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# Seeking the links between competition and telecommunications investments

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## 1. Introduction

This paper addresses the relationship between competition and investment in telecommunications, with a focus on developed countries. This issue has been at the center of policy debates since the mid-Eighties. Nevertheless the empirical research on the subject has been less continuous, and has not yielded compelling evidence.

It is generally acknowledged that competitive markets foster sector static efficiency, but their potential for dynamic efficiency remains a questionable issue. In particular, competition in telecommunications markets depends on pro-entry regulations. While fostering entrants' investments, measures as access regulation and unbundling obligations have been argued to hinder the incumbent's incentives to invest (Valletti, 2003; Pindyck, 2007; Cave, 2014). An in-depth analysis of the issue is also necessary to design broadband policies. Service-based competition was initially viewed as a stepping stone towards the roll-out of broadband networks (Cave & Vogelsang, 2003; Bourreau & Doğan, 2006). Questions then arose on the validity of the ladder-of-investment paradigm (Avenali, Matteucci, & Reverberi, 2010; Cambini, Hoernig, & Bohlin, 2012),

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especially if transition to fiber networks is the goal (Cave, 2014). Nowadays facility-based competition (FBC) is more commonly seen as an antecedent of Next Generation Networks.[1]

Eventually, after more than two decades of liberalization experiences, an ex-post assessment of the issue can be made, as the datasets that exist today cover a fairly large number of years. At the same time, gauging the effect of competition on investment in the telecommunications sector is still a challenge. The first empirical difficulty arises with the need to model the market opening process comprehensively. Absent alternative platforms such as cable networks, competition depends on regulations that make entry possible (Bouckaert, Van Dijk, & Verboven, 2010; Grajek & Röller, 2012; Cave, 2014). Second, confounding factors may be present, because the market opening process intertwines with other reforms, the most prominent of which is incumbent privatization (Lestage, Flacher, Kim, Kim, & Kim, 2013). Finally, investment feeds back on product market competition, in two main ways. The modernization of networks opens the way to service innovation, which in turn determines the market structure. Another reverse link may arise from pro-entry regulations, which have periodically been adjusted on the basis of concerns for investment (Armstrong & Sappington, 2006; Sadowski, Nucciarelli, & deRooij, 2009). In short, competition, policy instruments and investment are connected by a "complicated web of positive and negative effects" (Bauer, 2010). The empirical strategy should complement competition indicators with privatization and regulation indicators, and should allow for the possible endogeneity of independent variables.

It is thus no wonder that the available empirical evidence on the subject is inconclusive (Section 2). The relatively small number of econometric analyses that were performed in the decade following the pioneering cross-country study by Ros (1999) did not find a significant influence of competition on network investment. Later analyses instead found that entry deregulation spurs country-level investments, at least if certain accompanying measures are introduced (Wallsten, 2001; Fink, Mattoo, & Rathindran, 2003; Li & Xu, 2004; Alesina, Ardagna, Nicoletti, & Schiantarelli, 2005). Turning attention to the firm level, incumbent investments were initially considered not to be affected by product market competition (Bortolotti, D'Souza, Fantini, & Megginson, 2002; Jung, Gayle, & Lehman, 2008), but a recent article by Lesteage et al. (2013) has shown that competition has different effects on investment when incumbent ownership is taken into account. Finally, pro-entry regulations have been proven to have a null or negative effect on investment for both the incumbent and individual entrants (Grajek & Röller, 2012).

The research illustrated in the remainder of this paper adopts a neutral view of the relationship between competition and telecommunications investment. It also takes a wider perspective than other analyses on the same subject (e.g. Lestage et al., 2013), which generally privilege the in-depth investigation of a single theoretical question and use a single econometric approach. The present paper instead exploits multiple empirical models and methods, in an attempt to glean information on possible regularities in the competition–investment relationship at country and firm levels. Three very broad research questions are addressed:

- Does progress towards competitive markets determine telecommunications investments?
- Is pro-entry regulation a driver of infrastructure investments per se, or conditionally on its ability to spur competition?
- Is an accompanying measure as privatization necessary for competition to have an impact on investment?

Our first step was a retrospective and naïve look at the evolution of country-level telecommunications investments in 18 OECD economies. We have looked for unknown breakpoints in investment time series from 1975 to 2007, and discussed whether upward and downward shifts can be associated to the market opening events (Section 3). In order to remove the possible aggregation bias that arises from entrants' investments and the deployment of mobile networks, we then focused on the market leader, i.e. the incumbent, and controlled for the diffusion of mobile communications (Sections 4 and 5). The empirical analysis has been carried out on a sample of 29 incumbents from OECD countries (1993–2008). The causality relationship between firm-level investment and competition indicators, and the presence of unit roots have been explored, since reverse causality and non-stationarity of indicators cannot be excluded. Finally, micro-econometric models of firm-level investment have been specified and estimated through dynamic panel methods. The Bond–Meghir model takes into account endogeneity problems and offers a thorough representation of investment determinants at the firm level. As such, it has the potential to control confounding factors, and to insulate the effect of pro-entry regulation and competition on investment.

The paper is organized as follows. After a review of the previous empirical studies on competition, reforms and investment (Section 2), the structural break analysis is presented (Section 3). The empirical strategy adopted to model the incumbent's investment is then discussed (Section 4). The empirical findings are then reported and discussed (Section 5). Finally, some concluding remarks are presented (Section 6).

## 2. Literature review

This section synthesizes the most relevant theories on competition and investments for telecommunications. It then surveys results obtained by the extant empirical literature, with an emphasis on firm-level studies that investigate incumbents' investments.

[1] Since 2003, the US has shifted from network-sharing regulations towards a market-driven approach (Bauer, 2010). Supply-side aids can only be granted by the European Union governments to areas that are underserved or served only by one broadband network operator, provided that the eligibility criteria are met, while competitive areas are excluded from such policies (Sadowski, Nucciarelli & deRooij, 2009; European Commission, 2013).

First, the development of more advanced communication networks should be regarded as an innovation effort that is instrumental in differentiating the offered services. Aghion, Bloom, Blundell, Griffith, and Howitt (2005) show that the relationship between competition and innovation is better described as an inverted u-shaped function. If competition intensity increases from null to low or medium levels, as is the case of recently liberalized communications, firms try to escape rivalry through quality-enhancing innovations.[2] At higher levels of competition, a Schumpeterian effect emerges. Second, privatization may have a direct effect on investment, but it may also moderate the impact of market opening. Hart, Shleifer, and Vishny (1997) predict that private-sector firms are likely to indulge in cost-reducing activities, with possible noxious effects on quality-enhancing investments, unless the market is competitive. However, D'Souza, Megginson and Nash (2005) show that firms' capital expenditure increases significantly after privatization, and partial privatization especially, without sizeable differences between competitive and regulated industries. Finally, theories do not provide clear-cut predictions of the relationship between pro-entry regulation and investment. In short, cost-based access prices discourage the incumbent's investment (Jorde, Sidak, & Teece, 2000; Valletti, 2003). Facility-sharing and unbundling obligations shift the investment risk from entrants to incumbent (Pindyck, 2007). However, open access is not necessarily at odds with incumbent investments and service quality, if service-based competition is perceived as a temporary measure that allows entrants to learn about costs and customer preferences and to climb the first rung of an investment ladder (Cave & Vogelsang, 2003; Cave, 2006).[3]

The early empirical works used country-level data to analyze the impact of liberalization on investment and other performance indicators (e.g. efficiency, profitability, and employment). Ros (1999) reveal that ITU countries that permitted competition in basic services did not differ from monopolistic countries with reference to network expansion during the 1986–1995 period. Li and Xu (2004) analyze a comprehensive panel data set (162 countries observed from 1990 to 2001) and found that privatization and competition spur investments, especially when adopted together. Wallsten (2001) explore the performances of 30 African and Latin American industries from 1984 to 1997. He found that competition increases the number of mainlines only if it is accompanied by the institution of an independent regulator. Fink et al. (2003) analyze 86 developing countries over the 1985–1999 period. A comprehensive reform program, involving liberalization, privatization and the institution of an independent regulator, produced the largest gains. Similar results were obtained by Alesina et al.(2005) who find that private ownership has a weakly significant positive effects on investment for various regulated industries of OECD countries. Likewise, the marginal effect of deregulation on investment is increasing, i.e. small changes in a heavily regulated environment are not likely to produce much of an effect.

