Social heterogeneity and efficiency in Italian health care system:
A Simar-Wilson methodology analysis

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Abstract

In this paper, we have evaluated efficiency in health services across Italian provinces by assessing outputs (life expectancy, infant survival) against inputs directly used in the health system (doctors, beds, MRI units) and environmental variables (income per capita, drop out school, Gini index and corruption rate), applying the innovative two-stages procedure of Algorithm 2 proposed by Simar-Wilson (2007). It shows that income per capita, drop out school, Gini index and corruption rate are highly and significantly correlated to output scores. The results also suggest possible drawbacks for healthcare decentralization once interregional differences are taken into account.

JEL: C14, C61, H52, I11
Keywords: technical efficiency, health, DEA, bootstrap, semi-parametric

PRELIMINARY DRAFT, PLEASE DO NOT QUOTE.

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1 Introduction

When exploring inefficiency in health care provision several studies [Evans *et al.*,(2000); Green (2004); Retzlaff-Roberts *et al.*(2004); Spinks and Hollingsworth (2009); Afonso and Aubyn (2005)] show that socio-economic variables explain differences in efficiency in different national contexts. However, these studies are based on cross-country data, that cannot disentangle the problem of heterogeneity attributable to differences in the institutional settings of different national health care systems. Restricting the analysis to single countries with multiple jurisdictions providing health care, it is possible to overcome this problem. Italy is an interesting study case. Italian national health system (NHS) has been decentralized in the 1990's, following a process aimed at improving the performance and constraining the costs of healthcare system. But, in Italy, Northern and Southern regions widely differ in their socio-economic structure, and the decentralization process has fostered the divide in terms of healthcare infrastructures and expenditures. The NHS, founded in 1978, is a universal health care system providing comprehensive health insurance coverage and uniform health benefits to the whole population, subject to user charges for certain services. The system, now is organized on the three level governments (national, regional, and local organizations)[4]. In 1991, Essential Levels of Services (ELS) were for the first time introduced as a tool to define the amount of financial resources to be attributed to the single region and plan the provision of care. Responsibilities for ensuring the general objectives and fundamental principles of ELS are maintained on central government; the regional health authorities are responsible for providing ELS, through a network of about 200 local public health units (LHU) and accredited private health care providers. In this paper, we apply the innovative two-stages procedure of Algorithm 2 proposed by Simar -Wilson (2007) to estimate the efficiency determinants of health care in the Italian provinces, from 2001 to 2005. The most usual two-stage approach has been recently criticized by Barnum and Gleason (2008): DEA output scores are likely to be biased, for socio-economic variables are correlated to output and input variables. Bootstrap procedure suggested by Simar and Wilson (2007) overcome this bias. To our knowledge this procedure has not been applied for estimating health care efficiency in within country analysis (Afonso and Aubyn,

[4] An attempt for decentralization begun in the first half of the 90s', but it was only in 1997 that an increasingly extended regionalization and a strengthened role of municipalities became a remarkable feature of the Italian health care system.

2005 published a work with the same technique for comparison between countries OECD). The present paper applies the Simar-Wilson procedure to estimate the efficiency determinants of the Italian Provinces in health care, from 2001 to 2005. We found that income per capita, drop out school, Gini index and corruption rate are highly and significantly correlated to output scores. The results suggest possible drawbacks for healthcare decentralization once interregional differences are taken into account. The paper is organized as follows: section two examines discusses the econometric strategy and section three describes data set and variables. Results and conclusion are reported in the fourth and fifth section.

2.The Methodology

The two stage approach, with the bootstraps procedures suggested by Simar-Wilson (2007) is employed in this paper, to estimate the technical efficiency of the Italian health care system. In the first stage, to estimate the production frontier I have adopted the nonparametric methodology, known as data envelopment analysis (DEA), applied for the first times by Debreu (1951) and Farell (1957) and consolidated in terms of economic efficiency by Charnes *et al.* (1978) and Fare *et al.* (1985, 1994). [For detailed survey, see Lovell (1988) and Tavares (2002)]. In the second stage, the scores of technical efficiency from DEA are corrected using the bootstrap procedure (Algorithm 2) introduced by Simar-Wilson (2007).

