ABSTRACT

This paper assesses the effectiveness of vertical industrial policies within the European Union. *Vertical industrial policy is defined as government support of specific firms or industries ('picking winners' or 'supporting losers'). It is measured as state aid granted by Member States to the manufacturing sectors, with the aim to analyse to what extent this government intervention affects the growth of multifactor productivity (MFP) in manufacturing. The analysis is conducted with both sectoral and horizontal aid, since in many cases vertical aid is disguised as aid pursuing horizontal objectives. Controlling for the potential endogeneity of state aid policy, the results indicate that vertical state aid contributes positively to MFP growth.*

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Vertical industrial policy in the EU: an empirical analysis of the effectiveness of state aid

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1. State aid: a key tool of industrial policy in the EU

This paper assesses the effectiveness of vertical industrial policies within the EU. For the purpose of this paper, industrial policy is defined as "the set of government interventions that by way of taxes (or subsidies) and regulations on domestic products or factors of production attempt to modify the allocation of domestic resources that results from the free operation of the market" (Gual 1995, p. 9). To narrow down what otherwise is a very broad definition, we exclude measures directed to primary sectors as well as those related to non-tradable industries, such as housing services or retail trade. Policies that affect most firms in a country to a similar extent – for example, investment tax credits or subsidies for the employment of a particular kind of labour – are also excluded.

State aid is part of the toolkit available for governments to implement their preferred industrial policy. This toolkit is somewhat limited for EU countries due to the agreements and legislation directed towards creating a single internal market, including a common policy with respect to trade barriers, mutual recognition of standards, and so on. European laws defining the legality of state aid constitute perhaps the most important element in the agreed framework for implementing industrial policies within Europe.

The main economic justification for industrial policy, including state aid, is the quest for efficiency. Thus, government aid aims to correct market failures, such as externalities, asymmetric information, market power, coordination problems, and public goods. The most common example of (positive) externalities is the research and development (R&D) activity of private companies. Asymmetric information, in turn, is used as a justification for granting aid to small and medium-sized enterprises (SMEs). Asymmetric information between a bank and an SME about the latter's potential to repay a loan or about the riskiness of its projects may prevent even a profitable SME to access finance.

Market failures such as these justify the general objectives of R&D or SME support. Additional arguments are needed, however, to justify government intervention in specific industries or firms. Optimal use of government resources suggests that intervention should focus on those industries where externalities are particularly important. In the case of R&D, general support to all sectors may be desirable at the European level, while individual Member States tend to focus their support to those sectors where a substantial part of the benefits from the externality are likely to remain within the national boundaries.

Another type of market failure that justifies sector-specific support is the presence of agglomeration externalities. In this case, firms devoted to similar or related activities need to cluster, i.e., to locate in geographic proximity in order to transmit tacit knowledge, with the transmission cost increasing with geographical distance. Industrial policy may foster the creation of clusters by subsidising firms that generate agglomeration externalities. On the other hand, governments may not have all necessary information to determine which industries are capable of generating agglomeration effects. The case for industrial policy on the grounds of agglomeration externalities remains thus uncertain.

Yet another possible justification for sector-specific industrial policy rests on strategic trade considerations, first developed by Brander and Spencer (1983). The basic market failure justifying strategic trade policy is imperfect competition arising from scale economies in production. In oligopolistic market structures firms may realise some excess returns. Governments hence have an incentive to support national champions in order to maintain those rents within national boundaries. A classical example in the European context is the Airbus case, documented in Neven and Seabright (1995). An argument along this line is used by Collie (2005) to analyse also the effects of state aid to R&D.

This strategic trade policy justification may be particularly important in industries where network externalities are present. Those industries are prone to oligopolistic market structures once standards have been set. Hence, governments may want to intervene with a view to helping national firms during the early stages of competition for the market. Although standards are developed on a market-determined basis within the EU – meaning that national bodies only specify the basic requirements related to public health and environmental and consumer protection – this justification is still applicable to industries with global geographic markets. Thus, industries might exist for which the strategic trade justification could also be in the interest of the EU as a whole. An example is the development of the GSM standard for mobile telecommunications, which was promoted by Europe and declared the mandatory technology to be used in European mobile phones. This intervention may partly explain the faster development in Europe than in the United States of the mobile telecommunications industry. A second example is the development of Galileo, a technology intended to compete with the GPS and GLONASS systems, developed by the United States and Russia, respectively.

Apart from economic efficiency, equity concerns may also justify the provision of industrial policy support to specific industries when the benefits in terms of social equity outweigh the negative effects of compromising economic efficiency. Indeed, some forms of state aid involve a mix of efficiency and equity justifications. This is the case for aid provided under structural adjustment policies targeted at declining industries. It is possible that the existence of some market failure, such as factor market rigidities (Neary 1982), prevents the adjustment through market forces alone in some sectors. Typically, industrial policies towards these industries also involve a redistribution of income.

