | 0 | 8703.81 | 8454.96 | 8900.80 | ref | 8598.14 | 8375.89 | 8774.44 | ref |
| $\bar{A}$ | 1 | 8737.06 | 8494.64 | 8933.13 | 0.38% | 8546.02 | 8319.15 | 8731.88 | -0.61% |
| $\bar{A}$ + 5 years | 0 | 8590.13 | 8369.55 | 8764.89 | ref | 8422.87 | 8211.38 | 8593.06 | ref |
| $\bar{A}$ + 5 years | 1 | 8819.45 | 8585.79 | 9005.92 | 2.67% | 8719.16 | 8490.55 | 8893.89 | 3.52% |
| $\bar{A}$ + 1 s.d. | 0 | 8515.21 | 8289.49 | 8687.31 | ref | 8538.79 | 8289.25 | 8732.44 | ref |
| $\bar{A}$ + 1 s.d. | 1 | 8710.58 | 8473.60 | 8902.60 | 2.29% | 8548.10 | 8326.74 | 8725.33 | 0.11% |

*Note: C=1 denotes the crisis period (2008-2014), 1 s.d. is one standard deviation of cooperatives' age. Cooperatives' performance is measured by their turnover in K €.*

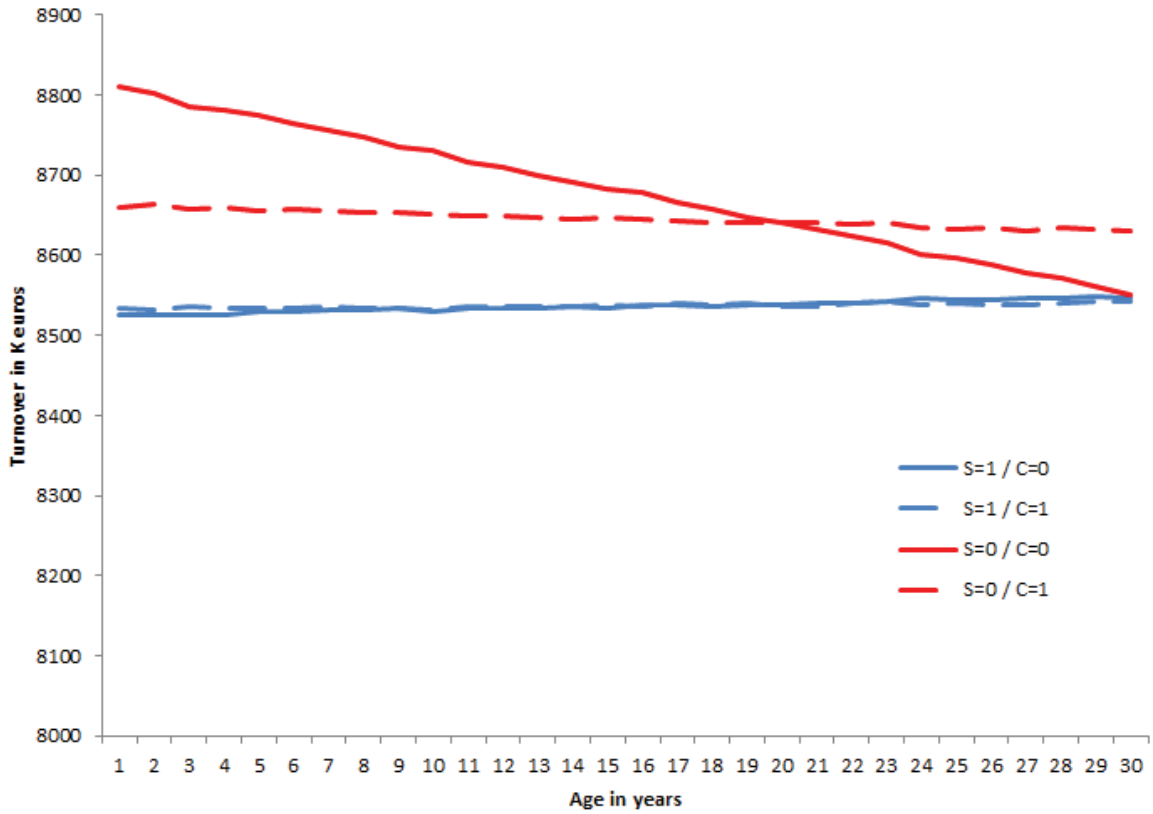



Figure 5: Marginal effect of the crisis on cooperatives' performance, by age and sector

## 6. Discussion and conclusion

Using an exhaustive database, we underline the presence of high economies of scale for the craftsmen cooperatives. Regarding agricultural cooperatives (e.g. Liu and Bailey (2013); Soboh *et al.* (2014)), the magnitude of the returns to scale show that the best strategy to improve the cooperative's competitive position is to increase its size. We observe a weak growth and a strong resilience of craftsmen cooperatives, which questions the alleged inexorable trade-off between democracy and efficiency (Jones and Kalmi, 2012). Previous studies on cooperatives find a decreasing relationship between size and social capital (Nilsson *et al.*, 2012; Feng *et al.*, 2016). This suggests that in large cooperatives profits from economies of scale and scope may be outweighed by weak democracy governance, widespread free-riding and loss of solidarity. Craftsmen cooperatives, as small grassroots organizations, seem to be the first step of growth described by Nilsson *et al.* (2012), where larger size increases economic performance without drain of social capital.

According to Malikov *et al.* (2017), the incentive to grow in size may be fueled not only by present economies of scale, but also by economies of diversification. Economies of diversification especially concern cooperatives that are not for profit maximizers, but rather seek to maximize service provision (in terms of quantity, price, and variety) to their members. As cooperatives are able to secure the demand for a more diversified scope of services, larger cooperative naturally have a higher incentive to grow in order to capitalize on economies of diversification.

We investigate how the 2008 crisis affected the French cooperatives in the carpentry and plumbing sectors. We find that, during the crisis the decrease in cooperatives' turnover was smaller in the carpentry sector. This points to a higher resilience of cooperatives from this sector in comparison to other components of the social economy (Bouchard and Rousselière, 2016; Pape *et al.*, 2016). Bouchard and Rousselière (2016) highlights a split in the population of the Montreal social economy between a component characterized by low growth and low hazard and a component with high growth and high hazard. According to our results, craftsmen cooperatives seem to belong to the former type.

We also underline a convergence effect or *a regression toward the mean*, but of a different nature than the one highlighted in Hart (2000). Young craftsmen cooperatives have a higher turnover than the older ones, but during the crisis they face a stronger decrease in income. This suggests that older cooperatives have a higher capacity to adapt to a changing economic context. They benefit more from economies of learning, while younger cooperatives may face the *liability of newness* due to their immature social organization (Brüderl and Schusseler, 1990). This finding is in line with the heterogenous responses towards the crisis suggesting by the theoretical literature on SME (Cucculelli and Peruzzi, 2018).