Firm-level studies return a richer picture. We focus our survey on empirical analyses of incumbents' investments. Bortolotti et al. (2002) use firm-level data of 31 communication companies from 25 developed and developing countries. The authors showed that neither privatization nor competition affected firm-level investment. However they focus on the 1981-1998 period, that is, they do not observe the effects of regulatory reforms for some countries. A more recent analysis, by Jung et al. (2008), shows that competition from entrants had a weak effect on investments by the US ILECs, provided that the persistence of investment is appropriately modeled. Finally, based on a sample of firms from 20 OECD countries (1994–2008), Lestage et al. (2013) discover that competition intensity fosters State-owned incumbents' capital expenditures, while it acts on private incumbents in the opposite way (i.e. opposite to Hart et al. (1997)

Any investigation of the competition–investments relationships in the telecommunications has to allow for the role of pro-entry regulation. It could be argued that firms' investment decisions are driven mainly by regulation, because current competition is a product of past reforms, while expectations about future competition lean on current regulation. Most of recent empirical studies have been centered on pro-entry regulation, i.e. mandated facility-sharing and local loop unbundling that favor service-based competition. Altogether, the results are not conclusive on the hypothesis that pro-entry regulation may represent a move towards a more intense development of advanced facilities.[4] The review of Cambini and Jiang (2009) suggest that the "ladder-of-investment" theory was neither confirmed nor rejected by econometric analyses. A part of empirical studies provided evidence on the advantages of facility-based competition, as opposed to access-based competition. Di Staso, Lupi and Manenti (2006) examine 14 European countries and discovered that facility-based competition is a key driver of broadband uptake, while pro-entry regulation plays a less significant role. Denni and Gruber (2007) analyze the US market and confirmed that in the long term access-based entry plays a minor role. However, firm-level analyses of the impact of pro-entry regulation on incumbent investments have so far offered mixed evidence. Chang, Koski, and Majumdar (2003) show that a lower access price promotes a greater deployment of digital technology among the ILECs. Willig (2006) also confirms that the prices of unbundled elements are negatively related to the incumbent's investment. Hausman and Sidak (2005) instead show through country studies that unbundling regulations is likely to curb the incumbent's investment. Similarly, Waverman, Meschi, Reillier, and Dasgupta (2007) estimate the demand for broadband lines in 12 European countries, and showed that lower local loop prices have created the conditions for

[2] Competition in one or few markets could be sufficient to offer the provider greater incentives to invest in service differentiation, because reputation spills over from competitive to regulated markets (Weisman, 2005).

[3] Consistently with this paradigm, dynamic access price regulation, that is rising access charges, has been proposed to foster facility-based competition (FBC) and to encourage the entrant to roll out its own network (Bourreau & Doğan, 2006). To this aim, the regulatory commitment to not reduce access charges ex-post can be considered a critical condition, while it is still unclear when access regulation should be removed to leave room for FBC (Avenali et al., 2010).

[4] An additional measure is functional separation, in different forms (Teppayon & Bohlin, 2010).

service-based operators to gain market shares, but access-based competition is achieved at the price of the development of alternative broadband facilities. Grajek and Röller (2012) use a sample that included more than 70 fixed-line operators from 20 EU countries during the 1997–2006 period. They found that regulators respond to higher investment by incumbents by mandating unbundling and facility sharing, which in turn discourages investment by incumbent and individual entrants.

From a methodological point of view the studies by Grajek and Röller (2012) and Lestage et al. (2013) are the most relevant references. The present empirical analysis should be considered as a continuation in the direction indicated in those investigations, with a few qualifications that will be discussed in Section 4.

## 3. Seeking breakpoints in investment series

As a first analysis, evidence is provided in this section on the occurrence of structural changes in investment at a country level. The analysis is aimed at assessing whether breakpoints are present in the country's total investments and whether they appear to be associated with major market reforms (i.e. liberalization of fixed voice markets; unbundling obligations).

A first step based on a macro-economic approach has three main justifications. It is true that incumbents are the main market players, and would be especially worth investigating. Unfortunately annual reports and other certified sources of firm-level investment data are available in most cases only after the privatization of former monopolists. With few exceptions, firm-level series are too short for a breakpoint analysis. Likewise regulatory reforms targeted fixed networks, and mobile investments should be subtracted from investment series. Mobile investments are available only for a few countries though. Finally, and in spite of the mentioned limitations, country-level analysis may still provide us with indirect yet valuable evidence on firm-level dynamics. By definition entrants and mobile operations increase fixed capital. If a downward shift is detected in aggregate investments in recent decades, i.e. despite new entries and the deployment of mobile networks, it could be concluded that incumbent's investments in fixed networks decreased.

We are aware that the analysis does not allow us to draw any conclusions on causal relationships, and put off this issue to Sections 4 and 5. We also acknowledge that the sample size is limited (i.e. 33 observations in the longest time series), and empirical results will only preliminarily indicate the presence (absence) of structural changes. At the same time we argue that this approach supports a preliminary statistical and visual check on the connection between market reforms and investment variations (see also the Appendix figures).

We used the methodology that was developed by Bai and Perron (1998, 2003). It has a few advantages against other similar techniques (Jones and Olken, 2008). Breakpoints are not chosen a priori, but they are determined by data. In order to detect unknown breakpoints, *F* statistics are computed over all possible breakdates. A breakpoint is stated to exist in the date for which the *F* statistic takes the largest value. As a result, major changes rather than mere turnarounds are captured. The Bai–Perron method extends the received approach, by allowing for multiple breakpoints. The total telecommunication investments (million US $) have been collected for 18 OECD countries, from 1975 to 2007, from the ICT Indicators Database provided by ITU.[5] The variable was deflated by the producer prices index for investment goods sourced by OECD (2005 US $).

We tested for the presence of one or two breakpoints in the series mean. The Bai–Perron model estimates are reported in the Appendix (Table A.2). The Appendix also reports the investment graphs and break dates for each country (Fig. A.1). It should be reminded that the variable sums up the investments of entrants and incumbent. Only one breakpoint has been detected for the investment series of Denmark, New Zealand, and Switzerland, while two breakpoints have been detected in the remaining 15 countries, at different times.

Table 1 illustrates the main results of structural break analysis. Given the purpose of the paper, only breakpoints that could be associated with market reforms are discussed in the rest of this section, while Table A.2 and Fig. A.1 of Appendix should be referred to for complete results.[6] Major reform milestones are summarized by Table A1 in the Appendix. Table 1 reports a classification of countries based on the temporal association between two market reforms, i.e. liberalization and unbundling obligations, and detected breakpoints. An association is identified whenever one break occurs in a time window around the market reform, from three years before to three years after. “Up-breaks”, i.e. breaks after which the investment mean increases, are then distinguished from “down-breaks”, i.e. breaks after which the investment mean decreases.

Table 1 summarizes the most interesting results, and reveals a substantial cross-country heterogeneity. Four main groups of countries are identified. For some countries, a positive effect of liberalization or unbundling on total investments cannot be excluded. Australia, Denmark, Greece, the Netherlands, and Spain experienced an “up-break” in coincidence with the liberalization of trunk telephony and the adoption of unbundling obligations. Moreover, an increase in the mean of total investments is estimated for Mexico, New Zealand, Sweden and Turkey in association with one of the two reforms.[7] The deployment of mobile networks or the completion of network digitization could have caused the investment upsurge, but the liberalization of wireline services and pro-entry regulations could have played a role as well. Market reforms do not appear to be associated with investment shifts for another group of countries, i.e. Belgium, France, Italy, Portugal and

[5] Countries are Australia, Austria, Belgium, Denmark, France, Germany, Greece, Hungary, Italy, Japan, Mexico, the Netherlands, New Zealand, Portugal, Spain, Sweden, Switzerland and Turkey. A sufficiently long time-series was not available for other OECD countries.

[6] For instance, several countries experienced an “up-break” during the Eighties, that is, earlier than market reforms. Network digitization programs are a likely explanation of the investment structural increase, also because two countries that decreased significantly their investment levels after 1980, i.e. Belgium and France, had been first movers in the digitization cycle. While relevant in its own this result is barely related to our research questions.

[7] Mexico did not implement unbundling in the observed years.

**Table 1**
Market reforms and breakpoints in countries' investment series (1975–2007).

| | *Up-break in the time window around market reforms* [a,b] | *Down-break in the time window around market reforms* [a,b] | *No break detected in the time window around market reforms* [a,b] |
|---|---|---|---|
| ***Liberalization***[c] | Australia<br>Denmark<br>Greece<br>Mexico<br>The Netherlands<br>New Zealand<br>Spain | Austria<br>Germany<br>Hungary | Belgium<br>France<br>Italy<br>Japan<br>Portugal<br>Sweden<br>Switzerland<br>Turkey |
| ***Unbundling***[c] | Australia<br>Denmark<br>Greece<br>The Netherlands<br>Spain<br>Sweden<br>Turkey | Austria<br>Germany<br>Hungary<br>Japan | Belgium<br>France<br>Italy<br>New Zealand<br>Portugal<br>Switzerland |

Notes.

[a] A [−3 years; +3 years] time window around the market reform years is explored.

[b] Up-break: the mean of investment series after the break is larger than before; down-break: the mean of investment series after the break is smaller than before; the break year is the final year of the prior investment regime; see estimation details in Table A2 of the Appendix.

[c] Market reforms are trunk telephony liberalization and adoption of unbundling or facility-sharing obligations; Mexico did not implement unbundling in the observed years.

Switzerland. Finally, reforms are associated with down-breaks in remaining countries (Austria, Germany, Hungary, and Japan).

Our method does not prove causation between market reforms and investment shifts. Nevertheless, whenever market reforms are associated to investment down-breaks, or no significant shifts, it can be argued that the incumbent has changed its investment conduct, because mobile investors and new entrants can only have made capital additions in those years.

In sum, the breakpoint analysis does not point to a uniform pattern for the sample countries. Only for some of them have significant breakpoints been detected around the pro-entry reforms. Furthermore investments result to rise after the break in some countries, and to decrease in others. The ambiguous empirical results do not necessarily mean that country-level investment and competition are totally unrelated. Rather, the relationship is likely to take various and even diverging forms, depending on contingent country-specific characteristics, such as the joint implementation of different market reforms or the presence of accompanying privatization programs.