DEA procedure

DEA measures efficiency by constructing an empirically based ''best-practice'' or efficient frontier . Under the existing technology, DEA assumes that Decision Making Units (DMUs) transform a set of N inputs using $x^j = (x_1^J,\ldots,{x_N}^J)$ to produce M outputs $y_1^i = ({y_1}^j,..,{y_M}^J)$. For the analysis of the efficiency of Italian health care system, the Italian Provinces are the DMUs. The outputs (a) and inputs (b) are the following: (a) life expectancy and Infant mortality rate[5] ; and (b) physician rate, beds rate and Resonance Imager Units (MRI). We suppose that DMUs can be characterized by technological set Ψ defined as:

[5]These health measure, have been used in several studies on health efficiency- see Retzlaff-Roberts *et al.*(2004) Spinks, J. Hollingsworth (2005); Afonso and Aubyn, (2005).

$$\Psi = \left\{ (x,y)\, \Re^N x \Re^M \mid x\, produce\, y \right\} \quad (1)$$

Not all DMUs units adopt the efficient technology. In this case, they lie below the technological frontier. The efficient transformation of inputs into output depends on different endogenous or exogenous factors. We use an output-oriented specification to assume the maximization of the output. For the efficiency estimation we adopt a Farrell-Debreu-type output oriented technical efficiency measure:

$$\delta (x,y) = max \left\{ \theta : (x, \theta y) \in \psi \right\} \quad (2)$$

with a score of technical efficiency $\delta_i > 1$ the DMU is inside the frontier (*i.e.* the Province is inefficient), while if δ_i=1 the DMU lies on the frontier (i.e. the Province is efficient). Since the existing technology is unknown, we can estimate the potential output by using the available observations and the DEA estimator introduced by Farrell (1957) and Charnes *et al.* (1978). We assume that the production set Ψ is convex, with constant returns to scale. DEA on the observed data X =$(x_i, y_i)$with i = 1,...n is defined as:

$$\hat{\Psi} = \left\{ (x,y) \in R^N \times R^M : \sum_{i=1} \gamma_i y_i \geq y; \sum_{i=1} \gamma_i x_i \leq x; \gamma \geq 0, i = 1, ..., n \right\} \quad (3)$$

Where, i > 0 (i = 1, ..., n) are the intensity variables; is the small convex free disposal cone that contains the input-output data, and it is a consistent estimator of the technology under the assumptions of conventional constant returns to scale[6] .

Bootstrap procedure

Classical DEA incorporates only discretionary input variables (i.e doctors, beds technology) directly affecting DMUs efficiency scores; while the effects of environmental variables are not considered. However, environmental variables (e.g. socio-economic variables) may exert a relevant influence on the efficiency scores (Afonso and Aubyn 2005). Usually, two stage procedure is employed to capture jointly effects of discretionary and "environmental" inputs. However , it is known that conventional two stage estimates can be biased when the discretionary inputs in the first stage are correlated with environmental inputs

[6] See Kneip et al. (1998, 2003) to proof the asymptotic consistency of the DEA under certain conditions.

in the second stage. Bootstrap procedures suggested by Simar and Wilson (2007) overcome these potential bias, caused by multicollinearity. In particular, this method draws from the empirical distribution of n production units several samples with a random procedure. Specifically, Simar and Wilson (2007) assume a truncated normal distribution with zero mean and variance σ^2, truncated in $\epsilon_j \geq 1 - z_j\beta$, formally defined as follows:

$$\delta_j = z_i\beta + \epsilon_j,\ j = 1, ...n \tag{4}$$

$$Where,\ \varepsilon_i : N(0, \sigma_\varepsilon^2),\ s.t.\ \varepsilon_j \geq 1 - z_j\beta,\ j = 1, ..., n \tag{5}$$

After estimating the coefficients, we apply the parametric bootstrap regression to obtain the confidence intervals of estimated parameters. The efficiency equation (4) allows the analysis of the relationship between inefficiency of the health care DMUs and socio-economic variables. The inefficiency is expressed as a linear function of the following socio-economic variables:

$$\delta_{it} = \beta_0 + \beta_1 DROP\_SC_{it} + \beta_2 CORR_{it} + \beta_3 INC + \beta_4 GINI_{it} + \varepsilon_{it} \tag{6}$$

where $DROP\_SC_{it}$ is the school dropout rate in the province i at time t; $CORR_{it}$ is the regional crime rate weighted for the provincial population; INC_{it} is the provincial per capita income; $GINI_{it}$ is an indicator of provincial income inequality, ranging from zero (perfect equality) to one (complete inequality). The parameters of the model (6) are estimated simultaneously using the maximum likelihood estimator.