An explanation based on the concept of commitment can also be provided. Commitment is defined by Fulton (1999) and Fulton and Giannakas (2001) as the preference of cooperative members to patronize a cooperative even when the cooperative's price or service is not as good as that provided by an investor-owned firm. Therefore, member commitment is "a sort of glue that allows membership and business volume to be maintained even as trade becomes more fluid and barriers to reorganization are broken down" (Fulton, 1999, p. 418). Younger cooperatives were created from scratch in a "top-down" way (with the support of the federation which tries to develop the cooperative system) (Auvolat, 2008; Billaudeau *et al.*, 2016). Because of their weaker link with their members, they may suffer more from the crisis. The few empirical papers describing "top-down cooperatives" provide mixed evidence on this issue (Kurakin and Visser, 2017). On the other hand, older cooperatives (developed before the federation) were created in a "bottom-up" manner at grass-root level. Their members have a deeper commitment, which may explain not only why they suffer less during the crisis, but also why they continue to growth. Commitment acts as a *glue* and determines members to be more supportive of their cooperative, or to get more involved in its governance during an economic crisis. Cechin *et al.* (2013) explain how democracy improves commitment, while control, monitoring, and increased formalization of agreements negatively affect members' commitment and the cooperative's performance.

Furthermore, craftsmen cooperatives differ from the agricultural ones from the point of view of the business model adopted by their members. Auvolat (2008) explains that craftsmen face an individual and local demand, and that their economic performance is less related to suppliers than in the case of farmers. Another distinctive feature of craftsmen is their suspicion of democracy with delegation, the rejection of gigantism and depersonalization. If craftsmen cooperatives, especially the oldest ones, choose not to grow in spite of the important economies of scale they could achieve, it may be due to the fact that members consider commitment and democracy more important for their performance than economic efficiency. Billaudeau *et al.* (2016), presenting a special case of a French craftsmen cooperative, demonstrated that this type of governance, emphasizing strong relationships and trust between the members and the cooperative and among members, leads to a success adaptation in a crisis period. Moreover, the optimal size of the cooperative may be different for craftsmen and farmers, as the competition between members is not of the same nature. Craftsmen face a local demand and the competitive advantage may consist of workers' know-how, while farmers may face a global market with a competition based on quantity and global prices (in which they may cooperate) and a local market (in which they compete) (Agbo *et al.*, 2015). Finally, the need of craftsmen for direct democracy and autonomy, coupled with commitment as a competitive advantage brought to the cooperative, lead to a special strategy. Craftsmen cooperatives follow the "low growth, low hazard" model in spite of large economies of scale and of our results proving them efficient during crises.

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# A. Appendix

## A.1. Measures of cooperatives' performance

Table A1: Measures of cooperatives' performance

| Study | Economic dimensions | Employment dimensions | Financial ratios | Survey | Sector |
|---|---|---|---|---|---|
| Arando *et al.* (2015) | Real sales of stores | Full-time equivalent workers | Worker cooperatives (Eroki and Gespa stores) | | |
| | Market index of the area served by store | Employee attitude index | | | |
| Carini and Carpita (2014) | Turnover | Employees by type of contract | | Survey: | Industry |
| | Profits | Temporary workers | | Investments internationalization | |
| | | Changes in employment by sector of activity | | Innovation and RD | |
| | | Forecast about employment | | | |
| Costa and Carini (2016) | Turnover | Permanent and fixed-term employees | Turnover/Operating Cost | Multiple Factor Analysis | Social Cooperatives |
| | Total Assets | Employees per coop | Profit (loss) / Turnover | | |
| | | | Equity/Total Assets | | |
| | | | Fixed Assets/Total Assets | | |
| Delboni and Reggiani (2013) | Sales | Employment | | | Production Cooperatives |
| | Profits | | | | Focus on constructions industry |
| | Equity | | | | |

*(Continued from previous page)*

| Study | Economic dimensions | Employment dimensions | Financial ratios | Survey | Sector |
|---|---|---|---|---|---|
| Fakhfakh *et al.* (2013) | Value-Added of Firm | | Returns to Scale | | Workers Cooperatives |
| Jones and Mygind (2002) | Profits | Employment No of workers | Elasticity of output with respect to capital and labor | | 660 Estonian Firms (by ownership) |
| | Sales<br>Assets<br>Output | | | | |
| Lambru and Petrescu (2014) | Income | Employees | Worker Cooperative in profit | Number of Coop | Workers Cooperatives |
| | Surplus | | | Numbers of Members | |
| | Deficit | | | | |
| Liu and Bailey (2013) | | | Growth rate (year-over-year growth in the cooperative's assets)<br>Economies of scale | | |
| Nunez-Nickel and Moyano-Fuentes (2004) | | | | Firm Failure | Agricultural Cooperatives (Olive oil) |
| Soboh *et al.* (2011) | | | Profit before interest and taxes / total assets<br>Material cost / Total asset<br>Total debt / total asset<br>Long-term debt / total equity | | Dairy Firms |

*(Continued from previous page)*

| Study | Economic dimensions | Employment dimensions | Financial ratios | Survey | Sector |
|---|---|---|---|---|---|
| | | | Currents assets / current liabilities<br>Turnover / fixed assets<br>Turnover / inventories<br>[NonissuedEquity(y+1)-NonissuedEquity(y)] / NonissuedEquity(y) | | |
| Soboh *et al.* (2012) | Total Turnover<br>Fixed Assets<br>Raw Materials<br>Labour | | | | Dairy Processing Firms |
| Soboh *et al.* (2014) | Total Turnover<br>Output<br>Fixed Assets<br>Raw Materials<br>Labor | | Efficiency relative to production frontiers<br>Elasticity of scale | | Dairy Cooperatives |

## A.2. Descriptive statistics

Table A2: Summary statistics

| Variable | Description | Mean | Std. Dev. | N |
|---|---|---|---|---|
| $\ln T$ | ln Turnover | 9.061 | 0.974 | 490 |
| $\ln IC$ | ln Intermediate Consumption | 8.855 | 0.978 | 490 |
| $\ln LE$ | ln Labor Expenditure | 6.68 | 0.98 | 490 |
| $\ln IA$ | ln Intangible Assets | 1.378 | 1.422 | 490 |
| $\ln TA$ | ln Tangible Assets | 6.182 | 1.838 | 490 |
| C | crisis dummy: =1 for 2008-2014; =0 for 2004-2007 | 0.594 | 0.492 | 490 |
| A | cooperative age (in years) | 12.622 | 11.536 | 490 |
| latitude | | 46.994 | 1.474 | 490 |
| longitude | | 0.817 | 2.655 | 490 |
| S (sector) | =1 for carpentry; =0 for plumbing | 0.49 | 0.5 | 490 |
| cooperatives in $\leq$ 50 km | | 1.939 | 0.999 | 490 |
| cooperatives in $\leq$ 100 km | | 4.959 | 2.951 | 490 |
| cooperatives in $\leq$ 200 km | | 1.414 | 0.700 | 490 |