Regional aid also presents a combination of efficiency and equity justifications. Rodrik (2004) adds a market failure justification to equity goals for aid targeted at depressed regions. He argues that there is a market failure in the process of discovering activities (not necessarily new) that can be profitably adapted to local conditions. The social value of experimenting with new activities is high, whereas private costs for entrepreneurs are significant and benefits, if they exist, would be shared with followers. In such cases, a partnership between the government and private firms could be desirable.

State aid in the EU aims chiefly at alleviating market failures and attaining distributional objectives.

Overall, the design of state aid in the EU aims at alleviating market failures and attaining distributional objectives, while support for cluster-like structures has not been explicitly regulated. However, industrial policy has increasingly concentrated on stimulating regional clusters (OECD 2001). Initiatives of cluster mapping have been launched for example in Belgium, Denmark, France, Austria, Finland, the United Kingdom and Norway (European Commission 2002), and some emphasis has recently been put on potentially positive effects of public policy in supporting clustering initiatives (Trends Business Research 2001). This support is mainly extended through regional or horizontal aid instruments – such as R&D or SME support – or aid for training.

Industrial policy in EU member states is, to a large extent, implemented within the agreed framework of EU state aid legislation. The objective of EU state aid policy is to regulate and monitor that industrial policy by Member States does not distort internal market competition, affect trade, or risk provoking a subsidy war. To this end, a set of regulations describes and limits the types of state aid that can be used in the EU (Box 1).

Box 1. Regulation of state aid in the EU

Industrial policy of EU member states is regulated and monitored in the framework of EU state aid legislation. The basis of EU state aid policy is contained in Articles 87 to 89 of the Treaty of Amsterdam[1]. Article 87(1) stipulates a general ban on state aid that distorts competition and affects trade. Article 87(2) states mandatory exceptions from this general prohibition – including aid with social character granted to individual consumers, aid related to natural disasters, and aid granted to Eastern Germany related to the effects of the post-war division of Germany. Article 87(3) allows some discretionary exceptions, including regional aid, aid to combat serious unemployment, aid for culture and heritage conservation, aid to advance important projects of common European interest, aid to deal with serious economic disturbances, and aid to some specified economic activities.

On top of these statutory foundations, Commission and Council regulations and guidelines specify administrative procedures for the implementation of state aid control. Traditionally, state aid monitored by the Commission has been classified in four broad categories: aid to horizontal objectives, regional aid, sectoral aid, and aid to individual firms for rescue and restructuring. Each of these is briefly described below.

Horizontal aid[2] includes aid to horizontal objectives, such as R&D, environment and energy saving, SMEs, employment, training, and risk capital. Aid to horizontal objectives is mainly justified by market failures.

Regional aid aims to promote the development of disadvantaged regions. It includes aid to assisted regions on the basis of Article 87(3)a and (3)c. In addition, the EU also provides support to projects that are financed jointly with the Member States, e.g., involving Structural Funds.

Sectoral aid has historically included three types of sectors. First, aid to agriculture, fisheries, and transport has been exempted from the general rules on state aid and has to comply with sector-specific regulations (Article 36 for agriculture and fisheries; Articles 73, 76, and 154 for the transport sector). Second, a number of industries have been classified as 'sensitive' due to their particularly severe economic problems. These industries include coal and steel, synthetic fibres, and shipbuilding. Specific rules apply to aid to these industries. In general, the rules try to ensure long-term adjustment. Third, a number of industries are supported because they have been exposed to international competition only recently. These include financial services, air transport, maritime transport, and motor vehicles. The goal was to facilitate a one-time adjustment to exogenous structural changes in market conditions.

Rescue and restructuring aid is aid awarded to individual firms in difficulties. A firm in difficulty is defined as one being unable, through its own resources and without outside intervention by the public authorities, to stem losses that will almost certainly condemn it to go out of business in the short or medium term. Rescue aid is temporary assistance. It should make it possible to keep a firm in difficulty afloat for the time needed to work out a restructuring or liquidation plan and/or for the length of time needed by the Commission or the national authorities to reach a decision on that plan. Restructuring aid, in turn, is based on a feasible, coherent, and far-reaching plan to restore a firm's long-term viability. Since it may distort competition, restructuring aid is governed by the 'one time, last time' condition, i.e., it may be granted only once.

The 1999 'Community Guidelines on State Aid for Rescuing and Restructuring Firms in Difficulty' lay out the conditions and procedures for awarding aid. These guidelines expired on October 9, 2004, and were replaced by 'Community Guidelines Applying Articles 87 and 88 of the Treaty to the Granting of Urgency and/or Restructuring Aid to Firms'. For a more detailed discussion, see Anestis *et al.* (2005).

In recent years, EU practice for new aid schemes has departed from the traditional classification. Horizontal objectives such as SME, training, and employment are handled with block exemptions. Some horizontal objectives – such as R&D aid, environmental aid, and risk capital – have got explicit guidelines for assessment. Special rules for particular sectors include only postal services, broadcasting, audiovisual production electricity, shipbuilding, and steel.