3.The Data

The data set is a yearly panel data for the 103 Italian Province for the period 2001- 2005[7] . We collected data on public health care system from Health for All of Italian National Institute of Statistics (ISTAT) . The data on corruption rate has been drawn from official surveys "*Information system on justice*" conducted by ISTAT . The descriptive statistics are reported in table 1. The outputs of our model are life expectancy at birth *(ASP_LIFE)* and infant mortality , *(INF_MOR)*. To improve our estimates scores, following Afonso and Aubyn

[7] After 2005 the Italian provinces are 110

(2005), we transform Infant Mortality Rate into Infant Survival Rate. The latter is preferred as a summary measure of premature mortality since it treats the life year saved – rather than life lost – as the unit of output (Or , 2000). Recall that the Infant Mortality Rate *(IMR)* is equal to:

$$IMR = \frac{(number\ of\ children\ who\ died\ before\ 12\ months}{number\ of\ born\ children} \times 10.000$$

Infant Survival Rate (ISR) is calculate as following:

$$ISR = \frac{(10.000 - IMR)}{IMR}$$

Three variables are considered as inputs into the health production process: the number of physicians per 10.000 inhabitants (PHYS) ; the number of hospital beds per 10.000 inhabitants; the Magnetic Resonance Imager (MRI) units per one million population. The socio-economic inputs are income_ per capita (INC), measured in Euro in nominal prices and adjusted for inflation; the Gini index (GINI); the dropout school rate (DROP_SC), measuring the percentage of students who drop out of school per 10.000 inhabitants; the corruption rate (CORR), measuring the ratio of crimes against public administration per 10.000 inhabitants.

$[TABLE\,1\ here]$

4. Results

Using the definition of Farrell-Debreu efficiency, we calculated the values of the output efficiency, assuming constant returns to scale (CRS). Table 2 shows the results of technical efficiency in the years 2001 and 2005 (respectively the first and the last year analyzed). For the sake of brevity in table 2 are reported only the provinces in the first and last positions (the complete ranking is given in Appendix). In 2001, the provinces at the top of the efficiency ranking are located in Northern Italy (Macerata, Florence,), while the provinces at the bottom of the ranking are located in southern Italy (Caserta and Naples). Also in 2005, the three provinces (Florence and Pesaro Urbino) at the top of the efficiency ranking are located in northern Italy; while at the bottom are found two southern Italian provinces (Caltanissetta, Caserta and Naples).

[*TABLE* 2 *here*]

[*FIGURE* 1 *here*]

Figure 1 shows the trends of efficiency score from 2001 to 2005 for all the provinces and for the two macro-areas of northern and southern Italy. It shows an increase of provincial health care efficiency (that is a reduction of estimated Debreu (1951) - Farrell (1957) efficiency measure), mainly in the northern provinces.

[*FIGURE* 2 *here*]

Figure 2 represents the distribution of efficiency scores, that confirms the divide between North and South of Italy; and the gap between efficient and less-efficient provinces increased during 2001-2003 and decreased from 2003 to 2005.

The socio-economic determinants of health care inefficiency: Bootstrap results The results of the relationship between inefficiency of the health care DMUs and socio-economic variables are shown in Tables 3 and 4. A positive sign of the explanatory variable indicates a negative effect on efficiency; while a negative sign indicates a positive influence on efficiency (Balcombe et al 2008). We report the coefficient and 95% confidence intervals. In table 3, we can observe the effects of socio-economic variables on the life expectancy, while table 4 reports the effects on infant survival rate.