## 4. Competition and the incumbent's investments: Empirical methods

The analysis of investment time series yields mixed results on the effects of liberalization and unbundling (Section 3). The lack of clear findings could be caused by an aggregation bias, i.e. entrants have different shares in different countries and follow investment patterns that are different from the incumbent. Additionally, no causality analysis has been performed.

We thus move to the firm level and focus on the sector leader, i.e. the incumbent. In principle, an analysis of entrants would also be worthwhile, but we believe that the mix of country-level evidence (Section 3) and incumbent-specific results (Section 5) offers a fairly comprehensive picture of competition–investments relationship. Impacts on incumbents' investments are more puzzling than impacts on entrants' investments, which cannot be depressed by market opening and unbundling obligations.

The broad research questions mentioned in Section 1 can be rephrased as follows: Is the incumbent likely to modify its fixed investment if product markets become more competitive? Is mandatory unbundling a driver of incumbent's investments per se or conditionally on its ability to foster competition? Is the impact moderated by an accompanying condition such as privatization?

We are aware that even nowadays samples are inevitably small, and the reform indicators are likely to be mutually collinear and endogenous to a firm's conduct and performances. These problems have motivated our decision to adopt a three stage empirical strategy.

A preliminary investigation of the investment dynamics is aimed at seeing whether deregulation and competition have caused *à la* Granger incumbent investments or vice versa. A test of stationarity is then conducted in order to identify consistent results. Finally, a structural investment model is specified according to the so-called Bond–Meghir, or micro-econometric, approach (Bond & Meghir, 1994; Bond & Van Reenen, 2007). The central feature of the model is a thorough

representation of the investment decision made by the firm. As a result, the risk of omitted variables is by far smaller than in the univariate analysis that has been discussed in Section 3 or the same Granger bivariate analysis.

### 4.1. Data and variables

Data have been collected on financial and economic indicators for the incumbents of 27 OECD countries over the 1993–2008 period. The dataset is an unbalanced panel of 29 incumbents (i.e. 2 firms are from the US while Telia–Sonera is analyzed as a separate enterprise from Telia and Sonera). The panel is unbalanced, since information is missing for a few firms in the early years, as can be seen in Table 2.

Table 3 gives the definition and sources of the variables. The key variable is *I/K*, i.e. the investment rate or the ratio between fixed (tangible and intangible) investments and the lagged level of fixed assets. The baseline structural investment model includes other financial indicators: the cash flow rate, *CF/K*, the debt rate, *D/K,* and the sales rate, *S/K*. These indicators are defined as the ratio between, respectively, the cash flows originating from operating activities, current and non-current

**Table 2**
Sample.

| State | Firm | Years |
|---|---|---|
| Australia | Telstra | 1995–2008 |
| Austria | Telekom Austria | 1998–2008 |
| Belgium | Belgacom | 1997–2008 |
| Canada | Bell Canada | 1994–2008 |
| The Czech Republic | Cesky Telecom | 1998–2008 |
| Denmark | TDC | 1995–2008 |
| Finland | Sonera | 1997–2001 |
| France | France Telecom | 1996–2008 |
| Germany | Deutsche Telekom | 1994–2008 |
| Greece | Ote | 1995–2008 |
| Hungary | Matav | 1996–2008 |
| Ireland | Eircom | 1999–2006 |
| Italy | Telecom Italia | 1998–2008 |
| Japan | NTT | 1998–2008 |
| Korea | Korea Telecom | 1997–2008 |
| Mexico | Telmex | 1994–2008 |
| The Netherlands | KPN | 1995–2008 |
| New Zealand | Telecom New Zealand | 1995–2008 |
| Norway | Telenor | 1998–2008 |
| Poland | TPSA | 1998–2008 |
| Portugal | Portugal Telecom | 1994–2008 |
| Spain | Telefonica | 1998–2008 |
| Sweden | Telia | 1997–2001 |
| Sweden/Finland | Teliasonera | 2002–2008 |
| Switzerland | Swisscom | 1995–2008 |
| Turkey | Turk Telekom | 2005–2008 |
| The UK | British Telecom | 1993–2008 |
| The US | AT&T | 1993–2008 |
| | Verizon | 1993–2008 |

**Table 3**
List of variables.
*Sources.* Conway and Nicoletti (2006); Annual company reports; Datastream; OECD Communication outlooks; OECD International Regulatory Database.

| Variable | Definition |
|---|---|
| *I* | Total fixed investment |
| *K* | Total fixed assets |
| *CF* | Cash flow from operating activities |
| *D* | Total current and non-current liabilities |
| *S* | Total sales |
| *Comp* | 6 – OECD “market power” indicator |
| *Nett* | New entrants market share in trunk telephone market (%) |
| *Neal* | New entrants market share in access lines (%) |
| *Unb* | Unbundling obligations (i.e. the indicator is equal to 1 if local loop unbundling or facility-sharing are mandatory, to 0 otherwise) |
| *Priv* | Private shareholding (%) |
| *Gdpcap* | Gross domestic product per capita |

**Table 4**
Descriptive statistics.

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| *I/K* | 319 | 0.149 | 0.074 | 0.037 | 0.451 |
| *CF/K* | 319 | 0.246 | 0.091 | −0.075 | 0.596 |
| *D/K* | 319 | 1.226 | 2.000 | 0.055 | 28.233 |
| *S/K* | 319 | 0.854 | 0.282 | 0.292 | 1.968 |
| *Comp* | 330 | 2.668 | 1.331 | 0 | 5.55 |
| *Nett* | 330 | 0.250 | 0.189 | 0 | 0.688 |
| *Neal* | 255 | 0.062 | 0.097 | 0 | 0.68 |
| *Unb* | 356 | 0.629 | 0.484 | 0 | 1 |
| *Priv* | 356 | 0.711 | 0.322 | 0 | 1 |
| *Ln(Gdpcap)* | 344 | 10.251 | 0.348 | 8.930 | 10.975 |

liabilities, sales and the lagged level of fixed assets. The mentioned indicators have been sourced from financial reports of firms and from Data stream.

Additional information has been gathered on reforms from reports and datasets provided by the OECD. *Comp*, i.e. the overall competition indicator, has been constructed from an OECD elementary indicator for the telecom sector (see OECD International Regulatory Database), which represents the new entrants' market shares in mobile services and fixed trunk as well as international services ("market power"). The elementary indicators range from 0 (low level of market power) to 6 (high level), and *Comp* is defined as its complement (i.e. it is set equal to 6 minus the "market power" indicator).

In order to have a more precise competition measure in the fixed telephone market, we have defined the variable *Nett* (market share of new entrants in the trunk telephony market) as the market shares of entrants in the trunk market. We have also been able to collect information on the entrants' market shares on the market for fixed access lines from the OECD Communication Outlook.[8] The indicator is *Neal* (market share of new entrants in access lines, not including unbundled or resold lines). In order to measure the relevance of pro-entry regulation, the chosen indicator is *Unb*, i.e. a binary variable that is set equal to 1 if the unbundling or sharing of access networks is mandatory. Ownership is controlled for through *Priv*, i.e. the percentage of shareholding owned by private investors or financial markets, is the measure of privatization. The GDP per capita variable is included in the structural investment model as a control variable.

Table 4 reports the descriptive statistics of the variables while Table 5 shows the correlation matrix. A fortunate circumstance is the weak correlation that reform and competition variables have mutually and with baseline variables (Table 5).

### 4.2. Models

Empirical analyses of the telecommunications industry are increasingly making use of the Granger method to investigate causality relations between variables, and to test endogeneity.[9] A causality test has been conducted to find out whether competition, as measured by *Z* variables (i.e. *Comp, Nett,* and *Neal*), causes the incumbent's investment, as measured by the investment rate *I/K*, or vice-versa.[10] Secondly, since the stationarity of variables is a pre-requisite for the consistency of dynamic panel estimates, unit roots have been sought in all variables in coincidence with causality analysis. The null hypothesis is the presence of unit roots in all panels, i.e. countries. Tests have been conducted under different specifications by making use of the so-called LLC and Fisher-like methods.[11]

The following two equations have been estimated for each competition indicator:

$$\frac{I_{i,t}}{K_{i,t-1}} = \alpha_1 \frac{I_{i,t-1}}{K_{i,t-2}} + \beta_1 Z_{i,t-1} + \mu_i + \lambda_t + \varepsilon_{i,t}, \tag{1}$$

$$Z_{i,t} = \gamma_1 Z_{i,t-1} + \delta_1 \frac{I_{i,t-1}}{K_{i,t-2}} + \mu_i + \lambda_t + \omega_{i,t}, \tag{2}$$

[8] The missing individual values were computed through linear interpolation; 7% of the observations were constructed in this way.

[9] For instance see Edwards and Waverman (2006), Gasmi and Recuero Virto (2010), Bortolotti, Cambini, Rondi, and Spiegel (2011), and Cambini and Rondi (2012).

[10] The same analysis cannot be conducted on *Unb*, even though unbundling obligations and other pro-entry regulations were introduced exactly to promote competition, due to the binary nature of the indicator. The econometric research has started addressing causality relationship and discrete variables only recently and not for panel data (Mosconi & Seri, 2006).