Table A3: Descriptive statistics

| year | stats | $\ln T$ | $\ln IC$ | $\ln LE$ | $\ln IA$ | $\ln TA$ |
|---|---|---|---|---|---|---|
| 2004 | mean | 8.005 | 7.767 | 5.950 | 1.199 | 4.331 |
| | std. dev. | 0.169 | 0.177 | 0.063 | 1.696 | 1.096 |
| | median | 8.005 | 7.767 | 5.950 | 1.199 | 4.331 |
| 2005 | mean | 9.049 | 8.858 | 6.532 | 0.782 | 6.100 |
| | std. dev. | 1.038 | 1.045 | 0.975 | 1.199 | 1.481 |
| | median | 8.947 | 8.723 | 6.439 | 0.000 | 6.019 |
| 2006 | mean | 8.983 | 8.779 | 6.475 | 0.945 | 5.851 |
| | std. dev. | 0.964 | 0.972 | 0.969 | 1.181 | 1.640 |
| | median | 8.911 | 8.737 | 6.377 | 0.000 | 5.541 |
| 2007 | mean | 9.035 | 8.834 | 6.591 | 1.405 | 6.089 |
| | std. dev. | 0.964 | 0.972 | 0.982 | 1.353 | 1.716 |
| | median | 8.888 | 8.663 | 6.458 | 1.099 | 5.984 |
| 2008 | mean | 8.994 | 8.794 | 6.532 | 1.592 | 6.091 |
| | std. dev. | 1.027 | 1.026 | 1.074 | 1.435 | 1.853 |
| | median | 8.845 | 8.648 | 6.515 | 1.386 | 5.970 |
| 2009 | mean | 9.014 | 8.809 | 6.632 | 1.415 | 6.258 |
| | std. dev. | 0.964 | 0.966 | 0.989 | 1.416 | 1.754 |
| | median | 8.803 | 8.613 | 6.547 | 1.099 | 6.223 |
| 2010 | mean | 9.045 | 8.835 | 6.682 | 1.482 | 6.253 |
| | std. dev. | 0.977 | 0.978 | 0.974 | 1.350 | 1.757 |
| | median | 8.834 | 8.633 | 6.468 | 1.386 | 6.407 |
| 2011 | mean | 9.105 | 8.895 | 6.753 | 1.573 | 6.354 |
| | std. dev. | 0.972 | 0.973 | 0.967 | 1.421 | 1.813 |
| | median | 8.940 | 8.755 | 6.600 | 1.701 | 6.351 |
| 2012 | mean | 9.125 | 8.912 | 6.811 | 1.470 | 6.311 |
| | std. dev. | 0.978 | 0.980 | 0.977 | 1.505 | 1.921 |
| | median | 9.139 | 8.919 | 6.723 | 1.099 | 6.418 |
| 2013 | mean | 9.114 | 8.903 | 6.809 | 1.336 | 6.274 |
| | std. dev. | 0.975 | 0.980 | 0.961 | 1.595 | 2.017 |
| | median | 9.019 | 8.842 | 6.771 | 0.347 | 6.563 |
| 2014 | mean | 9.166 | 8.954 | 6.869 | 1.503 | 6.235 |
| | std. dev. | 1.003 | 1.012 | 0.991 | 1.529 | 2.190 |
| | median | 9.224 | 9.038 | 6.884 | 1.386 | 6.625 |
| Total | mean | 9.061 | 8.855 | 6.680 | 1.378 | 6.182 |
| | std. dev. | 0.974 | 0.978 | 0.980 | 1.422 | 1.838 |
| | median | 8.930 | 8.731 | 6.561 | 1.099 | 6.246 |

### A.3. Robustness checks and results for alternative specifications

Various additional robustness checks have been made. A large set of flexible functional forms is available to the empirical researcher (Thompson, 1988). Giannakas *et al.* (2003) show that an inappropriate choice of the functional form could result in significantly biased efficiency estimates and misleading policy recommendations regarding efficiency improvements. Their results strongly reject the *ad hoc* imposition of a functional form and underline the importance of searching for the write specification. Cobb-Douglas is a special case of the Translog model. Less parsimonious function forms such as Generalized Leontieff can also be used, but with they lack parsimony in the case of our small sample.

We conduct Bayesian model selection based on WAIC and LOO. These two information criteria reject the Cobb-Douglas function that has a slightly worse fit ($WAIC = -2232.62.19$ and $LOO = -2229.19$ for the Cobb-Douglas function *vs.* $WAIC = -2261.61$ and $LOO = -2255.17$ for the Translog function). We can also place a lasso prior on the population-level effects (Park and Casella, 2008). This shrinkage prior is the Bayesian equivalent to the lasso method for performing variable selection. The model with a lasso prior selects at least some parameters included in the Translog model ($\ln IC^2$, $\ln TA^2$, $\ln LE \times \ln TA$, $\ln IA \times \ln TA$), suggesting a better fit for this model.

Table A4: Results for the Cobb-Douglas Model

| Parameter | ESS | mean | s.d. | 2.5% | 50% | 97.5% |
|---|---|---|---|---|---|---|
| Intercept | 5578 | 0.382 | 0.022 | 0.339 | 0.381 | 0.424 |
| $\ln IC$ | 5727 | 0.926 | 0.006 | 0.914 | 0.926 | 0.938 |
| $\ln LE$ | 5532 | 0.076 | 0.006 | 0.064 | 0.076 | 0.088 |
| $\ln IA$ | 10000 | 0.000 | 0.001 | -0.002 | -0.000 | 0.001 |
| $\ln TA$ | 8615 | -0.001 | 0.001 | -0.003 | -0.001 | 0.001 |
| $S$ | 3464 | -0.029 | 0.008 | -0.045 | -0.029 | -0.014 |
| $C$ | 7355 | -0.015 | 0.005 | -0.024 | -0.015 | -0.006 |
| $A$ | 5154 | -0.001 | 0.000 | -0.001 | -0.001 | -0.000 |
| $S \times C$ | 6659 | 0.019 | 0.007 | 0.006 | 0.018 | 0.032 |
| $S \times A$ | 4767 | 0.001 | 0.001 | -0.000 | 0.001 | 0.002 |
| $C \times A$ | 8406 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 |
| $S \times C \times A$ | 8261 | -0.001 | 0.000 | -0.002 | -0.001 | 0.000 |
| $\phi$ | 2732 | 0.014 | 0.002 | 0.011 | 0.014 | 0.018 |
| $\sigma$ | 10000 | 0.015 | 0.001 | 0.014 | 0.015 | 0.016 |