[*TABLE* 3 *here*]

[*TABLE* 4 *here*]

We observed a positive relationship between efficiency and income per capita provincial *(INC)*: the efficiency increases with income in line as observed in previous studies (Green, 2004). *GINI* indicates that an increase in inequality causes a decrease in life expectancy and in infant survival rate, in line with Kennedy *et al.*, (1996) ; Kaplan *et al.*, (1996) that showed a direct relationship between income inequality and mortality rate. Dropout rate *(DROP_SC)* appear to have a negative impact on the health system DMUs Italian (positive values on estimated inefficiency). A similar result is obtained for the regional corruption rate.

5. Conclusion

In this paper, we have evaluated efficiency in health services across Italian provinces by assessing outputs (life expectancy, infant survival) against inputs directly used in the health system (doctors, beds, MRI units) and environmental variables (income per capita, drop out school, Gini index and corruption rate), applying the innovative two-stages procedure of Algorithm 2 proposed by Simar-Wilson (2007) to overcomes the problem of DEA. In methodological terms, we have employed a two-stage semi-parametric procedure. Firstly, output efficiency scores were estimated by solving a standard DEA problem with countries as DMUs. Secondly, these scores were explained in a regression with the environmental variables as independent variables. The fact that a provinces is seen as far away from the efficiency frontier is not necessarily a result of inefficiencies engendered within the health system. Our second stage procedures shows that income per capita, drop out school, Gini index and corruption rate are highly and significantly correlated to output scores. Non-discretionary outputs considered here cannot be changed in the short run. For instance, drop out high school is essentially given in the coming year. However, contemporaneous educational and social policy will have an impact on future educational attainment. A similar reasoning applies to corruption rate, which are difficult to change, (in particular in South of Italy) but where, for instance, anti-corruption policies, and greater transparency of the health policy should be considered and implemented by the governments. Further, our results suggest policy implications and drawbacks for the decentralization of healthcare when regional differences are wide. Without improving socio-economic conditions and administrative culture in less developed regions decentralization may enhance regional differences. This may require a strong role for central government in controlling and monitoring regional healthcare outcomes and to equalize the starting conditions between regions.

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Table 1: Table 1. Descriptive statistics

Variables	***Definitions***	***Mean***	***Std.Dev***	***Min.***	***Max.***
Health inputs					
PHYS	Rate of physicians/inhabitants (10.000)	18.84	4.97	0.86	37.07
BED	Rate of beds/inhabitants (10.000)	40.078	10,.004	16.89	91.42
MRI	Rate of Resonance Imager (MRI) units /inhabitants (10.000)	8.33	5.47	1	51.8
Social environmental inputs					
INC	Income per capita	19 170	4 910	10 320	32 762
CORR	Rate of crimes against public administration/inhabitants (10.000)	3.48	1.23	1.32	13.52
GINI	Gini index	0.28	0.02	0.22	0.33
DROP_SC	Rate of drop out school/student (10.000)	11.03	2.34	4,69	17,58
Health output					
LIFE_EXP	Life expenctancy at birth	80.37	0.89	78	82
MOR_INF	Rate of infant mortality (10.000)	38.29	11.51	10	89

Table 2: Technical efficiency score for Italia Provinces (2001-2005)

rank_2001	Prov.	TE	rank_2005	Prov.	TE
1	Macerata	1.0000	1	Firenze	1.0000
2	Firenze	1.0005	2	Pesaro Urbino	1.0000
3	Rimini	1.0078	3	Macerata	1.0000
4	Ascoli Piceno	1.0118	4	Ascoli Piceno	1.0000
5	Prato	1.0123	5	Rimini	1.0018
6	Pescara	1.0126	6	Chieti	1.0024
7	Siena	1.0130	7	Venezia	1.0028
8	Pordenone	1.0134	8	Ancona	1.0032
9	Forlì	1.0141	9	Ravenna	1.0034
10	Treviso	1.0148	10	Prato	1.0036
94	Caltanissetta	1.0395	94	Pavia	1.0282
95	Pavia	1.0401	95	Cremona	1.0285
96	Alessandria	1.0416	96	Messina	1.0290
97	Lodi	1.0420	97	Biella	1.0293
98	Gorizia	1.0437	98	Catania	1.0297
99	Catania	1.0447	99	Lodi	1.0308
100	Vercelli	1.0467	100	Aosta	1.0350
101	Aosta	1.0478	101	Caltanissetta	1.0355
102	Caserta	1.0481	102	Caserta	1.0404
103	Napoli	1.0538	103	Napoli	1.0461
	North	**1.0248**		**North**	**1.0145**
	South	**1.0274**		**South**	**1.0200**
	Average	**1.0257**		**Average**	**1.0116**
	Average	**1.0257**		**Average**	**1.0116**

Values of efficiency "output oriented" using the measure of efficiency Debreu (1951) - Farrell (1957) and corrected for Distortion. Estimates obtained using MatLab.