[11] The null hypothesis that unit roots are present in all panels, i.e. countries, has been tested in ten different ways. The Fisher-like method combines the *p*-Values from the panel-specific unit root tests using four statistics (Choi, 2001). It has been used in addition to the so called LLC test developed by Levin, Lin, and James Chu (2002). In all cases, the auto-regressive processes allow for cross-country correlation because OECD countries have acted in pretty similar ways in the domain of regulatory reforms, i.e. models demean the series. On the other hand, since we do not have precise conjectures about the evolution of variables over time, both models that include and do not include a linear time trend are estimated.

**Table 5**
Correlation matrix.

| Variable | *I/K* | *CF/K* | *D/K* | *S/K* | *Comp* | *Unb* | *Nett* | *Neal* | *Priv* |
|---|---|---|---|---|---|---|---|---|---|
| *I/K* | 1.000 | | | | | | | | |
| *CF/K* | 0.337 | 1.000 | | | | | | | |
| *D/K* | 0.396 | 0.062 | 1.000 | | | | | | |
| *S/K* | 0.552 | 0.672 | 0.375 | 1.000 | | | | | |
| *Comp* | −0.116 | −0.115 | 0.139 | 0.003 | 1.000 | | | | |
| *Unb* | −0.159 | −0.056 | 0.070 | 0.043 | 0.428 | 1.000 | | | |
| *Nett* | −0.078 | −0.034 | 0.184 | 0.074 | 0.913 | 0.312 | 1.000 | | |
| *Neal* | −0.199 | −0.060 | −0.006 | −0.031 | 0.509 | 0.227 | 0.406 | 1.000 | |
| *Priv* | −0.197 | −0.083 | −0.023 | −0.157 | 0.392 | 0.100 | 0.319 | 0.449 | 1.000 |

where $\mu_i$ and $\lambda_t$ are the unobservable country- and time-specific characteristics and $\varepsilon_{i,t}$ and $\omega_{i,t}$ are the i.i.d. disturbance terms. A long-run effect of independent variables is admitted owing to the lagged dependent variable.[12] Estimates are obtained by means of two dynamic panel data methods, the corrected Least Square Dummies Variable method (LSDVc; Bruno, 2005), and the Difference Generalized Method of Moments (GMMd; Arellano & Bond, 1991). They can be considered as being relatively complementary, since they rely, respectively, on the assumptions that the explanatory variable is exogenous, and the sample is not too limited in size.[13] As regards the GMMd estimator, the weakest possible assumption has been made and, in addition to the lagged dependent variable, all the competition variables have been considered as being potentially endogenous. In other words, lagged values have been employed in $t-2$ and $t-3$ as instruments for both types of variables in Equations sets (1) and (2).

The structural investment model portrayed by Eq. (3) is rooted in a well-established tradition that analyzes the derived demand for capital at a firm level (Bond & Meghir, 1994; Bond & Van Reenen, 2007). Profit flows are maximized under the assumption of adjustment costs, i.e. time and cost frictions that accompany investment decisions and realizations. The following expression was used as the baseline model:

$$\frac{I_{i,t}}{K_{i,t-1}} = \rho\frac{I_{i,t-1}}{K_{i,t-2}} + \beta_1\left(\frac{I_{i,t-1}}{K_{i,t-2}}\right)^2 + \beta_2\left(\frac{CF_{i,t-1}}{K_{i,t-2}}\right)^2 + \beta_3\left(\frac{D_{i,t-1}}{K_{i,t-2}}\right)^2 + \beta_4\left(\frac{S_{i,t-1}}{K_{i,t-2}}\right)^2 + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

where $\mu_i$ and $\lambda_t$ are the unobservable country- and time-specific characteristics and $\varepsilon_{i,t}$ is the i.i.d. disturbance term. The baseline model is then augmented to include the lagged competition and reform variables. The lagged dependent variable takes into account the persistence of series and the squared lagged dependent variable controls adjustment costs.[14] Financial sourcing reflects into the debt and cash flow rates. The cash flow variable, in particular, is included to account for capital market imperfections and asymmetric information problems. The term related to sales is used to control increasing returns to scale and imperfect competition.

In principle, an investment model should take into account the wide technological change occurred in telecommunications networks in last decades, i.e. factors such as transmission and switching digitization, the development of mobile communications, advances in opto-electronic technologies and so on. Unfortunately cross-country datasets are not available for technology progress and penetration indicators for the whole sample, or are not sufficiently consistent over time, with the possible exception of mobile services and technologies (see Section 5 for a related robustness check). Nevertheless, we believe that the inclusion of fixed year effects in (3) allows us to capture major shifts in the global supply of new technologies.

Estimates of the enlarged version of Eq. (3) are obtained through two dynamic panel techniques, GMMd and Within-group Least Squares (WG). The LSDVc estimator would be inappropriate here because it cannot fix the endogeneity of the squared lagged dependent variable. The GMMd estimator takes into account the endogeneity of independent variables, but it makes an extensive use of internal instrumental variables, i.e. lagged model variables, and for this reason it does not perform very well for small samples. Thus additional GMMd estimates that make use of external instruments are obtained. External instruments are used both in combination with internal variables and alone. Following a well-established approach to this issue (Ai & Sappington, 2002; Bortolotti, Cambini, & Rondi, 2013), external instruments are drawn from

[12] The long-run effect is equal to $\beta_1/(1-\alpha_1)$ or to $\delta_1/(1-\gamma_1)$ (Garrone & Grilli, 2010). A different specification, which includes the two lags of both the dependent and independent variables in Eqs. (1) and (2), has not provided different results from the results reported in Table 5 and, above all, has always been rejected in the restriction tests.

[13] The LSDVc estimator differs from the traditional Within Group (WG) technique, since it takes into account the endogeneity of lagged dependent variable.

[14] Adjustment costs reflect frictions in the change of input factors. They are assumed to be strictly convex and differentiable, which will tend to smooth the adjustment of quasi-fixed factors to new information, since a series of small adjustments is assumed to be cheaper than a single large change in the level of these inputs (Bond & Meghir, 1994).

**Table 6**
Incumbent investments: Causality analysis *à la* Granger.

| **Direct causality links** | **GMMd**[a] | **LSDVc**[a] |
|---|---|---|
| *Comp→I/K* | 0.014 (0.018) | 0.004 (0.007) |
| *Nett→I/K* | 0.126 (0.140) | 0.012 (0.039) |
| *Neal→I/K* | −0.559 (1.045) | 0.058 (0.099) |
| *Time- and country-specific effects* | Yes | Yes |
| **Reverse causality links** | | |
| *I/K→Comp* | −1.337 (0.837) | −0.944** (0.438) |
| *I/K→Nett* | −0.184 (0.194) | −0.090 (0.118) |
| *I/K→Neal* | 0.004 (0.112) | 0.240*** (0.073) |
| *Time- and country-specific effects* | Yes | Yes |

Notes.
[a] Standard errors in parentheses; ***, ** and *: significance levels equal to 1%, 5% and 10%, respectively; estimates and tests performed by the Stata 11 software; see the Appendix for estimation details.

political-institutional indicators of the World Bank Database of Political Institutions (Beck, Clarke, Groff, Keefer, & Walsh, 2001), namely government stability, political orientation, election date, and the presence of checks and balances.

## 5. Competition and the incumbent's investments: results

This section illustrates econometric results at the firm level. As a preliminary analysis, a bivariate causality analysis has been conducted to learn whether incumbent investment is caused by changes occurred in product market competition, or vice versa (see Granger models, (1) and (2)), i.e. to test endogeneity of competition variables. In order to assess the validity of causality analysis, the presence of unit roots has been tested. The joint use of stationarity and causality results allows us to decide upon competition indicators that can be included in model (3). The core part of this section consists in the presentation and discussion of WG and GMMd estimates of the structural investment model. Finally, a robustness check that controls for the penetration of mobile communications is illustrated.

The results of causality analysis are summarized in Table 6 (see also Tables A.3 and A.4).
The bivariate models do not reveal direct or reverse robust causality patterns, between investment and individual measures of competition. Although the LSDVc estimates of *I/K* coefficients in the reverse models of *Comp* (i.e. a synthetic measure of market power in individual markets) and *Neal* (i.e. market share of new entrants in access lines, not including unbundled or resold lines) are significantly different from 0, the GMMd estimates are not significant at standard levels. For the sake of synthesis, here we summarize the empirical evidence resulting from the ancillary analysis of stationarity, but detailed results are available upon request from authors. According to the tests that have been introduced in Section 4.2, the risk of spurious correlations is unlikely to be significant, because the dependent variable, *I/K*, is found to be stationary, irrespectively of tests and specifications. The stationarity of *Comp* and *Nett* is also robust to tests and specifications, while the remaining indicator, *Neal*, may be either stationary or integrated of order 1.

Findings obtained so far are interesting for a few reasons, even though we acknowledge that the test and treatment of unit roots in small micro-econometric panels are not without uncertainty (Baltagi, 2013, pp. 275–276). First, Granger analyses offer a preliminary hint about the general weakness of the relationships between incumbent's investments and market reforms, at least when the latter are not considered jointly. Second, results from the stationarity tests confer a greater robustness to causation links that have been estimated for *Comp* and *Nett*, while they confirm the opportunity to leave *Neal* aside. Finally, results from causality analyses allow us to exclude that *Nett* is endogenous to investment, differently from *Comp* and *Neal*. [15] Overall, causality and stationarity analyses lead us to include only *Nett*, i.e. the market share of new entrants in fixed trunk telephony, as a competition proxy in structural investment models.