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1 In the Treaty of Maastricht and the Treaty of Rome, the paragraphs on state aid are numbered 92 – 94.

2 Aid for regional development and rescue and restructuring is sometimes also classified as aid for horizontal objectives. For the sake of conceptual clarity they will, however, be treated separately throughout this paper.

To set the stage for the core of this paper, let us sketch trends in state aid in the EU-15 member states (for more details see Riess and Välilä, this volume). For a start, it is important to point out that the analysis of state-aid statistics is affected by the state-aid classification of the European Commission. The primary reporting tool of the Commission is the State Aid Scoreboard, compiled by the Directorate General (DG) Competition, from which the following statistics are drawn. While aid schemes may have different objectives, the Commission classifies them according to the primary objective. Hence, all aid with a horizontal objective as the primary objective is considered horizontal aid (for various types of horizontal objectives see Box 1). Regional aid is usually considered as horizontal aid, whereas aid for rescue and restructuring is included as part of sectoral aid.

Bearing this classification in mind, trends in state aid extended by Member States in the period 1995-2003 show three salient features. First, total state aid in the EU-15 fell from €76 billion in 1995 to €53 billion in 2003. In relation to GDP, this represented a decline from 1 percent to a little more than one half of a percent. There are important differences between countries, however. To illustrate, in 2003, state aid ranged from 0.3 percent of GDP in the United Kingdom to 1.4 percent in Finland.

The drop in total state aid is almost exclusively due to a decline in sectoral aid.

Second, a decline in sectoral aid almost fully accounts for the drop in total state aid. More specifically, the aid classified as sectoral that was directed exclusively to the manufacturing sector decreased most (€13 billion), followed by that directed to coal (€4 billion), agriculture (€3 billion), and transport (€2 billion). As a share of total state aid, sectoral aid decreased from 60 percent in 1995 to 44 percent in 2003 (or from 46 percent to 21 percent if we exclude agriculture, fisheries, and transport from the sectoral aid figures). Concerning the sectoral composition of state aid, the manufacturing sector is clearly the biggest recipient with a share of 55-60 percent. Agriculture is the second biggest recipient (20-25 percent), followed by coal (10-15 percent), services (3-5 percent), transport (2 percent) and fisheries (1 percent). There are significant differences in aid distribution across EU countries. Manufacturing is the biggest recipient in nine Member States, with its share ranging from 74 percent of total aid in Italy to 40 percent in Spain. In five Member States (Finland, Austria, the Netherlands, Ireland, France), agriculture is the main recipient. In Portugal, the services sector is the biggest recipient. Aid to the coal industry is almost exclusively extended in Spain, Germany, and France.

Third – and following from the first two points – state aid with horizontal objectives was fairly stable, amounting to some €30 billion a year. However, separating out aid for regional development offers a different view: state aid for regional development decreased from about €18 billion in 1995 to less than €8 billion in 2003. Thus, state aid for horizontal objectives other than promoting regional development nearly doubled from €12½ billion to almost €22 billion. The most important horizontal objectives include environmental protection and energy saving (29 percent of aid awarded to horizontal objectives in 2003), R&D (18 percent), and SMEs (16 percent). In eight countries (Austria, Belgium, Finland, Greece, Italy, Luxembourg, Sweden, and the United Kingdom), all or almost all state aid (excluding aid to agriculture, fisheries, and transport) is channelled through horizontal instruments. This shift towards horizontal aid is a clearly stated goal in the Lisbon Agenda, but – as we will argue below – it is likely that schemes classified as horizontal in fact correspond to (sectoral) vertical state aid.

Having thus described the substance and recent evolution of state aid in the EU, we now turn to an analysis of how effective vertical state aid has been. Section 2 will provide a review of earlier empirical studies on this topic. Section 3 will present the empirical model to be estimated here, and Section 4 reports the results of the analysis. Section 5 concludes.

2. Earlier evidence of the effectiveness of vertical state aid

As mentioned above, vertical state aid is awarded to specific sectors or firms. It can be broken down into sectoral aid and aid for rescue and restructuring - a split we will follow in this section when reviewing earlier empirical studies on the effectiveness of vertical aid. Sectoral aid is considered vertical aid because it is granted to firms in a particular sector and is subject to specific regulations by the Commission. Aid for rescue and restructuring is usually included in the sectoral aid figures due to its potentially negative impact on competition.[1]

2.1 Studies on sectoral aid

There are two types of studies that examine the effect of sectoral aid: case studies for specific sectors and broader empirical analyses of support to manufacturing.

There are only a few case studies examining the effect of sectoral state aid.

Starting with case studies, there is only a limited number of comprehensive descriptions on the effects of sectoral state aid. Röller and von Hirschhausen (1996) examine state aid to the shipbuilding and synthetic fibre industries in East Germany (the former German Democratic Republic) after the opening up of its markets in the early 1990s. The Danish Competition Authority (2002), in turn, analyses an aid scheme to the shipbuilding industry.