Table 3: **Truncated bootstrapped two-stage regression, dependent variable:life expectancy**

	Coefficient	Lower 95%	Upper 95%
CONST	0.9443*	0.9157	0.9726
DROP_SC	0.0149*	0.0115	0.0184
CORR	0.0034*	0.0026	0.0042
GINI	0.0346*	0.0248	0.0447
INC	−0.0228*	−0.0318	−0.0137

Notes: * implies significance at the 5 percent level. The estimation is done according to Algorithm 1and 2 of Simar and Wilson (2007) with 1,000 bootstrap replications for bias correction and 2,000 for confidence intervals of the estimated regression coefficient. The regressor is the DEA estimate of the unobserved inefficiency score of the countries. Estimations are done in MatLab.

Table 4: **Truncated bootstrapped two-stage regression, dependent variable: infant survival**

	Coefficient	Lower 95%	Upper 95%
CONST	18.4680*	15.7285	21.1459
DROP_SC	2.0421*	1.8145	2.2833
CORR	0.0500	−0.3931	−0.2948
GINI	4.5252*	3.5019	5.5927
INC	−1.6065*	−1.9148	−1.2788

Notes: * implies significance at the 5 percent level. The estimation is done according to Algorithm 1and 2 of Simar and Wilson (2007) with 1,000 bootstrap replications for bias correction and 2,000 for confidence intervals of the estimated regression coefficient. The regressor is the DEA estimate of the unobserved inefficiency score of the countries. Estimations are done in MatLab.

Figure 1: Trends of efficiency in health Italian Provinces 2001-2005

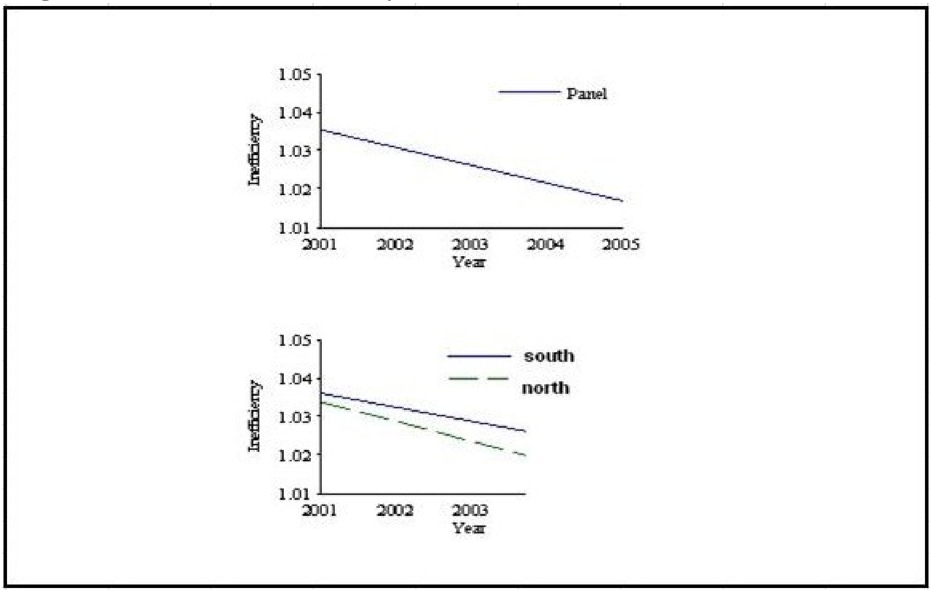
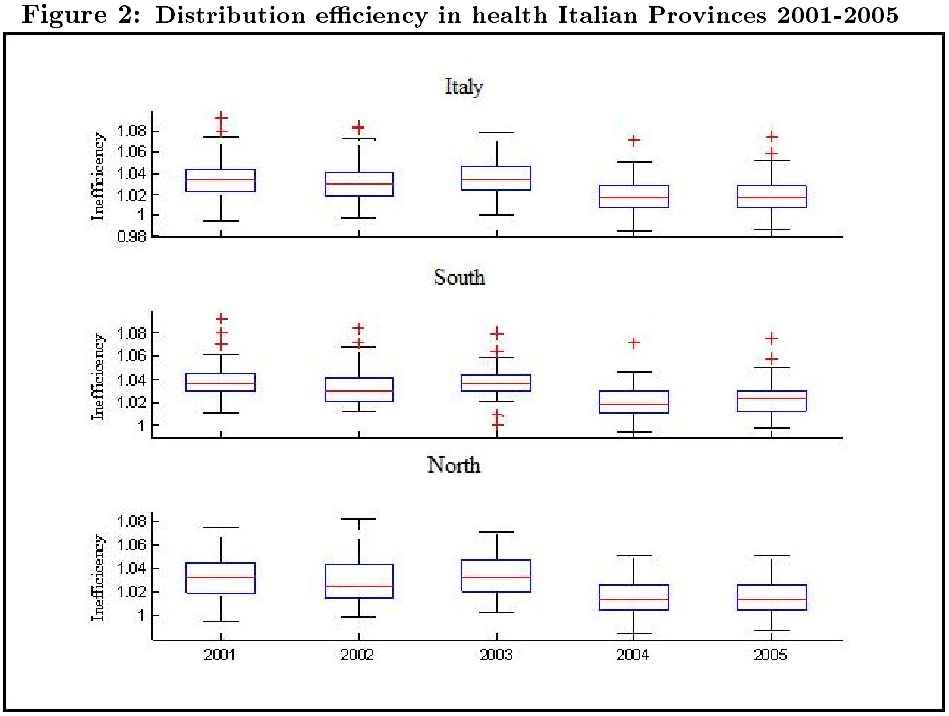