Results from the micro-econometric investment models that use *Nett* as a proxy of product market competition provide a more thorough picture of incumbent investment behavior (see (3)). Table 7 reports dynamic panel data estimates. Column (1) results are obtained by making use of the WG estimator, while column (2)–(4) results presents estimates obtained from the GMMd estimator (Section 4.2). Different strategy have been adopted with GMMd instruments that may be only internal (lagged $t-2$ and $t-3$ variables; column (2)), both external and internal (political-institutional indicators as external instruments; see Section 4.2; column (3)), or only external (column (4).

Some hints of the quality of the micro-econometric model can be drawn from a review of the estimates obtained for the "baseline variables", i.e. *I/K* (the lagged investment rate), squared *I/K* (the squared lagged investment rate), *CF/K* (the cash flow rate), *D/K* (the debt rate) and *S/K* (the sales rate) (Table 7). The *I/K* coefficient is significant and positive and the squared *I/K* coefficient is significant and negative, i.e. the investment rate series is persistent and the adjustment costs are convex. GMMd estimates with external instruments alone are an exception (column (4)), but their consistency is weak also based on

[15] In spite of the fact that *Neal* and *Comp* result to be endogenous to the investment rate (Table 6), estimates of *Neal* and *Comp* models do not differ substantially from *Nett* model estimates, and are available upon request from the authors.

**Table 7**
Incumbent's investments: Micro-econometric model.

| *Estimates*[a] | (1) (WG) | (2) (GMMd) | (3) (GMMd) | (4) (GMMd) |
|---|---|---|---|---|
| $(I/K)_{t-1}$ | 0.398** | 0.872*** | 0.818*** | 1.492 |
| | (0.157) | (0.242) | (0.224) | (1.125) |
| $(I/K)^2_{t-1}$ | −0.624* | −1.425*** | −1.340*** | −3.237 |
| | (0.325) | (0.431) | (0.399) | (2.664) |
| $D/K_t$ | 0.006** | 0.003** | 0.004** | 0.003 |
| | (0.003) | (0.001) | (0.002) | (0.002) |
| $CF/K_t$ | 0.127+ | 0.118 | 0.121 | 0.111 |
| | (0.073) | (0.083) | (0.082) | (0.089) |
| $S/K_t$ | 0.104*** | 0.166*** | 0.159*** | 0.127*** |
| | (0.020) | (0.024) | (0.025) | (0.049) |
| $Nett_{t-1}$ | −0.035 | 0.089 | 0.097 | 0.136 |
| | (0.073) | (0.098) | (0.118) | (0.133) |
| $Unb_{t-1}$ | −0.027* | −0.013 | −0.015 | −0.005 |
| | (0.012) | (0.013) | (0.013) | (0.016) |
| $Unb_{t-1}$ * $Nett_{t-1}$ | 0.099*** | 0.091* | 0.096** | 0.084* |
| | (0.035) | (0.047) | (0.047) | (0.049) |
| $Priv_{t-1}$ | −0.036* | 0.054 | 0.046 | 0.051 |
| | (0.020) | (0.034) | (0.033) | (0.034) |
| $Priv_{t-1}$ * $Nett_{t-1}$ | −0.097 | −0.228* | −0.219 | −0.298 |
| | (0.082) | (0.138) | (0.154) | (0.186) |
| $Ln(\text{Gdpcap})_t$ | 0.060 | 0.093 | 0.108 | 0.015 |
| | (0.064) | (0.098) | (0.102) | (0.163) |
| Time- and country- specific effects | Yes | Yes | Yes | Yes |
| *N* | 278 | 249 | 249 | 249 |
| *Instruments:* | | Internal | Internal and external | External |
| *Tests*[b] | | | | |
| Ar (1) | | −2.296 | −2.411 | −1.067 |
| *p*-Value | | 0.022 | 0.016 | 0.286 |
| Ar (2) | | −1.531 | −1.469 | −1.123 |
| *p*-Value | | 0.126 | 0.142 | 0.261 |
| Hansen test | | 0.200 | 4.021 | 1.511 |
| *p*-Value | | 0.905 | 0.946 | 0.959 |

Notes.

[a] Standard errors in parentheses; ***, ** and *: significance levels equal to 1%, 5% and 10%; GMMd estimates are based on the hypothesis that the Eq. (3) independent variables are endogenous, which implies the use of internal ((*t*−2) and (*t*−3) values) and external (political-institutional) variables as instruments; GMMd bootstrapped standard errors are based on 50 replications (coefficients from the Arellano-Bond (1991) estimator used as initial parameters; chosen approximation is O(1/NT\widehat2)); estimates and tests performed by the Stata 11 software.

[b] AR(1) and AR(2): test of no serial correlation in the error term; Hansen: test of the validity of overidentifying restrictions.

the serial correlation test. Moreover, the *S/K* coefficient is positive and significant, as a hint of the presence of increasing returns or imperfect competition in the product markets. The financial structure did not seem to play any role (i.e. see *CF/K* and *D/K* coefficients). It is quite encouraging that the sign, significance and sometimes even the magnitude of the baseline variables for WG and GMMd estimates with internal instruments, and with internal and external instruments, are in line with the results obtained in most empirical works on firm-level investment. In addition, they are rather stable across the specifications and do not change to any great extent when different estimators were used (WG v. GMMd estimates).

As regards the estimates of competition and reform variables, the most valuable result concerns the relevance of competition (*Nett*) in interaction with unbundling obligations (*Unb*). The cross-term coefficient is found to be positive and significant across all models, while the competition coefficient alone (*Nett*) takes a positive sign but it is never significantly different from 0. Likewise, the unbundling coefficient (*Unb*) is always negative, but not significant across GMMd estimates (columns (2)-(4)). In other words, if pro-entry regulation, and more particularly unbundling obligations, succeeds in increasing product market competition, they are more likely to have a positive effect on incumbent's incentives to invest. The WG linear coefficient of *Priv* results to be significant (column (1)), but when GMMd estimates are focused on, privatization programs (*Priv*) are found not to affect incumbent's investments, whether they are implemented in insulation, or in combination with market opening (*Priv–Nett* cross term coefficient).

As regards our research questions, we find that competition does not play an autonomous significant role in incumbents' incentives to invest (see *Nett* estimates), nor it interacts with privatization (the cross term of *Priv* and *Nett* resulted to be not significant). Estimates of structural investment model indicate that the incumbent is likely to increase its fixed investment if pre-entry regulation has been implemented and competition in service markets is intense. Unbundling obligations are not per se a driver of incumbent's investments, but they have been shown to have a positive effect conditionally on their ability to foster competition. For the sake of illustration, one can compare a scenario of poor competition and absence of

**Table 8**
Incumbent's investments: Control model (penetration rate of mobile subscribers).

| *Estimates*[a] | (1) (WG) | (2) (GMMd) | (3) (GMMd) | (4) (GMMd) |
|---|---|---|---|---|
| $(I/K)_{t-1}$ | 0.377** | 0.880*** | 0.820*** | 1.393 |
| | (0.157) | (0.257) | (0.230) | (1.171) |
| $(I/K)^2_{t-1}$ | −0.582* | −1.432*** | −1.335*** | −3.054 |
| | (0.323) | (0.445) | (0.400) | (2.729) |
| $D/K_t$ | 0.006** | 0.003** | 0.004** | 0.003 |
| | (0.003) | (0.001) | (0.002) | (0.002) |
| $CF/K_t$ | 0.116 | 0.118 | 0.122 | 0.110 |
| | (0.078) | (0.083) | (0.081) | (0.086) |
| $S/K_t$ | 0.109*** | 0.166*** | 0.159*** | 0.127*** |
| | (0.021) | (0.023) | (0.024) | (0.048) |
| $Nett_{t-1}$ | −0.020 | 0.095 | 0.096 | 0.132 |
| | (0.081) | (0.087) | (0.114) | (0.132) |
| $Unb_{t-1}$ | −0.024* | −0.012 | −0.015 | −0.007 |
| | (0.013) | (0.015) | (0.014) | (0.017) |
| $Unb_{t-1}$ * $Nett_{t-1}$ | 0.094** | 0.089* | 0.097* | 0.085* |
| | (0.035) | (0.052) | (0.050) | (0.050) |
| $Priv_{t-1}$ | −0.033* | 0.054** | 0.046 | 0.050 |
| | (0.019) | (0.033) | (0.033) | (0.034) |
| $Priv_{t-1}$ * $Nett_{t-1}$ | −0.107 | −0.233** | −0.218 | −0.294 |
| | (0.085) | (0.130) | (0.152) | (0.187) |
| $Ln(\text{Gdpcap})_t$ | 0.055 | 0.095 | 0.112 | 0.026 |
| | (0.061) | (0.099) | (0.103) | (0.166) |
| $Mob_{t-1}$ | −0.000 | −0.000 | −0.000 | −0.000 |
| | (0.000) | (0.001) | (0.001) | (0.001) |
| Time- and country- specific effects | Yes | Yes | Yes | Yes |
| *N* | 278 | 249 | 249 | 249 |
| *Instruments:* | | Internal | Internal and external | External |
| *Tests*[b] | | | | |
| Ar (1) | | −2.375 | −2.477 | −0.988 |
| *p*-Value | | 0.018 | 0.013 | 0.323 |
| Ar (2) | | −1.535 | −1.460 | −1.117 |
| *p*-Value | | 0.125 | 0.144 | 0.264 |
| Hansen test | | 0.179 | 1.790 | 1.668 |
| *p*-Value | | 0.914 | 0.998 | 0.948 |

Notes.