A major restructuring backed by state aid measures was undertaken to turn around the economically unviable East German shipyards after German reunification. Röller and von Hirschhausen (1996) conclude that there was no static economic rationale justifying the large investment in East German shipyards. The market structure was highly competitive and no static gain was to be expected from an increase in competition due to existing overcapacity in the industry in Europe. Moreover, the amount of state aid was very high. The shipbuilding industry most hurt by this additional capacity seems to have been the West German shipyards, whose market share fell from over 30 percent to 21 percent, whereas the distribution of market shares among the other large European shipbuilding countries, i.e., Denmark, Spain, and Italy, was not significantly altered. Taking a dynamic perspective, the authors argue that aid to East German shipyards might have some economic rationale since they are likely to be among the most productive shipyards in Europe. This, however, implies rent shifting between countries, which would be inefficient from a broader European perspective.

As regards state aid to the synthetic fibre industry, Röller and von Hirschhausen conclude that there was no static economic justification for state aid. The industry was highly competitive both on the supply and on the demand side. As in the shipyard case, overcapacity existed, so state aid did not increase competition. Again, the competitors suffering most from this aid seem to have been those in West Germany, since they experienced a significant loss of market share, while the three largest European synthetic fibre producers either increased their market share (Spain, Benelux) or kept it constant (Italy). From a dynamic perspective, there might again have been some rent shifting, but there was no evidence of an immediate adverse effect on European industry.

1 European Commission (2005, p. 20): "In contrast, aid to support specific sectors is likely to distort competition more than aid for horizontal objectives and also tends to favour other objectives than identified market failures. Moreover, a significant part of such aid is granted to rescue or restructure companies in difficulty, one of the most potentially distortive types of State aid."

The Danish Competition Authority (2002) analyses the performance of the shipbuilding industry in Denmark, which received practically all Danish sectoral state aid during the past decade (1995-2005). The study concludes that turnover, employment, and the number of shipyards have all been declining over the past decades, while public subsidies have been increasing, reaching 70 percent of wages in 2001. There is some evidence of rent-seeking activities by the subsidies' recipients, as productivity in Danish shipyards has increased less than in other manufacturing industries and as wages for workers at shipyards have been 8-20 percent higher than for other workers in the metal and iron industry in same regions. However, profits have been low, indicating that state aid has not been channelled into excessive (accounting) profits.

Broader empirical analysis of aid to the manufacturing sector is scarce, too.

Turning then from case studies to broader empirical analyses of aid to the manufacturing sector, very little work has been done so far to measure its impact within the EU[2]: Bergström (1998) and the Danish Competition Authority (2001) analyse the effects of public capital subsidies on total factor productivity and growth. They use firm-level data and compare the development of firms having received state aid with the development of those that have not received any type of aid.

Bergström (1998) analyses 72 companies in the manufacturing sector that received state aid in Sweden during 1989-95 and compares them to a random sample of 832 non-aid-receiving firms. He analyses selective regional subsidies, i.e., subsidies specifically directed towards firms in support areas and for which firms have to apply. These subsidies include localisation subsidies and loans, development support, support to sparsely populated areas, and loans to investment firms. Such subsidies must be used primarily for investments in machinery and buildings. He finds that in the short run, the productivity of subsidised firms increased more than the productivity of non-subsidised firms, but that already after three years productivity was lower in subsidised than in non-subsidised firms. Bergström (1998) concludes that subsidisation might give rise to allocative inefficiencies and/or technical (X) inefficiencies due to slack or rent-seeking activities.

The Danish Competition Authority (2001) conducted a similar study on companies receiving some form of aid during 1994–97. The subsidy objectives mainly included horizontal objectives, such as R&D, quality development, export and international cooperation, entrepreneurs, environment, energy, and regional business development. The study analysed 1,491 aid-receiving companies from industries belonging to five different sectors (manufacturing, business activities, trade/hotels/restaurants, transport, and construction) and compared them to 22,112 non-aid-receiving firms. Using the pooled sample, no significant influence of firm-specific subsidies on productivity growth was found. The authors analysed also the aggregated value at industry level of all firm-specific subsidies. Results showed a negative correlation between overall subsidy intensity at the industry level and firms' productivity growth. The direction of causality in this relationship is, however, unclear: it might be that subsidies are given to firms with lower productivity growth *ex ante,* or that high subsidies actually cause low productivity growth. When the analysis is conducted separately for industries belonging to each of the five sectors, they find that for the manufacturing sector this correlation turns out to be significantly positive: industries with higher productivity growth show higher subsidy intensity.

2 Lee (1996) finds in a study for South Korea that government industrial policies primarily targeted low-productivity industries during 1963-83. He finds that subsidies through tax incentives and subsidised credits have not been successful in promoting productivity growth. Beason and Weinstein (1996) find in a study on Japanese industrial policy that a disproportionate amount of state aid was extended to sectors with decreasing returns to scale and low growth. They also report no evidence of productivity enhancement through industrial policies.