*Notes: ESS: Effective Sample Size, s.d.: standard deviation.*

Table A5: Results for the Translog model with a lasso prior

| Parameter | ESS | mean | s.d. | 2.5% | 50% | 97.5% |
|---|---|---|---|---|---|---|
| Intercept | 2337 | -0.008 | 0.145 | -0.296 | -0.006 | 0.268 |
| $\ln IC$ | 1392 | 1.113 | 0.062 | 1.002 | 1.111 | 1.241 |
| $\ln LE$ | 1129 | -0.056 | 0.051 | -0.167 | -0.050 | 0.029 |
| $\ln IA$ | 2856 | -0.028 | 0.011 | -0.051 | -0.027 | -0.006 |
| $\ln TA$ | 2417 | 0.003 | 0.015 | -0.025 | 0.003 | 0.033 |
| $\ln IC^2$ | 1038 | -0.020 | 0.009 | -0.040 | -0.019 | -0.004 |
| $\ln LE^2$ | 1336 | 0.001 | 0.009 | -0.019 | 0.001 | 0.018 |
| $\ln IA^2$ | 4000 | 0.001 | 0.001 | -0.000 | 0.001 | 0.002 |
| $\ln TA^2$ | 4000 | 0.002 | 0.001 | 0.000 | 0.002 | 0.003 |
| $S$ | 1588 | -0.030 | 0.008 | -0.046 | -0.030 | -0.014 |
| $C$ | 3215 | -0.018 | 0.005 | -0.027 | -0.018 | -0.008 |
| $A$ | 2110 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 |
| $\ln IC \times \ln LE$ | 1086 | 0.020 | 0.018 | -0.011 | 0.019 | 0.059 |
| $\ln IC \times \ln IA$ | 2533 | 0.004 | 0.003 | -0.002 | 0.004 | 0.011 |
| $\ln IC \times \ln TA$ | 2597 | 0.005 | 0.004 | -0.003 | 0.005 | 0.013 |
| $\ln LE \times \ln IA$ | 2698 | -0.000 | 0.003 | -0.006 | -0.000 | 0.006 |
| $\ln LE \times \ln TA$ | 3086 | -0.010 | 0.004 | -0.017 | -0.010 | -0.003 |
| $\ln IA \times \ln TA$ | 4000 | -0.002 | 0.001 | -0.004 | -0.002 | -0.001 |
| $S \times C$ | 2987 | 0.018 | 0.007 | 0.005 | 0.018 | 0.031 |
| $S \times A$ | 2179 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 |
| $C \times A$ | 3387 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 |
| $S \times C \times A$ | 3282 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 |
| $\phi$ | 1164 | 0.014 | 0.002 | 0.011 | 0.014 | 0.018 |
| $\sigma$ | 4000 | 0.015 | 0.001 | 0.014 | 0.015 | 0.016 |
| lasso $\lambda^{-1}$ | 4000 | 0.007 | 0.002 | 0.004 | 0.007 | 0.011 |

*Notes: ESS: Effective Sample Size, s.d.: standard deviation.*

Next, we test for unobserved heterogeneity. Unobserved heterogeneity is where correlation between observables and unobservables may be expected(Arellano, 2003). This issue may lead to biased estimations. We test several alternative methods that lead to the same results. A first possibility is the choice to add an inefficiency error term in the production function regression, that becomes a random effects stochastic frontier analysis (Greene, 2005). A first preliminary analysis allows us to reject this approach.[4]

More generally, as any production analysis based on longitudinal data, our results may suffer from endogeneity (between the dependent variable and one or several independent variables) or unobserved heterogeneity. We have a sample with a small $T$ (short time frame) and small $N$ (few individuals). Therefore, the GMM (Generalized Method of Moments) may produce even more biased estimates (Roodman, 2009). A first simple and robust approach is to use the Mundlak-Chamberlain correction (Wooldridge, 2010). In production function and efficiency analysis, this method has already been implemented by Emvalomatis (2012) and Griffiths and Hajargasht (2016). We just have to test the joint hypothesis of nullity for added parameters, namely the average of each time varying variable, using a VAT (Variable addition test). The Bayesian test reject this hypothesis ($Estimate = 0.0394$ with $e.s. = 0.0447$). We have also a higher WAIC. Another possibility is to reestimate our model using Lewbel (2012)'s method. This method serves to identify structural parameters in regression models with potentially endogeneous regressors in the absence of traditional identifying information, such as external instruments or repeated measurements based on large panels (see Mishra and Smyth (2015) for an example). Results are slightly similar to our previous results (economies of scale=1.56), for both the amplitude and the statistical significance of parameters. We implement the unconditional quasi-maximum likelihood estimator of Hsiao *et al.* (2002) for linear dynamic panel models with fixed effects. Authors provide simulation evidence indicating that their estimator performs better than the GMM estimator. Obtained results are also similar and lead us to reject the addition of a lagged dependent variable. The economies of scale estimated are slightly higher (1.82). Finally, in order to give a broader comparison, we provide the estimations for the classical Arellano and Bond (1991) GMM method, although results may be biased for our panel, as explained above. Again, the economies of scale are similar to those estimated with our benchmark model (economies of scale=1.49).

[4]The two models were estimated using maximum likelihood. The stochastic frontier model with time inefficiency has a $BIC = -2078.545$; for the model without the inefficiency error term $BIC = -2084.556$, suggesting a better fit. The two models have a likelihood $L = 1102.417$; the difference lies in the higher degrees of freedom needed for the stochastic frontier model.