[a] Standard errors in parentheses; ***, ** and *: significance levels equal to 1%, 5% and 10%; GMMd estimates are based on the hypothesis that the Eq. (3) independent variables are endogenous, which implies the use of internal ((*t*−2) and (*t*−3) values) and external (political-institutional) variables as instruments; GMMd bootstrapped standard errors are based on 50 replications (coefficients from the Arellano-Bond (1991) estimator used as initial parameters; chosen approximation is O(1/NT\widehat2)); estimates and tests performed by the Stata 11 software.

[b] AR(1) and AR(2): test of no serial correlation in the error term; Hansen: test of the validity of overidentifying restrictions.

unbundling obligations with a scenario where facility-sharing or unbundling are made compulsory and, perhaps after an introductory period, other operators enter and compete with the incumbent. The incumbent does not significantly modify its investment decisions merely in response to the adoption of unbundling obligations, but its incentives to invest increase if pro-entry regulation leads entrants to increase their market shares. Intense service-based competition revitalizes the incumbent's investments.

An issue may arise with estimates discussed so far, owing to the presence of OECD incumbent firms in mobile markets. In principle, market opening and pro-entry regulation are expected to impact only on investments in regulated markets of fixed communications, but our measure of investment, the *I/K* investment rate also includes investments in mobile networks. At the same time, advanced mobile networks of rivals could act as an alternative platform for facility-based competition. We are not able to disaggregate the incumbents' investments, nor to control the diffusion of advanced mobile networks, since detailed data on investments in mobile markets are not available for the whole sample. As a compromise option, we conducted a robustness check and included the ratio between mobile subscribers and inhabitants (*Mob*), among control variables. Table 8 reports results obtained from the control regressions. The penetration rate of mobile subscribers is not found to play any significant role, but Table 8 estimates confirm the central finding of our micro-econometric analysis. The cross term between competition (*Nett*) and unbundling obligations (*Unb*) remains significant and positive, even when the model allows for the development of mobile markets.

In conclusion, the present results reveal that product market competition in the fixed network services does not have a direct effect on the incumbent's investment (first research question). As far as the accompanying measures are concerned, there isn't any robust evidence to show that privatization interacts either positively or negatively with competition.

Moreover, it can be added that ownership does not have by itself a sizeable influence on investment. The most remarkable and robust results concern the role of unbundling, which is found to increase the incumbent's incentives to invest only if the incumbent is exposed to competitive pressure in the market of fixed telecommunications services. Our analysis does not reveal the mechanism through which service-based competition determines the incumbent's incentives to invest, but two conjectures can be made. Entrants could remain dependent on incumbent's facilities, i.e. they do not succeed in "jumping off" the ladder of investments (Cave, 2014). In this case, the incumbent augments its investments to leverage the wholesale market. Secondly, the new capital additions could be instrumental in differentiating the offered services, that is, in escaping rivalry through quality-enhancing innovations (Aghion et al., 2005).

## 6. Conclusions

The paper is an attempt to offer empirical evidence on the relationship between market competition and fixed investments in telecommunications networks and services. The literature findings on the subject are not conclusive. Divergent results have emerged, depending on the level of analysis (i.e. country v. firm) and on the model specification (e.g. whether accompanying measures are included).

A retrospective analysis of the issue in advanced countries is now feasible because the available investment data have a fair longitudinal span. The adopted empirical strategy has involved the use of various models and methods in an attempt to address two major difficulties that hinder the analysis of the impact of competition on investment, i.e. feedbacks from investment to competition and the confounding effects of parallel reforms. Through this strategy we believe we have added empirical evidence to the existing literature on the subject.

A preliminary analysis, using country-level data, was conducted to investigate the presence of unknown structural breaks in fixed investment time series. The results did not show any unambiguous relationship between market opening reforms and total fixed investments of advanced countries. An effort was then made to estimate the effects of competition on incumbent investments, using firm-level data and dynamic panel models.

A bivariate framework was first used to detect the causality relationships that may link competition and incumbent investments. In general terms, no significant connections have been found. Then, in order to reduce the risk of omitted variables and confounding factors, a structural model of the investment rate has then been specified, adopting a micro-econometric approach. The estimates indicate, in a robust way, that investment variations cannot be attributed in a direct way to changes that occur in product market competition (first research question). Countries in which the markets for fixed services are fairly competitive do not differ substantially from countries in which the same markets are still dominated by the incumbent. However, even though competition does not play an autonomous role, it determines the incumbent's investment by interacting with the unbundling regime (second research question). Differently from Grajek and RÖller (2012), pro-entry regulation has not been found to have per se a significant and negative effect on incumbent incentives to invest. By contrast, if the unbundling regime succeeds in fostering product market competition, then the incumbent's incentives to invest are revitalized.

Our research can be considered as an ex-post assessment of market openings. After almost 25 years from the first liberalization experiences, the traditional concerns about possible negative effects of competition on the dynamic efficiency of the industry appear to be ill-founded. Particularly, neither pro-entry regulation nor the resulting product market competition have slowed down the incumbent's investment. They have had a neutral impact when implemented independently and a positive impact when combined. Arguably, it is difficult to attribute possible problems in network reliability or network modernization to competition and pro-entry regulations. Second, our findings may help in the design of broadband policies. The unbundling regime has been shown not to be noxious to investment if service markets become more competitive. This could be considered preliminary evidence of a need for new, geographically differentiated, regulatory instruments in order to spur broadband investment (Cambini et al., 2012; Bourreau, Cambini, & Hoernig, 2012).

Our analysis has considered country- and firm-level investment, but it has not dealt with entrants. This might be considered a limitation insofar as a neutral effect of competition on investment at the country level can coexist with a multiplicity of impacts on entrants. Moreover, we have not distinguished between investments in fixed networks and investments in mobile networks, nor we have investigated broadband investments in a specific way. All these issues are possible subjects of further research.

## Appendix

See Appendix Fig. A.1 and Tables A1–A4.