2.2 Studies on rescue and restructuring aid

During 1995-2003, there were 94 rescue and restructuring cases notified to the European Commission. To our knowledge, London Economics (2004) is the only comprehensive study investigating state aid for rescue and restructuring. It was prepared for the European Commission and examined all companies that received state aid for rescue and restructuring during this period, with the aid process having ended by 2004 (i.e., by 2004, the rescue aid had been repaid or restructuring plans had come to an end). London Economics considered 86 cases[3], of which 52 (or 60 percent) were restructuring cases. About 60 percent of the cases were in three Member States: Germany (26 cases), Italy (16), and France (12). Sectors most affected by state aid for restructuring and rescue were construction/engineering (10 cases), the financial sector (9), and machinery (8).

London Economics define an aid-receiving company as having failed if it became bankrupt or was liquidated, the latter result including the sale of parts of its (core) business. Cases where the aid has not been repaid or where the restructuring plans have not been finished (15 cases) are excluded from the analysis, as such cases are not considered closed and thus the aid impact cannot be assessed. Among the 71 companies examined, 29 were rescue aid cases and 42 restructuring aid cases. Out of the 29 rescue aid cases, 14 survived, 14 went bankrupt, and for one the status is still undetermined since the firm is insolvent[4]. Out of the 42 restructuring cases, 33 survived, eight went bankrupt, and for one the outcome is still undetermined.

Restructuring aid seems to be associated with a higher probability of firm survival than rescue aid.

The study seeks to determine which factors affect the survival of aid-receiving firms. It found that firms receiving restructuring aid have a higher probability to survive than firms receiving rescue aid. Moreover, if a firm's difficulties are due to market decline or poor management, its chances of survival after receiving restructuring or rescue aid are higher by as much as 30 percent. On the other hand, firm characteristics such as size, age, legal status, sector growth, its condition at the time of aid (measured in profits per employee), or even the relative size of aid have no significant effect on the probability of survival. Neither has the design of the rescue or restructuring plan, measured as the duration of restructuring, capacity reductions, personnel reductions, focus on core business activities, cost-cutting, financial consolidation, selling or closure of plants and assets, new investment, training and upgrading, or plant relocation.

London Economics (2004) further analyse the post-aid performance of the firms having received aid in the period 1995-99. They analyse relative growth in employment, turnover, profitability, and labour productivity from the year of award of the aid until 2002. They compare aid-receiving firms with a set of firms comparable in terms of geography, activities, and size, with the industry average defined as the average growth of the relevant variables calculated for this set of comparable firms. The results suggest that out of the 22 aid-receiving companies analysed, about half increased employment faster than the industry average. Out of 21 companies analysed, nine (or 43 percent) grew faster in terms of turnover than comparable competitors, with only one company reaching levels of turnover above industry average. In terms of profitability, out of the 18 companies analysed, 13 (or 72 percent) improved their position relative to the industry average, with four reaching above average profitability and the remaining 14 staying well below this average. Finally, in terms of labour productivity, out of the

3 Five cases were excluded due to their location (East Germany); one case was ignored as the aid decision had been pending; one case was considered a R&D case; and two cases collapsed into one as they shared the same state aid package.

4 Insolvency differs from bankruptcy in that the former is a transition state: the firm can either recover and survive or end up in bankruptcy.

21 firms analysed, 16 (or 76 percent) increased labour productivity faster than industry average, with four companies improving the productivity from below to above the industry average.

Firms receiving state aid do not seem to significantly outperform their competitors.

Summarising the empirical evidence on rescue and restructuring aid, two main results seem to stand out. First, design rules of restructuring and rescue aid plans (including the relative amount of aid) do not seem to affect the probability of survival. On the contrary, this probability increases when the difficulties of the firm stem from poor management or market decline. Second, in terms of overall growth (turnover, employment), companies receiving state aid did not significantly outperform their competitors after the grant. However, there are signs that firms in difficulties do partially close the gap regarding profitability and productivity levels after receiving state aid.

3. Model specification

3.1 Reduced-form empirical model

Several variables could be used as a measure of performance to assess the effects of state aid. Productivity is arguably the most important one, given the relationship between productivity and economic growth.

Country differences in productivity can be explained by endogenous growth models, in which the mechanisms of technology diffusion play an important role. These models predict convergence of the technologically lagging countries towards the leading country. Studies analysing convergence of multifactor productivity (MFP) across countries include Bernard and Jones (1996), Griffith *et al*. (2001), Scarpetta and Tressel (2002), and Nicoletti and Scarpetta (2003). The evidence reported in these papers suggests convergence of 'lagging' countries towards the leading country – with convergence the faster, the larger the gap to the leader.

The steady-state equilibrium predicted by endogenous growth models depends on factors such as the cost of innovation/imitation, the regulatory environment, and other institutional factors considered as given and exogenous. Empirical applications need to control for these factors in the estimation of productivity growth, and it seems natural to think of state aid as one of these factors. Griffith *et al*. (2001) focus on the effect of R&D investment. Scarpetta and Tressel (2002) concentrate on the interaction between regulation and convergence. The purpose of our paper is to widen this approach by introducing state aid as another explanatory factor. Our analysis focuses on the manufacturing sector given the measurement problems that characterise non-manufacturing industries. Moreover, manufacturing is a footloose industry and, thus, arguably more likely to receive vertical state aid.