Figure 2: Distribution efficiency in health Italian Provinces 2001-2005



Appendix

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2	Firenze	1.0005	2	Pesaro Urbino	1.0000
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4	Ascoli Piceno	1.0118	4	Ascoli Piceno	1.0000
5	Prato	1.0123	5	Rimini	1.0018
6	Pescara	1.0126	6	Chieti	1.0024
7	Siena	1.0130	7	Venezia	1.0028
8	Pordenone	1.0134	8	Ancona	1.0032
9	Forlì	1.0141	9	Ravenna	1.0034
10	Treviso	1.0148	10	Prato	1.0036
11	Padova	1.0149	11	Forlì	1.0049
12	Pistoia	1.0151	12	Trento	1.0053
13	Verona	1.0152	13	Treviso	1.0055
14	Cosenza	1.0153	14	Modena	1.0060
15	Vicenza	1.0155	15	Padova	1.0074
16	Ancona	1.0156	16	Verona	1.0081
17	Pesaro Urbino	1.0157	17	Bologna	1.0086
18	Trento	1.0158	18	Pistoia	1.0090
19	Bologna	1.0164	19	Arezzo	1.0091
20	Varese	1.0172	20	Siena	1.0094
21	Ravenna	1.0175	21	Brindisi	1.0094
22	Modena	1.0184	22	Pisa	1.0095
23	Arezzo	1.0185	23	Vicenza	1.0096
24	Chieti	1.0185	24	Latina	1.0104
25	Bolzano	1.0190	25	Perugia	1.0106
26	Teramo	1.0192	26	Pescara	1.0111
27	Rieti	1.0195	27	Como	1.0112
28	Catanzano	1.0197.	28	Milano	1.0112
29	Oristano	1.0197	29	Varese	1.0114
30	Terni	1.0199	30	Lecco	1.0114
31	Brindisi	1.0199	31	Bolzano	1.0116
32	L'Aquila	1.0211	32	Brescia	1.0117
33	La Spezia	1.0212	33	Bari	1.0118
34	Frosinone	1.0218	34	Parma	1.0119
35	Venezia	1.0219	35	Lecce	1.0121
36	Lecco	1.0220	36	Cosenza	1.0121
37	Lecce	1.0220	37	Asti	1.0123
38	Torino	1.0221	38	Oristano	1.0123
39	Taranto	1.0222	39	Pordenone	1.0125
40	Como	1.0223	40	Teramo	1.0131