Table A6: Estimation using Mundlak Model

| Parameter | ESS | mean | s.d. | 2.5% | 50% | 97.5% |
|---|---|---|---|---|---|---|
| Intercept | 6918 | -0.144 | 0.157 | -0.451 | -0.144 | 0.160 |
| $\ln IC$ | 4404 | 1.249 | 0.068 | 1.116 | 1.249 | 1.383 |
| $\ln ICmean$ | 3685 | -0.040 | 0.020 | -0.080 | -0.041 | 0.000 |
| $\ln LE$ | 3795 | -0.169 | 0.063 | -0.292 | -0.169 | -0.046 |
| $\ln LEmean$ | 3109 | 0.033 | 0.019 | -0.003 | 0.033 | 0.071 |
| $\ln IA$ | 6104 | -0.028 | 0.012 | -0.052 | -0.029 | -0.005 |
| $\ln IAmean$ | 5054 | 0.000 | 0.003 | -0.005 | 0.000 | 0.005 |
| $\ln TA$ | 6031 | -0.005 | 0.018 | -0.038 | -0.005 | 0.029 |
| $\ln TAmean$ | 4874 | 0.004 | 0.003 | -0.003 | 0.004 | 0.010 |
| $\ln IC^2$ | 3588 | -0.041 | 0.011 | -0.064 | -0.041 | -0.019 |
| $\ln LE^2$ | 4383 | -0.014 | 0.011 | -0.037 | -0.014 | 0.008 |
| $\ln IA^2$ | 10000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 |
| $\ln TA^2$ | 8115 | 0.001 | 0.001 | 0.000 | 0.002 | 0.003 |
| $S$ | 4513 | -0.024 | 0.011 | -0.045 | -0.024 | -0.004 |
| $C$ | 7832 | -0.015 | 0.005 | -0.025 | -0.015 | -0.005 |
| $Cmean$ | 5371 | 0.046 | 0.044 | -0.043 | 0.046 | 0.131 |
| $A$ | 10000 | -0.002 | 0.001 | -0.003 | -0.002 | 0.000 |
| $Amean$ | 10000 | 0.001 | 0.001 | -0.001 | 0.001 | 0.002 |
| $\ln IC \times \ln LE$ | 3735 | 0.056 | 0.022 | 0.012 | 0.056 | 0.101 |
| $\ln IC \times \ln IA$ | 5455 | 0.005 | 0.003 | -0.002 | 0.005 | 0.012 |
| $\ln IC \times \ln TA$ | 5789 | 0.007 | 0.004 | -0.002 | 0.007 | 0.016 |
| $\ln LE \times \ln IA$ | 6412 | -0.001 | 0.003 | -0.007 | -0.001 | 0.006 |
| $\ln LE \times \ln TA$ | 6550 | -0.012 | 0.004 | -0.019 | -0.012 | -0.005 |
| $\ln IA \times \ln TA$ | 10000 | -0.002 | 0.001 | -0.004 | -0.002 | 0.000 |
| $S \times C$ | 7616 | 0.019 | 0.007 | 0.005 | 0.019 | 0.032 |
| $S \times A$ | 7009 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 |
| $C \times A$ | 8182 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 |
| $S \times C \times A$ | 8596 | -0.001 | 0.000 | -0.002 | -0.001 | 0.000 |
| $\phi$ | 3140 | 0.014 | 0.002 | 0.010 | 0.014 | 0.018 |
| $\sigma$ | 10000 | 0.015 | 0.001 | 0.013 | 0.015 | 0.016 |

*Notes: ESS: Effective Sample Size, s.d.: standard deviation.*

Table A7: Estimation using Lewbel (2012)'s method

| Variable | coef. | s.e. |
|---|---|---|
| $\ln IC$ | 1.357*** | 0.110 |
| $\ln LE$ | -0.241** | 0.106 |
| $\ln IA$ | -0.010 | 0.023 |
| $\ln TA$ | -0.051 | 0.036 |
| $\ln IC^2$ | -0.074*** | 0.018 |
| $\ln LE^2$ | -0.051*** | 0.019 |
| $\ln IA^2$ | -0.000 | 0.001 |
| $\ln TA^2$ | 0.000 | 0.001 |
| $\ln IC \times \ln LE$ | 0.120*** | 0.036 |
| $\ln IC \times \ln IA$ | -0.001 | 0.007 |
| $\ln IC \times \ln TA$ | 0.018** | 0.009 |
| $\ln LE \times \ln IA$ | 0.002 | 0.007 |
| $\ln LE \times \ln TA$ | -0.017** | 0.008 |
| $\ln IA \times \ln TA$ | 0.001 | 0.002 |
| $S$ | - | - |
| $C$ | -0.017*** | 0.007 |
| $A$ | -0.001 | 0.001 |
| $S \times C$ | 0.020** | 0.009 |
| $S \times A$ | 0.002 | 0.001 |
| $C \times A$ | 0.001*** | 0.000 |
| $S \times C \times A$ | -0.001** | 0.001 |
| Underidentification test | chi2(71)=69.130 | p-value=0.541 |
| Overidentification Sargan test | chi2(70)=75.819 | p-value=0.296 |

*Notes: s.e.: standard error;* * $p < 0.1$*;* ** $p < 0.05$*;* *** $p < 0.01$.

Table A8: Estimation using Hsiao *et al.* (2002)'s method

| Variable | coef. | s.e. |
|---|---|---|
| $Lag(\ln T)$ | 0.002 | 0.008 |
| $\ln IC$ | 1.437*** | 0.082 |
| $\ln LE$ | -0.378*** | 0.083 |
| $\ln IA$ | -0.024 | 0.015 |
| $\ln TA$ | 0.049* | 0.025 |
| $\ln IC^2$ | -0.069*** | 0.014 |
| $\ln LE^2$ | -0.037*** | 0.014 |
| $\ln IA^2$ | -0.000 | 0.001 |
| $\ln TA^2$ | 0.003*** | 0.001 |
| $\ln IC \times \ln LE$ | 0.111*** | 0.028 |
| $\ln IC \times \ln IA$ | 0.005 | 0.004 |
| $\ln IC \times \ln TA$ | -0.004 | 0.006 |
| $\ln LE \times \ln IA$ | -0.002 | 0.005 |
| $\ln LE \times \ln TA$ | -0.008 | 0.006 |
| $\ln IA \times \ln TA$ | -0.000 | 0.001 |
| $S$ | 0.000 | 0.000 |
| $C$ | -0.015** | 0.007 |
| $A$ | 0.000 | 0.001 |
| $S \times C$ | 0.016 | 0.010 |
| $S \times A$ | -0.001 | 0.001 |
| $C \times A$ | 0.001*** | 0.000 |
| $S \times C \times A$ | -0.000 | 0.000 |
| Intercept | -0.564*** | 0.211 |

*Notes: s.e.: standard error;* * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A9: Estimation using Arellano and Bond (1991)'s method

| Variable | coef. | s.e. |
|---|---|---|
| $Lag(\ln T)$ | 0.003 | 0.004 |
| $\ln IC$ | 1.279*** | 0.052 |
| $\ln LE$ | -0.231*** | 0.046 |
| $\ln IA$ | -0.032*** | 0.010 |
| $\ln TA$ | 0.049*** | 0.012 |
| $\ln IC^2$ | -0.043*** | 0.009 |
| $\ln LE^2$ | -0.020** | 0.009 |
| $\ln IA^2$ | -0.000 | 0.001 |
| $\ln TA^2$ | 0.003*** | 0.001 |
| $\ln IC \times \ln LE$ | 0.067*** | 0.017 |
| $\ln IC \times \ln IA$ | 0.004 | 0.003 |
| $\ln IC \times \ln TA$ | -0.005 | 0.004 |
| $\ln LE \times \ln IA$ | 0.001 | 0.003 |
| $\ln LE \times \ln TA$ | -0.005 | 0.004 |
| $\ln IA \times \ln TA$ | -0.001* | 0.001 |
| $S$ | -0.022*** | 0.006 |
| $C$ | -0.010** | 0.005 |
| $A$ | -0.001*** | 0.000 |
| $S \times C$ | 0.010 | 0.006 |
| $S \times A$ | 0.001 | 0.000 |
| $C \times A$ | 0.001*** | 0.000 |
| $S \times C \times A$ | -0.001 | 0.000 |
| Intercept | -0.325*** | 0.106 |