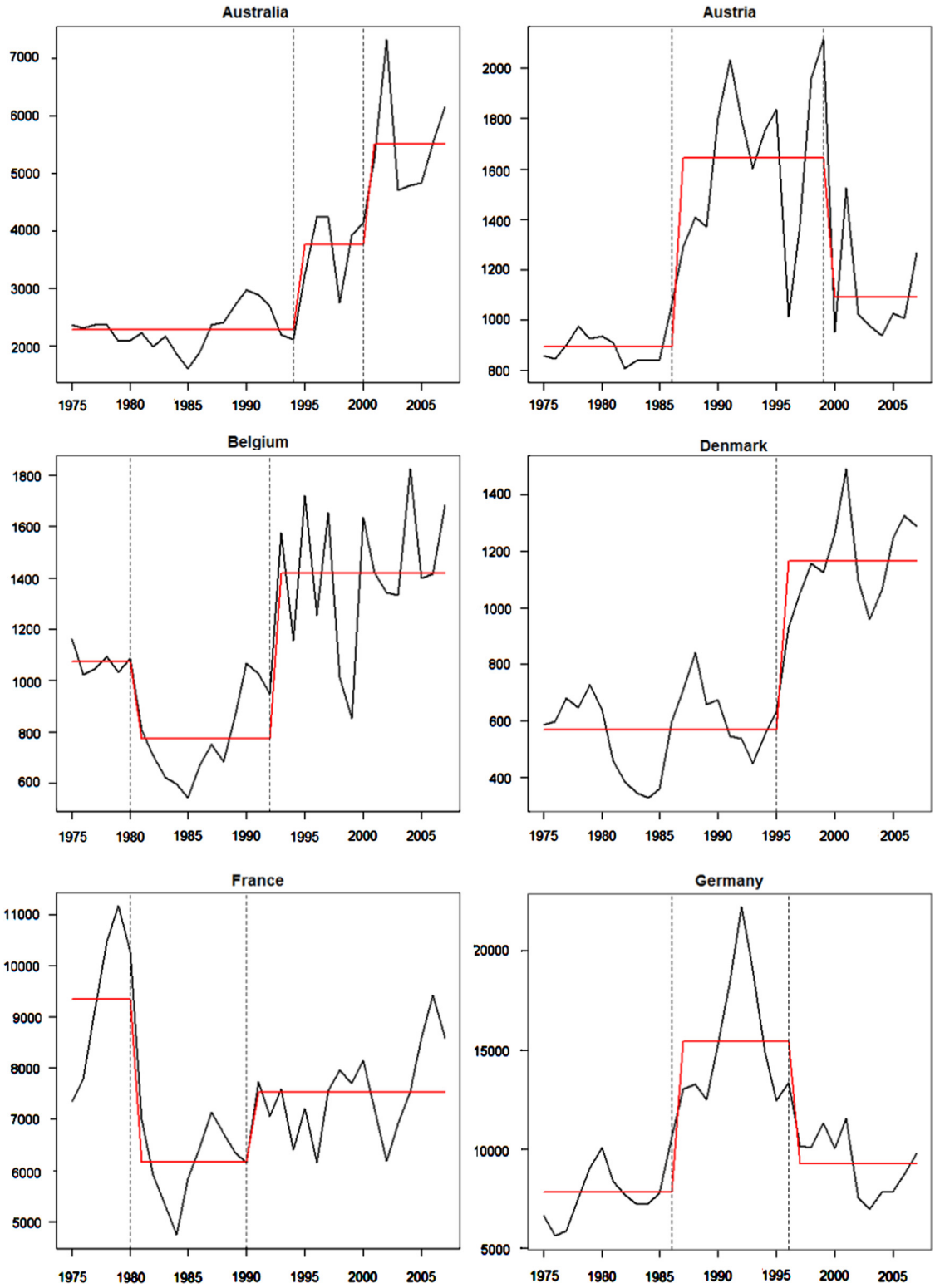


**Fig. A1.** Investment and break points at a country-level.

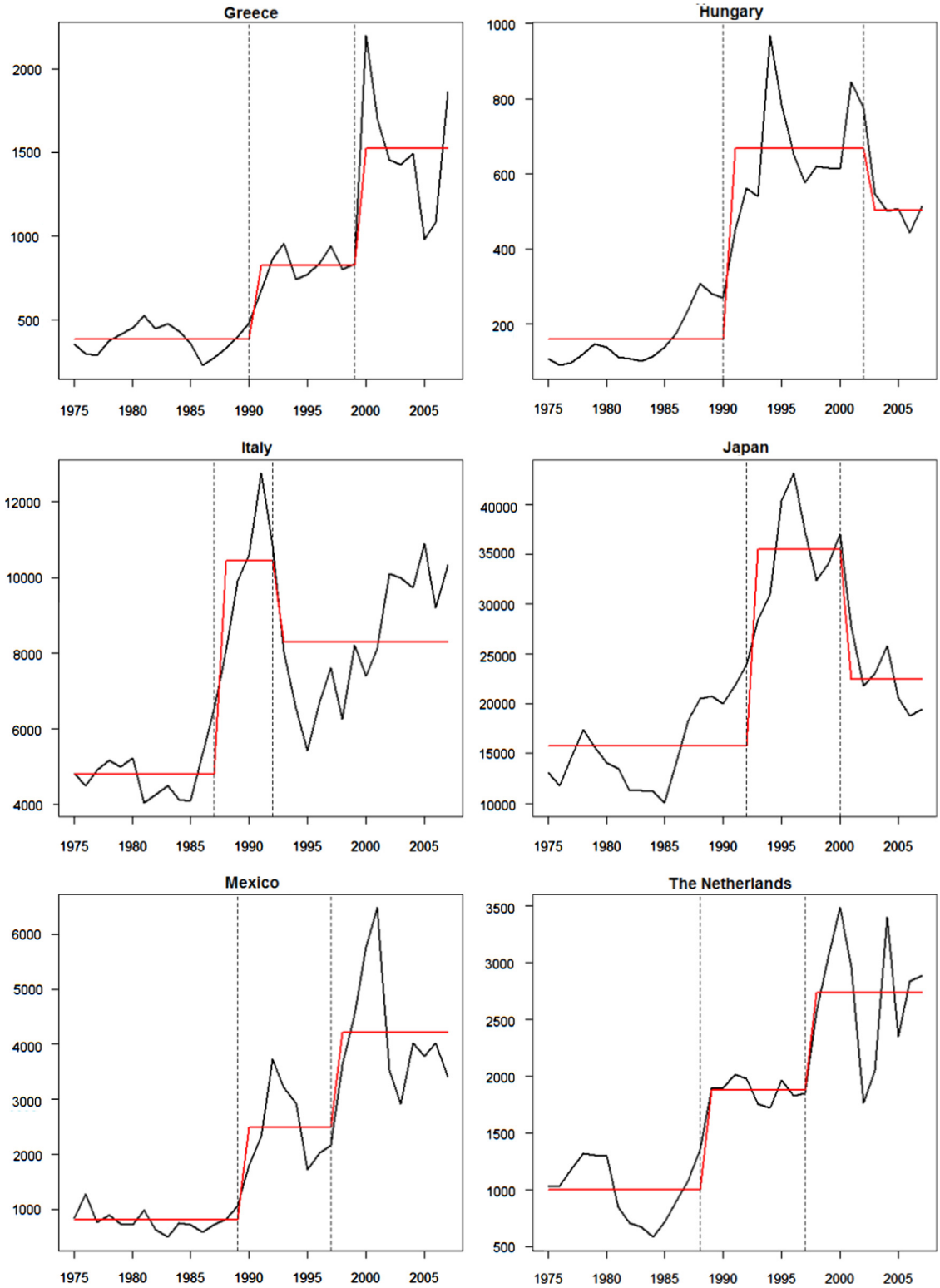


**Fig. A1.** (*continued*)

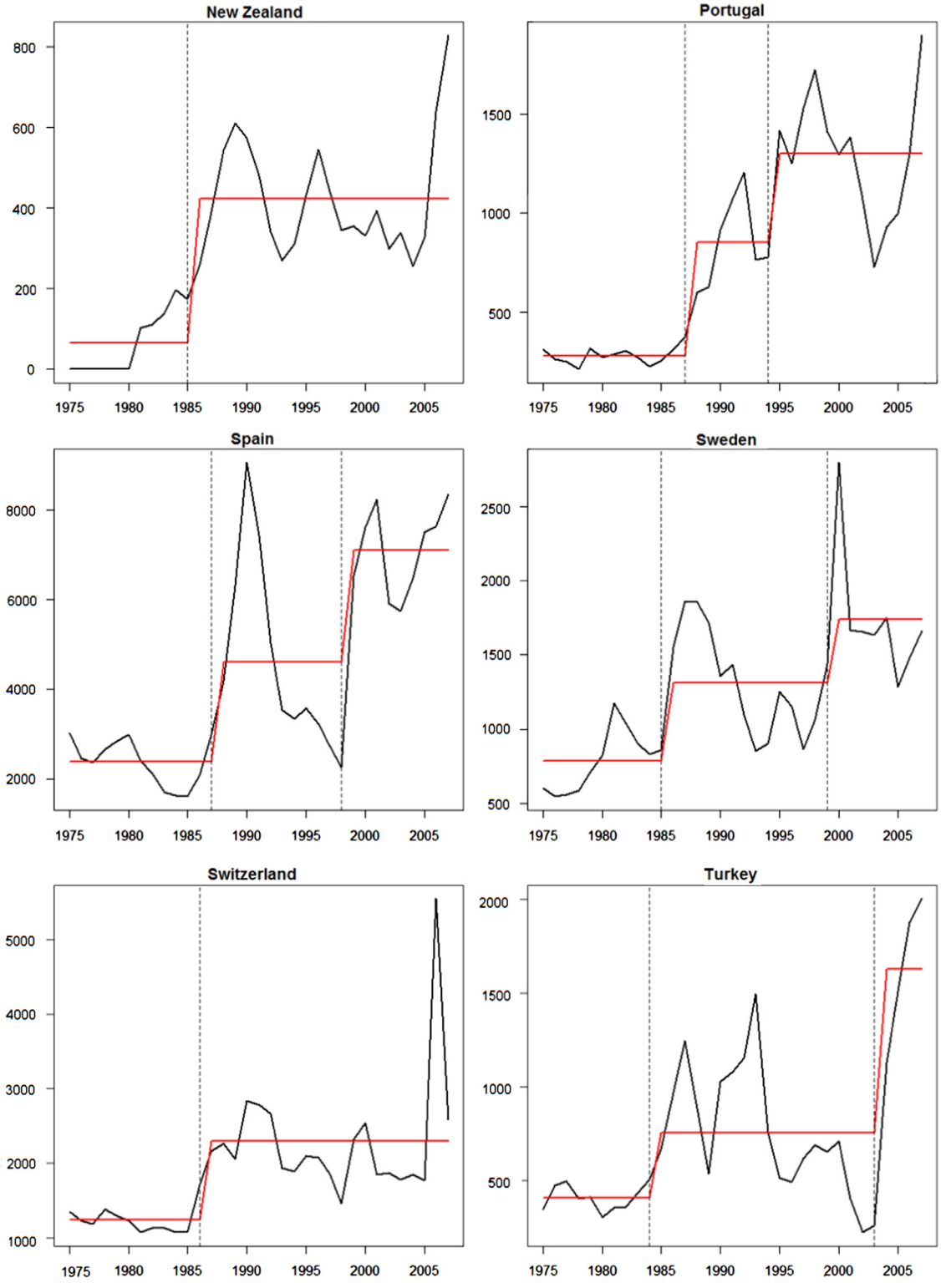


**Fig. A1.** (*continued*)

**Table A1**
Reforms in the sample countries.
*Sources:* Conway, P. and G. Nicoletti (2006) Product Market Regulation in non-manufacturing sectors in OECD countries: measurement and highlights. *OECD Economics Department Working Paper* No.530; OECD Communication Outlooks; the OECD International Regulatory Database; Annual company reports.