Following the convergence literature, we introduce technology transfer as a source of productivity growth for countries below the technological frontier.[5] The technological frontier is defined by the country with the highest MFP in a given year. Issues related to the measurement of MFP and the distance of a country to the technological frontier are discussed in Box 2.

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5 For a detailed derivation see Griffith *et al.* (2000); compare also Scarpetta and Tressel (2002) and Kolasa and Zólkiewski (2004)

Box 2. Measurement of multifactor productivity and distance to the technological frontier

To calculate MFP growth and the MFP level of country *i* relative to the frontier country (i.e, the distance to the technological frontier), the superlative index number approach of Caves *et al*. (1982a, b) is used. It can be considered the discrete-time analogue of the continuous-time formula derived by Solow to measure the rate of technological progress. The difference comes from the use of a translog production function instead of the more standard Cobb-Douglas production function. However, the assumptions of constant returns to scale and perfect competition in the input markets are maintained.

MFP growth is then given by the following expression:

$$\Delta MFP_{i,t} = \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right) - \frac{1}{2}(\alpha_{i,t} + \alpha_{i,t-1})\ln\left(\frac{L_{i,t}}{L_{i,t-1}}\right) - \left(1 - \frac{1}{2}(\alpha_{i,t} + \alpha_{i,t-1})\right)\ln\left(\frac{K_{i,t}}{K_{i,t-1}}\right)$$

where $\alpha_{i,t}$ is the share of labour in value-added; $Y_{i,t}$ is output, $L_{i,t}$ is labour input, and $K_{i,t}$ is capital input – all at time *t*.

Estimating the level of MFP of country *i* compared to the frontier country rests on a similar approach, essentially involving three steps. First, the level of MFP of each country is evaluated relative to a common reference point – the geometric mean of all countries – using the following productivity index:

$$MMFP_{i,t} = \ln\left(\frac{Y_{i,t}}{\overline{Y}_t}\right) - \frac{1}{2}(\alpha_{i,t} + \overline{\alpha}_t)\ln\left(\frac{L_{i,t}}{\overline{L}_t}\right) - \left(1 - \frac{1}{2}(\alpha_{i,t} + \overline{\alpha}_t)\right)\ln\left(\frac{K_{i,t}}{\overline{K}_t}\right)$$

where an upper bar above the variable denotes a geometric mean across countries. Second, for each year, the country with the highest MFP relative to the geometric mean (MMFP) is defined as the frontier country, denoted $MMFP_{F,t}$. For the identification of the frontier country, non-EU OECD countries (e.g., Canada, Japan, and the United States) are included in the analysis to identify the world technology leader. Third, to derive the position of country *i* relative to the frontier in year *t* ($RMFP_{i,t}$: the superlative index number measure of relative MFP for country *i* in each year), $MMFP_{F,t}$ is subtracted from $MMFP_{i,t}$:

$$RMFP_{i,t} = MMFP_{i,t} - MMFP_{F,t}$$

One problem with this estimation of MFP and the distance to the technological frontier is that the share of labour in value added ($\alpha_{i,t}$) tends to be rather volatile. This might be due to measurement errors, short-run fluctuations in demand, and the fact that wage negotiations are not on an annual basis. Following Harrigan (1997) and Griffith *et al*. (2001), we exploit a property of the translog production function with constant returns to scale and the assumption of competitive input markets to smooth the share of labour in value added. Indeed, for this production function, the equalisation of the marginal product of labour to the wage produces a stable relationship between the share of labour in value added and the logarithm of the capital-labour ratio. Assuming that the observed share differs randomly from this stable relationship, one can estimate:

$$\alpha_{i,t} = \upsilon_i + \varphi \ln\left(K_{i,t}/L_{i,t}\right) + \varepsilon_{i,t}$$

where $\varepsilon_{i,t}$ is an i.i.d. error term and υ_i are country fixed effects. This formulation with country fixed effects assumes that the structure of production differs among countries only through differences in the first-order translog parameters (Caves 1982a, b). The fitted values of $\alpha_{i,t}$ from this equation are used in the calculations of $\Delta MFP_{i,t}$ and $MMFP_{i,t}$.