*Notes: s.e.: standard error;* * $p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

Another point is the spatial dimension of data. The craftsmen cooperatives are unevenly distributed across France and in some regions they may be in competition. A simple first approach is to count the number of cooperatives in a given radius (50, 100 or 200 km). We can also estimate GAMM (Generalized Additive Mixed Models) (Wood, 2006; Santias *et al.*, 2011) using latitude and longitude coordinates. Adding the number of cooperatives in a 100 km radius lead to a slightly better fit, but has no impact on the parameters of interest. The 200 km radius model and the GAMM model lead to a worst fit.

Table A10: Results for the GAMM model

| Parameter | ESS | mean | s.d. | 2.5% | 50% | 97.5% |
|---|---|---|---|---|---|---|
| Intercept | 7731 | -0.197 | 0.145 | -0.489 | -0.197 | 0.090 |
| $\ln IC$ | 4612 | 1.238 | 0.067 | 1.104 | 0.238 | 1.369 |
| $\ln LE$ | 3493 | -0.172 | 0.061 | -0.290 | -0.172 | -0.054 |
| $\ln IA$ | 6446 | -0.021 | 0.012 | -0.044 | -0.021 | 0.001 |
| $\ln TA$ | 6107 | 0.003 | 0.016 | -0.028 | 0.003 | 0.035 |
| $I(\ln IC2)$ | 3764 | -0.044 | 0.011 | -0.065 | -0.044 | -0.022 |
| $I(\ln LE2)$ | 4645 | -0.019 | 0.011 | -0.040 | -0.019 | 0.002 |
| $I(\ln IA2)$ | 10000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 |
| $I(\ln TA2)$ | 8160 | 0.002 | 0.001 | 0.000 | 0.002 | 0.003 |
| $S$ | 4733 | -0.016 | 0.005 | -0.026 | -0.016 | -0.006 |
| $C$ | 10000 | -0.008 | 0.003 | -0.014 | -0.008 | -0.001 |
| $A$ | 7402 | -0.001 | 0.000 | -0.001 | -0.001 | 0.000 |
| $\ln IC \times \ln LE$ | 3530 | 0.064 | 0.021 | 0.023 | 0.065 | 0.106 |
| $\ln IC \times \ln IA$ | 5550 | 0.001 | 0.003 | -0.006 | 0.001 | 0.008 |
| $\ln IC \times \ln TA$ | 5748 | 0.007 | 0.004 | -0.001 | 0.007 | 0.015 |
| $\ln LE \times \ln IA$ | 5848 | 0.003 | 0.003 | -0.003 | 0.003 | 0.010 |
| $\ln LE \times \ln TA$ | 7075 | -0.013 | 0.004 | -0.020 | -0.013 | -0.005 |
| $\ln IA \times \ln TA$ | 10000 | -0.002 | 0.001 | -0.004 | -0.002 | -0.001 |
| $C : A$ | 10000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| s(lat,lon)Fx1 | 5851 | 0.002 | 0.003 | -0.004 | 0.002 | 0.008 |
| s(lat,lon)Fx2 | 3792 | -0.001 | 0.005 | -0.012 | 0.000 | 0.008 |
| b[s(lat,lon) Xr:1] | 10000 | 0.001 | 0.012 | -0.024 | 0.000 | 0.028 |
| b[s(lat,lon) Xr:2] | 10000 | 0.001 | 0.012 | -0.025 | 0.000 | 0.027 |
| b[s(lat,lon) Xr:3] | 10000 | 0.000 | 0.012 | -0.025 | -0.000 | 0.027 |
| b[s(lat,lon) Xr:4] | 10000 | -0.002 | 0.012 | -0.031 | -0.000 | 0.020 |
| b[s(lat,lon) Xr:5] | 10000 | -0.002 | 0.012 | -0.032 | -0.000 | 0.023 |
| b[s(lat,lon) Xr:6] | 10000 | -0.004 | 0.013 | -0.039 | -0.001 | 0.015 |
| b[s(lat,lon) Xr:7] | 10000 | -0.003 | 0.012 | -0.032 | -0.001 | 0.019 |
| b[s(lat,lon) Xr:8] | 10000 | 0.003 | 0.012 | -0.017 | 0.001 | 0.034 |
| b[s(lat,lon) Xr:9] | 10000 | 0.000 | 0.011 | -0.024 | 0.000 | 0.025 |
| b[s(lat,lon) Xr:10] | 10000 | 0.000 | 0.012 | -0.025 | 0.000 | 0.027 |
| b[s(lat,lon) Xr:11] | 4013 | -0.006 | 0.013 | -0.042 | -0.002 | 0.014 |
| b[s(lat,lon) Xr:12] | 10000 | -0.002 | 0.012 | -0.029 | -0.000 | 0.021 |
| b[s(lat,lon) Xr:13] | 5915 | -0.004 | 0.012 | -0.035 | -0.001 | 0.016 |
| b[s(lat,lon) Xr:14] | 10000 | 0.002 | 0.011 | -0.020 | 0.000 | 0.028 |
| b[s(lat,lon) Xr:15] | 10000 | 0.002 | 0.012 | -0.022 | 0.001 | 0.030 |
| b[s(lat,lon) Xr:16] | 5023 | -0.004 | 0.012 | -0.033 | -0.001 | 0.016 |
| b[s(lat,lon) Xr:17] | 10000 | -0.001 | 0.011 | -0.027 | -0.000 | 0.021 |
| b[s(lat,lon) Xr:18] | 10000 | 0.003 | 0.012 | -0.017 | 0.001 | 0.033 |
| b[s(lat,lon) Xr:19] | 3460 | -0.007 | 0.013 | -0.040 | -0.003 | 0.011 |
| b[s(lat,lon) Xr:20] | 4030 | -0.006 | 0.012 | -0.036 | -0.002 | 0.011 |
| b[s(lat,lon) Xr:21] | 8295 | -0.001 | 0.009 | -0.022 | -0.000 | 0.018 |
| b[s(lat,lon) Xr:22] | 6763 | 0.004 | 0.010 | -0.013 | 0.002 | 0.029 |
| b[s(lat,lon) Xr:23] | 10000 | -0.000 | 0.009 | -0.020 | -0.000 | 0.018 |
| b[s(lat,lon) Xr:24] | 10000 | -0.001 | 0.008 | -0.018 | -0.000 | 0.016 |
| b[s(lat,lon) Xr:25] | 3955 | -0.004 | 0.008 | -0.023 | -0.002 | 0.010 |
| b[s(lat,lon) Xr:26] | 1955 | -0.010 | 0.010 | -0.034 | -0.008 | 0.003 |
| b[s(lat,lon) Xr:27] | 3370 | -0.005 | 0.009 | -0.028 | -0.003 | 0.008 |
| $\sigma$ | 10000 | 0.015 | 0.001 | 0.014 | 0.015 | 0.016 |
| log-posterior | 1685 | 1019.016 | 9.441 | 999.191 | 1019.291 | 1036.604 |