Table A1 (continued)

rank_2001	Prov.	TE	rank_2005	Prov.	TE
41	Pisa	1.0227	41	Rieti	1.0136
42	Perugia	1.0227	42	Frosinone	1.0138
43	Benevento	1.0228	43	Torino	1.0140
44	Bari	1.0233	44	Novara	1.0140
45	Campobasso	1.0236	45	Livorno	1.0140
46	Potenza	1.0241	46	Taranto	1.0141
47	Reggio Emilia	1.0242	47	Reggio Emilia	1.0143
48	Parma	1.0244	48	Cagliari	1.0143
49	Ragusa	1.0246	49	Mantova	1.0153
50	Cagliari	1.0249	50	Ragusa	1.0153
51	Mantova	1.0262	51	Trapani	1.0155
52	Vibo Valentia	1.0262	52	Imperia	1.0163
53	Novara	1.0264	53	Massa Carrara	1.0164
54	Napoli	1.0266	54	Campobasso	1.0164
55	Crotone	1.0267	55	Sassari	1.0165
56	Reggio Calabria	1.0268	56	Foggia	1.0168
57	Enna	1.0269	57	Genova	1.0173
58	Milano	1.0270	58	Gorizia	1.0178
59	Roma	1.0270	59	Avellino	1.0179
60	Matera	1.0272	60	Crotone	1.0179
61	Piacenza	1.0273	61	L'Aquila	1.0182
62	Brescia	1.0274	62	Bergamo	1.0183
63	Verbano C.O.	1.0274	63	Catanzaro	1.0184
64	Foggia	1.0278	64	La Spezia	1.0187
65	Genova	1.0281	65	Lucca	1.0189
66	Nuoro	1.0282	66	Matera	1.0192
67	Grosseto	1.0288	67	Terni	1.0197
68	Sassari	1.0288	68	Reggio Calabria	1.0198
69	Avellino	1.0289	69	Udine	1.0199
70	Livorno	1.0290	70	Piacenza	1.0206
71	Lucca	1.0294	71	Belluno	1.0207
72	Viterbo	1.0294	72	Savona	1.0211
73	Rovigo	1.0297	73	Potenza	1.0213
74	Siracusa	1.0297	74	Enna	1.0213
75	Cuneo	1.0298	75	Ferrara	1.0214
76	Bergamo	1.0300	76	Grosseto	1.0218
77	Messina	1.0301	77	Rovigo	1.0220
78	Latina	1.0304	78	Agrigento	1.0221
79	Salerno	1.0304	79	Cuneo	1.0222
80	Udine	1.0308	80	Vibo Valentia	1.0224

Table A1 (continued)

rank_2001	Prov.	TE	rank_2005	Prov.	TE
81	Cremona	1.0314	81	Benevento	1.0226
82	Agrigento	1.0315	82	Roma	1.0233
83	Massa Carrara	1.0318	83	Sondrio	1.0236
84	Savona	1.0320	84	Siracusa	1.0236
85	Asti	1.0327	85	Trieste	1.0238
86	Sondrio	1.0330	86	Salerno	1.0238
87	Ferrara	1.0330	87	Alessandria	1.0241
88	Biella	1.0337	88	Palermo	1.0248
89	Trieste	1.0338	89	Viterbo	1.0249
90	Palermo	1.0355	90	Verbano C.O.	1.0254
91	Isernia	1.0360	91	Nuoro	1.0254
92	Belluno	1.0372	92	Vercelli	1.0264
93	Imperia	1.0383	93	Isernia	1.0278
94	Caltanissetta	1.0395	94	Pavia	1.0282
95	Pavia	1.0401	95	Cremona	1.0285
96	Alessandria	1.0416	96	Messina	1.0290
97	Lodi	1.0420	97	Biella	1.0293
98	Gorizia	1.0437	98	Catania	1.0297
99	Catania	1.0447	99	Lodi	1.0308
100	Vercelli	1.0467	100	Aosta	1.0350
101	Aosta	1.0478	101	Caltanissetta	1.0355
102	Caserta	1.0481	102	Caserta	1.0404
103	Napoli	1.0538	103	Napoli	1.0461