| | Liberalization – trunk telephony market | Liberalization – mobile market | Privatization | 100% Privatization | Unbundling obligations |
|---|---|---|---|---|---|
| Australia | 1991 | 1991 | 1997 | – | 1999 |
| Austria | 1999 | 1995 | 1999 | – | 1997 |
| Belgium | 1999 | 1995 | 1995 | – | 2000 |
| Canada | 1990 | 1991 | private | private | 1997 |
| The Czech Republic | 2002 | 1997 | 1995 | 2005 | 2003 |
| Denmark | 1995 | 1991 | 1992 | 1998 | 1998 |
| Finland | 1991 | 1991 | 1999 | – | 1997 |
| France | 1998 | 1990 | 1997 | – | 2001 |
| Germany | 1999 | 1991 | 1998 | – | 1996 |
| Greece | 2002 | 1993 | 1995 | – | 2001 |
| Hungary | 2002 | 1994 | 1994 | 1999 | 2001 |
| Ireland | 1999 | 1995 | 1996 | 2001 | 2000 |
| Italy | 1998 | 1994 | 1991 | 2003 | 2001 |
| Japan | 1988 | 1985 | 1986 | – | 1997 |
| Korea | 1998 | 1994 | 1990 | 2002 | 2001 |
| Mexico | 1997 | 1997 | 1992 | 1992 | – |
| The Netherlands | 1997 | 1994 | 1994 | 2007 | 1999 |
| New Zealand | 1988 | 1987 | 1991 | 1991 | 2007 |
| Norway | 1999 | 1991 | 1999 | – | 2000 |
| Poland | 2002 | 1996 | 1999 | 2003 | 2003 |
| Portugal | 2000 | 1993 | 1995 | – | 2000 |
| Spain | 1996 | 1995 | 1987 | 1997 | 2000 |
| Sweden | 1991 | 1986 | 1999 | – | 2000 |
| Switzerland | 1998 | 1998 | 1998 | – | 2003 |
| Turkey | 2007 | 1998 | 2005 | – | 2005 |
| The UK | 1982 | 1985 | 1984 | 1997 | 2000 |
| The USA | 1984 | 1983 | private | private | 1996 |

**Table A2**
Break points in country-level investment series (1975–2007): Bai and Perron test.

| *Estimates*[a] | Initial mean | Break 1 | | Break 2 | |
|---|---|---|---|---|---|
| | | Date | Post-break mean | Date | Post-break mean |
| *Australia* | 2286*** (1 2 6) | **1994** | 3758*** (2 6 2) | **2000** | 5508*** (2 4 7) |
| *Austria* | 895*** (67) | **1986** | 1642*** (93) | **1999** | 1089 (1 0 6) |
| *Belgium* | 1073*** (88) | **1980** | 773** (1 0 7) | **1992** | 1417** (1 0 4) |
| *Denmark* | 568*** (32) | **1995** | 1166*** (53) | – | |
| *France* | 9356*** (4 0 2) | **1980** | 6162*** (5 0 9) | **1990** | 7529*** (4 6 8) |
| *Germany* | 7817*** (6 4 6) | **1986** | 15442*** (9 5 8) | **1996** | 9268 (9 3 4) |
| *Greece* | 385*** (52) | **1990** | 827*** (86) | **1999** | 1526*** (89) |
| *Hungary* | 159*** (26) | **1990** | 667** (40) | **2002** | 502*** (53) |
| *Italy* | 4802*** (3 7 9) | **1987** | 10433*** (7 2 0) | **1992** | 8302*** (5 1 8) |
| *Japan* | 15750*** (1002) | **1992** | 35472*** (1806) | **2000** | 22453*** (1893) |
| *Mexico* | 799*** (1 8 4) | **1989** | 2487*** (3 1 2) | **1997** | 4205*** (2 9 1) |
| *The Netherlands* | 1002*** (95) | **1988** | 1878*** (1 5 2) | **1997** | 2737*** (1 4 7) |
| *New Zealand* | 66*** (39) | **1985** | 423*** (47) | – | |
| *Portugal* | 282*** (63) | **1987** | 853*** (1 0 7) | **1994** | 1303*** (89) |
| *Spain* | 2384*** (3 8 1) | **1987** | 4615*** (5 6 2) | **1998** | 7114*** (5 9 5) |
| *Sweden* | 786*** (1 0 2) | **1985** | 1316*** (1 3 6) | **1999** | 1743*** (1 5 7) |
| *Switzerland* | 1238*** (1 9 5) | **1986** | 2295*** (2 4 5) | – | |
| *Turkey* | 410*** (92) | **1984** | 757** (1 1 4) | **2003** | 1628*** (1 7 3) |

Note:
[a] Standard errors in parentheses. ***, **, and * indicate significance levels of $< 1\%$, $< 5\%$ and $< 10\%$ respectively (null hypothesis: the post-break mean is not significantly different from the mean before the break date); estimates performed by the EViews 8 software.

**Table A3**
Granger analysis: direct causality.

| *Estimates*[a] | (I/K) GMMd | (I/K) LSDVc | (I/K) GMMd | (I/K) LSDVc | (I/K) GMMd | (I/K) LSDVc |
|---|---|---|---|---|---|---|
| $(I/K)_{t-1}$ | 0.271** | 0.680*** | 0.267* | 0.686*** | 0.139 | 0.645*** |
| | (0.126) | (0.124) | (0.137) | (0.133) | (0.136) | (0.158) |
| $Comp_{t-1}$ | 0.014 | 0.004 | | | | |
| | (0.018) | (0.007) | | | | |
| $Nett_{t-1}$ | | | 0.126 | 0.012 | | |
| | | | (0.140) | (0.039) | | |
| $Neal_{t-1}$ | | | | | −0.559 | 0.058 |
| | | | | | (1.045) | (0.099) |
| Time- and country-specific effects | Yes | Yes | Yes | Yes | Yes | Yes |
| *N* | 261 | 290 | 261 | 290 | 164 | 205 |
| Ar (1) | −3.471 | | −3.379 | | −2.045 | |
| *p*-Value | 0.001 | | 0.001 | | 0.041 | |
| Ar (2) | −0.759 | | −0.596 | | −2.017 | |
| *p*-Value | 0.448 | | 0.551 | | 0.044 | |
| Hansen | 2.814 | | 3.035 | | 0.526 | |
| *p*-Value | 0.245 | | 0.219 | | 0.769 | |

Notes.

[a] Standard errors in parentheses; ***, ** and *: significance levels equal to 1%, 5% and 10%; GMMd estimates are based on the hypothesis that the independent variable is endogenous, which implies the use of its $(t-2)$ and $(t-2)$ as instruments; GMMd bootstrapped standard errors are based on 50 replications (coefficients from the Arellano-Bond (1991) estimator used as initial parameters; chosen approximation is O(1/NT\widehat2)); estimates and tests performed by the Stata 11 software. (b): TestsAR(1) and AR(2): test of no serial correlation in the error term; Hansen: test of the validity of overidentifying restrictions.

**Table A4**
Granger analysis: reverse causality.

| *Estimates*[a] | (Comp) GMMd | (Comp) LSDVc | (Nett) GMMd | (Nett) LSDVc | (Neal) GMMd | (Neal) LSDVc |
|---|---|---|---|---|---|---|
| $Comp_{t-1}$ | 0.933*** | 0.832*** | | | | |
| | (0.115) | (0.038) | | | | |
| $Nett_{t-1}$ | | | 0.938*** | 1.189*** | | |
| | | | (0.138) | (0.119) | | |
| $Neal_{t-1}$ | | | | | 0.594 | 3.162*** |
| | | | | | (0.477) | (0.000) |
| $(I/K)_{t-1}$ | −1.337 | −0.944** | −0.184 | −0.090 | 0.004 | 0.240*** |
| | (0.837) | (0.438) | (0.194) | (0.118) | (0.112) | (0.073) |
| Time- and country-specific effects | Yes | Yes | Yes | Yes | Yes | Yes |
| *N* | 261 | 290 | 235 | 264 | 129 | 167 |
| *Tests*[b] | | | | | | |
| Ar (1) | −2.716 | | −2.934 | | −0.960 | |
| *p*-Value | 0.007 | | 0.003 | | 0.337 | |
| Ar (2) | −0.113 | | −0.701 | | −0.776 | |
| *p*-Value | 0.910 | | 0.483 | | 0.438 | |
| Hansen | 6.861 | | 4.175 | | 0.604 | |
| *p*-Value | 0.032 | | 0.124 | | 0.739 | |

Notes.

[a] Standard errors in parentheses; ***, ** and *: significance levels equal to 1%, 5% and 10%; GMMd estimates are based on the hypothesis that the independent variable is endogenous, which implies the use of its $(t-2)$ and $(t-2)$ as instruments; GMMd bootstrapped standard errors are based on 50 replications (coefficients from the Arellano-Bond (1991) estimator used as initial parameters; chosen approximation is O(1/NT\widehat2)); estimates and tests performed by the Stata 11 software.

[b] TestsAR(1) and AR(2): test of no serial correlation in the error term; Hansen: test of the validity of overidentifying restrictions.

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