MFP is modelled as an auto-regressive distributed lag ARDL(1,1) where the level of MFP is cointegrated with the level of MFP of the technological frontier country F:

(1) $$ln\ A_{i,t} = \theta_1\ ln\ A_{i,t-1} + \theta_2 ln\ A_{F,t} + \theta_3 lnA_{F,t-1} + \omega_{i,t} + \varepsilon_{i,t}$$

where A_F is MFP in the frontier country and ω stands for all observable and non-observable factors influencing the level of MFP. Additionally, we assume convergence towards a steady state where the growth rates of MFP are equal across countries and over time and $\omega_{i,t}$ is constant. Formally, this means that $\Delta lnA_{i,t} = \Delta lnA_{F,t}$ and $\Delta lnA_{i,t} = \Delta lnA_{i,t-1}$. With this and (1) we can derive the steady-state condition: $(1\text{-}\theta_1) = (\theta_2+\theta_3)$. Rearranging (1) and assuming steady-state convergence, MFP growth can be written as an error correction model of the form:

(2) $$\Delta ln\ A_{i,t} = \theta_2\ \Delta ln\ A_{F,t} + (\theta_1\text{-}1)\ ln(A_{i,t-1}/A_{F,t-1}) + \omega_{i,t} + \varepsilon_{i,t}$$

Equation (2) describes the variation in the level of technology around its long-run trend as a function of a set of exogenous factors (ω), the variation in the leader's technology around its trend (the first term on the right-hand side of the equation), and an error correction (the second term), which depends on the technology of country *i* compared to the leader. The first term, which captures the diffusion of technological advances from the leading country to the rest, is expected to be positive. The second term, which captures the catch up of lagging countries to the technology leader, is expected to be positive, too. Note, however, that catching up implies that $(\theta_1\text{-}1)$ is negative because $ln(A_{i,t-1}/A_{F,t-1})$ is negative, too, since $A_{i,t-1} < A_{F,t-1}$. The larger the parameter $(\theta_1\text{-}1)$ in absolute terms, the stronger the catching-up effect. The MFP of countries further away from the technology frontier is thus expected to grow faster.

Vertical state aid is introduced as another factor affecting the equilibrium level of technology in a country.

The set of $\omega_{i,t}$ variables affects the equilibrium level of technology in country *i*. Therefore, a natural way to assess the effect of vertical state aid on productivity is to introduce it as a component in $\omega_{i,t}$. Its expected sign is ambiguous, since the efficiency-enhancing effect of vertical aid may be quite weak – agglomeration effects, alleviation of credit constraints, and so on – and may not compensate for the distortions it creates – rent capture, allocative inefficiencies, and so on. Moreover, vertical aid may adversely affect productivity through its impact on competition. That said, the relationship between competition and innovation and, thus, productivity is not clear either, as argued by Aghion and Griffith (2005).

Let us now turn to other variables included in $\omega_{i,t}$. They are discussed conceptually below; the data used in the estimations are explained in Annex 1.

As stressed by the endogenous growth literature, the accumulation of R&D knowledge is an important source of output growth. Our measure of MFP growth accounts for what cannot be explained by the accumulation of physical capital and labour. In this respect, the growth of the R&D knowledge stock is part of MFP growth. Following Griffith *et al*. (2001) and Scarpetta and Tressel (2002), we include R&D intensity as an explanatory variable. Assuming a small rate of depreciation of this knowledge stock, its growth is mostly determined by R&D investment. This allows using R&D investment to capture the growth of R&D intensity. To avoid endogeneity problems of current R&D investment, we use lagged R&D investment as an explanatory variable. Similarly, public capital has been shown to exert some influence on growth (see Romp and de Haan 2005), so we include it as another explanatory variable. Since physical capital measures only include private capital, the effect of productive public capital is included in our MFP measure. Hence, we include the growth of public capital as an additional variable.

Scarpetta and Tressel (2002) find that product market regulation (PMR) and employment protection legislation (EPL) have a significant (negative) impact on MFP growth rates. We therefore introduce

PMR and EPL indicators for the different countries. Specifically, we use an indicator of administrative barriers (ADMIN) to proxy for PMR in the manufacturing sector (see Annex).

Other factors, such as the quality of human capital and industry structure are believed to be reasonably stable over the estimation period within individual countries and will hence be captured via the introduction of country dummies.

Due to the relatively small data set, we do not introduce time dummies. The results of Smolny (2002) suggest that a large part of the annual fixed effects can be captured by introducing a dummy for the business cycle.[6] We use the EU-15 output gap as a proxy for the business cycle to capture these effects.

Consequently, the final model specification reads as follows:

$$(3) \qquad \Delta ln\, A_{i,t} = \beta_1 \Delta ln\, A_{F,t} + \beta_2\, ln(A_{i,t-1}/A_{F,t-1}) + \beta_3\, (AID_{i,t-1}/VA_{i,t-1}) + \\ +\beta_4\, (R_{i,t-1}/VA_{i,t-1}) + \beta_5\, ADMIN_i + \beta_6\, EPL_{i,t} + \beta_7\, (Y_t - Y_t^*)/Y_t^* + \delta_i + \varepsilon_{i,t}$$

Similar to equation (2), in equation (3), we would expect $\beta_1 > 0$ and $\beta_2 < 0$, with $\beta_1 \Delta lnA_{F,t}$ and $\beta_2 ln(A_{i,t-1}/A_{F,t-1})$ capturing technology diffusion and catch-up, respectively. *AID* denotes state aid as a share of manufacturing value added (*VA*); *R* denotes R&D intensity, *ADMIN* is a time-stable indicator to proxy for product market regulation, *EPL* a time-varying indicator for employment protection legislation, and $(Y-Y^*)/Y^*$ denotes the EU-15 output gap; δ is a country fixed effect; and ε an i.i.d. shock.