*Notes: ESS: Effective Sample Size, s.d.: standard deviation.*

Table A11: Results for radius of 50 km, 100 km, and 200 km

| | Radius 50 km | | | | | | Radius 100 km | | | | | | Radius 200 km | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | ESS | mean | s.d. | 2.5% | 50% | 97.5% | ESS | mean | s.d. | 2.5% | 50% | 97.5% | ESS | mean | s.d. | 2.5% | 50% | 97.5% |
| Intercept | 6242 | -0.190 | 0.151 | -0.486 | -0.188 | 0.104 | 6072 | -0.201 | 0.147 | -0.488 | -0.203 | 0.082 | 5097 | -0.194 | 0.148 | -0.484 | -0.195 | 0.098 |
| $\ln IC$ | 3775 | 1.236 | 0.067 | 1.106 | 1.236 | 1.366 | 3405 | 1.237 | 0.066 | 1.108 | 1.237 | 1.365 | 2831 | 1.237 | 0.068 | 1.101 | 1.236 | 1.371 |
| $\ln LE$ | 3050 | -0.167 | 0.061 | -0.284 | -0.166 | -0.045 | 2818 | -0.166 | 0.059 | -0.285 | -0.165 | -0.051 | 2443 | -0.166 | 0.062 | -0.288 | -0.166 | -0.045 |
| $\ln IA$ | 5149 | -0.028 | 0.012 | -0.051 | -0.028 | -0.005 | 5342 | -0.029 | 0.012 | -0.052 | -0.029 | -0.006 | 4790 | -0.028 | 0.012 | -0.051 | -0.028 | -0.004 |
| $\ln TA$ | 4577 | 0.004 | 0.016 | -0.029 | 0.003 | 0.036 | 5069 | 0.005 | 0.017 | -0.028 | 0.005 | 0.037 | 4074 | 0.003 | 0.016 | -0.028 | 0.003 | 0.036 |
| $\ln IC^2$ | 2966 | -0.039 | 0.011 | -0.061 | -0.039 | -0.018 | 2577 | -0.039 | 0.011 | -0.062 | -0.039 | -0.017 | 2239 | -0.040 | 0.011 | -0.062 | -0.039 | -0.017 |
| $\ln LE^2$ | 3568 | -0.013 | 0.011 | -0.034 | -0.013 | 0.009 | 3117 | -0.012 | 0.011 | -0.034 | -0.012 | 0.009 | 2757 | -0.013 | 0.011 | -0.034 | -0.013 | 0.009 |
| $\ln IA^2$ | 10000 | 0.001 | 0.001 | -0.000 | 0.001 | 0.002 | 10000 | 0.001 | 0.001 | -0.000 | 0.001 | 0.002 | 10000 | 0.001 | 0.001 | -0.000 | 0.001 | 0.002 |
| $\ln TA^2$ | 6833 | 0.002 | 0.001 | 0.000 | 0.002 | 0.003 | 7382 | 0.002 | 0.001 | 0.000 | 0.002 | 0.003 | 6356 | 0.002 | 0.001 | 0.000 | 0.002 | 0.003 |
| $S$ | 3261 | -0.033 | 0.008 | -0.049 | -0.033 | -0.017 | 3940 | -0.034 | 0.008 | -0.051 | -0.035 | -0.018 | 3532 | -0.033 | 0.008 | -0.050 | -0.033 | -0.017 |
| $C$ | 6299 | -0.018 | 0.005 | -0.027 | -0.018 | -0.008 | 6540 | -0.017 | 0.005 | -0.027 | -0.017 | -0.008 | 5466 | -0.018 | 0.005 | -0.027 | -0.018 | -0.008 |
| $A$ | 5214 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 | 4556 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 | 4428 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 |
| coop in $\leq$ 50 km | 3310 | -0.000 | 0.003 | -0.006 | -0.000 | 0.005 | | | | | | | | | | | | |
| coop in $\leq$ 100 km | | | | | | | 3243 | 0.001 | 0.001 | -0.001 | 0.001 | 0.003 | | | | | | |
| coop in $\leq$ 200 km | | | | | | | | | | | | | 2649 | -0.000 | 0.004 | -0.007 | -0.000 | 0.007 |
| $\ln IC \times \ln LE$ | 3016 | 0.054 | 0.022 | 0.011 | 0.054 | 0.096 | 2673 | 0.053 | 0.021 | 0.011 | 0.053 | 0.095 | 2331 | 0.054 | 0.022 | 0.011 | 0.054 | 0.097 |
| $\ln IC \times \ln IA$ | 4587 | 0.004 | 0.003 | -0.003 | 0.004 | 0.011 | 4589 | 0.004 | 0.003 | -0.003 | 0.004 | 0.011 | 3999 | 0.004 | 0.003 | -0.003 | 0.004 | 0.011 |
| $\ln IC \times \ln TA$ | 4476 | 0.006 | 0.004 | -0.003 | 0.006 | 0.014 | 4918 | 0.005 | 0.004 | -0.003 | 0.005 | 0.014 | 4337 | 0.006 | 0.004 | -0.002 | 0.006 | 0.014 |
| $\ln LE \times \ln IA$ | 5263 | 0.000 | 0.003 | -0.006 | 0.000 | 0.007 | 5107 | 0.000 | 0.003 | -0.006 | 0.000 | 0.007 | 4474 | 0.000 | 0.003 | -0.006 | 0.000 | 0.007 |
| $\ln LE \times \ln TA$ | 5696 | -0.011 | 0.004 | -0.019 | -0.011 | -0.004 | 5853 | -0.011 | 0.004 | -0.018 | -0.011 | -0.004 | 4669 | -0.011 | 0.004 | -0.018 | -0.011 | -0.004 |
| $\ln IA \times \ln TA$ | 10000 | -0.002 | 0.001 | -0.004 | -0.002 | -0.001 | 10000 | -0.002 | 0.001 | -0.004 | -0.002 | -0.001 | 10000 | -0.002 | 0.001 | -0.004 | -0.002 | -0.001 |
| $S \times C$ | 6221 | 0.019 | 0.007 | 0.006 | 0.019 | 0.032 | 6267 | 0.019 | 0.007 | 0.006 | 0.019 | 0.032 | 5030 | 0.019 | 0.007 | 0.005 | 0.019 | 0.031 |
| $S \times A$ | 3866 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 | 4763 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 | 4252 | 0.001 | 0.001 | 0.000 | 0.001 | 0.002 |
| $C \times A$ | 7175 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 7462 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 6195 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 |
| $S \times C \times A$ | 7599 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 | 7484 | -0.001 | 0.000 | -0.002 | -0.001 | 0.000 | 5934 | -0.001 | 0.000 | -0.002 | -0.001 | -0.000 |
| $\phi$ | 2915 | 0.015 | 0.002 | 0.011 | 0.014 | 0.019 | 2732 | 0.014 | 0.002 | 0.011 | 0.015 | 0.019 | 2475 | 0.014 | 0.002 | 0.011 | 0.014 | 0.019 |
| $\sigma$ | 10000 | 0.014 | 0.001 | 0.013 | 0.014 | 0.016 | 10000 | 0.014 | 0.001 | 0.013 | 0.014 | 0.016 | 10000 | 0.014 | 0.001 | 0.013 | 0.014 | 0.016 |

*Notes: ESS: Effective Sample Size, s.d.: standard deviation.*

Finally, in order to account for uncertainty induced by model selection inconstancy (Piironen and Vehatari, 2015), we can correct the estimates with model averaging based on models weights (Yao *et al.*, 2018). These model weights are analogous to posterior probabilities of models, conditional on expected future data. Following Piironen and Vehatari (2015), we choose two main weighting methods. The first one are the Aikake-type weights (McElreath, 2016):

$$w_m^{Aikake} = \frac{\exp(\frac{-1}{2} dWAIC_m)}{\sum_{n=1}^{N} \exp(\frac{-1}{2} dWAIC_n)} \tag{3}$$

where $dWAIC_m$ the WAIC difference between model $m$ and the model with the lowest WAIC.

The second method are the pseudo-BMA (Bayesian model averaging) weights based on $elpd_{loo}$ (Yao *et al.*, 2018), the LOO expected log pointwise predictive density (see Vehtari *et al.* (2017) for a definition):

$$w_m^{pseudo-BMA} = \frac{\exp(\hat{elpd}_{loo}^m - \frac{1}{2} se(elpd_{loo}^m))}{\sum_{n=1}^{N} \exp(\hat{elpd}_{loo}^n)} \tag{4}$$

Table A12: Information criteria for the various specifications

| | LOO | | WAIC | | Weights | |
|---|---|---|---|---|---|---|
| Model | estimate | s.e. | estimate | s.e. | Aikake | Pseudo BMA |
| Translog | -2255.17 | 52.74 | -2261.62 | 51.5 | 0.229 | 0.168 |
| Cobb-Douglas | -2229.19 | 51.34 | -2232.62 | 50.69 | 0.000 | 0.040 |
| Mundlak | -2250.6 | 52.56 | -2256.93 | 5158 | 0.022 | 0.060 |
| GAMM | -2250.21 | 52.25 | -2255.53 | 51.34 | 0.011 | 0.163 |
| Radius 50km | -2255.74 | 52.58 | -2262.19 | 51.4 | 0.305 | 0.210 |
| Radius 100km | -2255.91 | 52.46 | -2261.77 | 51.42 | 0.247 | 0.231 |
| Radius 200km | -2254.74 | 52.54 | -2261.2 | 51.46 | 0.186 | 0.127 |

*Note: s.e.: standard error.*

Population estimates are reported in Table A13.[5] We see that there are only slightly changes with respect to the benchmark model.

Table A13: Main estimates: benchmark model vs. model averaging

| | Translog | | Model averaging | | | |
|---|---|---|---|---|---|---|
| | | | Aikake | | Pseudo BMA | |
| | estimate | s.e. | estimate | s.e. | estimate | s.e. |
| $\ln IC$ | 1.235 | 0.067 | 1.237 | 0.067 | 1.224 | 0.077 |
| $\ln LE$ | -0.165 | 0.060 | -0.166 | 0.061 | -0.157 | 0.068 |
| $\ln IA$ | -0.028 | 0.012 | -0.028 | 0.012 | -0.026 | 0.013 |
| $\ln TA$ | 0.003 | 0.016 | 0.004 | 0.016 | 0.003 | 0.016 |
| $\ln IC^2$ | -0.039 | 0.011 | -0.039 | 0.011 | -0.038 | 0.012 |
| $\ln LE^2$ | -0.013 | 0.011 | -0.013 | 0.011 | -0.013 | 0.011 |
| $\ln IA^2$ | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| $\ln TA^2$ | 0.002 | 0.001 | 0.002 | 0.001 | 0.002 | 0.001 |
| $\ln IC \times \ln LE$ | 0.053 | 0.021 | 0.054 | 0.022 | 0.053 | 0.023 |
| $\ln IC \times \ln IA$ | 0.004 | 0.003 | 0.004 | 0.003 | 0.003 | 0.003 |
| $\ln IC \times \ln TA$ | 0.006 | 0.004 | 0.006 | 0.004 | 0.006 | 0.004 |
| $\ln LE \times \ln IA$ | 0.000 | 0.003 | 0.000 | 0.003 | 0.000 | 0.003 |
| $\ln LE \times \ln TA$ | -0.011 | 0.004 | -0.011 | 0.004 | -0.011 | 0.004 |
| $\ln IA \times \ln TA$ | -0.002 | 0.001 | -0.002 | 0.001 | -0.002 | 0.001 |
| $S$ | -0.033 | 0.008 | -0.033 | 0.008 | -0.030 | 0.010 |
| $C$ | -0.018 | 0.005 | -0.018 | 0.005 | -0.016 | 0.006 |
| $A$ | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | 0.000 |
| $S \times C$ | 0.019 | 0.007 | 0.019 | 0.007 | 0.016 | 0.009 |
| $S \times A$ | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| $C \times A$ | 0.001 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 |
| $S \times C \times A$ | -0.001 | 0.000 | -0.001 | 0.000 | -0.001 | 0.000 |
| Intercept | -0.190 | 0.150 | -0.193 | 0.122 | -0.168 | 0.148 |

*Note: s.e.: standard error.*

[5] See Yao *et al.* (2018) and Burnham and Anderson (2004) for the details on the averaging methods.

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