3.2 Measurement of vertical aid

In the manufacturing sector, four sub-sectors are eligible for so-called sectoral aid under specific aid schemes: steel, shipbuilding, synthetic fibres, and motor vehicles. Additionally, aid for rescue and restructuring is considered vertical state aid to the manufacturing sector.

Overall, total state aid to manufacturing (including that with horizontal objectives) dropped from €44 billion in 1995 to €29 billion in 2003. This decrease was almost exclusively due to a drop (of €13 billion) in vertical aid directed to the manufacturing sector, which amounted to only €1.3 billion in 2003. As a result, the share of state aid with horizontal objectives in aggregate aid to manufacturing increased from 68 percent in 1995 to 94 percent in 2003. Only two states channel a significant amount of their state aid to the manufacturing sector through vertical instruments: Ireland (68 percent) and Portugal (91 percent).

Only Ireland and Portugal extend a significant amount of state aid to manufacturing using vertical instruments.

However, a closer look at so-called 'state aid with horizontal objectives' for the manufacturing sector reveals some interesting details. First, about 96 percent of total state aid for horizontal objectives is awarded to the manufacturing sector (average 1995-2003)[7]. The share of manufacturing in total horizontal aid ranges from around 80 percent in Sweden and Portugal to almost 100 percent in the United Kingdom, Finland, and Greece.

6 In a cross-sectoral study on sources of productivity growth in Germany by Smolny (2000), the introduction of time dummies did not affect R^2. But it reduced the influence of a proxy for business cycle by half and rendered it insignificant, indicating that a large part of the fixed time factor is captured by a business cycle proxy.

7 This figure decreased from 97 percent in 1995 to 94 percent in 2003. But in interpreting this figure one should bear in mind that the apparently high share of manufacturing 'state aid with horizontal objectives' might also be due to measurement difficulties when attributing state aid volumes to different sectors. Concerning the sectoral distribution, European Commission (2005, p.15) states: "The data currently available do not provide an accurate picture of the final recipients of the aid. Nevertheless, they do give some indication as to which sectors are favoured by each Member State."

Second, as mentioned in Section 1, state aid is always classified by the European Commission as horizontal when its primary objective is horizontal. However, there are numerous cases of state aid where the primary objective is horizontal, but the aid is limited to a certain industry, sub-sector, or sector.[8] In these cases there appears to be a mixture of horizontal objectives with vertical orientation of the aid. The data published in the State Aid Scoreboard does not allow distinguishing between horizontal aid designed for all sectors and horizontal aid awarded only to specific industries, sub-sectors, or sectors.

An indicator of the extent to which Members States are able to provide vertical state aid in the form of horizontal aid can be obtained from the pattern of, for example, Spanish aid notifications between 1993 and 2005. During this period, Spain submitted around 305 notifications of state aid, the major part of which were notified as aid to investment, to SMEs, to training, or as regional aid. Aid to investment constituted the main objective in 21 cases, 9 of which were explicitly targeted towards specific sectors. Of the 44 notifications of state aid with regional support as primary objective, 22 were targeted at specific sectors, sub-sectors or firms. And then, of the 60 cases notified as SME support as primary objective, 22 were sector-, sub-sector-, or firm-specific.

State aid labelled 'horizontal' can, in fact, be horizontal or vertical aid.

We conclude that state aid labelled as 'horizontal' at the aggregate level for the manufacturing sector can, in fact, be horizontal or vertical state aid. Considering only aid labelled as sectoral (i.e., aid for steel, shipbuilding, synthetic fibres and motor vehicles as well as rescue and restructuring aid) surely underestimates the actual amount of vertical aid. That said, considering all aid to the manufacturing sector as vertical most likely overestimates the actual amount of vertical state aid. In the empirical analysis we will therefore analyse the effects of aid labelled as sectoral and of total state aid to the manufacturing sector.

As about 20 percent of total state aid is in favour of R&D and because such aid affects R&D intensity – another explanatory variable in model (3) – in an unknown way, the inclusion of both total state aid and R&D intensity as explanatory variables would bias the estimation results. A possible solution to this problem is to replace R&D intensity with a function of its determinants, which would include aid for R&D in the manufacturing sector as an unobservable, and to use total aid as the measure for vertical state aid. In this case, the effect of the unobserved R&D aid would be captured by the coefficient of total aid. Due to data constraints, however, we have chosen to include both variables and perform robustness checks by replacing business R&D with a measure of the business R&D component financed by industry alone.

3.3 Endogeneity of state aid

There is a possibility that vertical aid is more likely to go to industries or firms with a particular level of productivity than to other industries or firms. For instance, if the policy objective is to pick winners, vertical aid might overwhelmingly go to high-productivity industries or firms. By contrast, if the objective is to support losers (with a view to helping them to adjust to a changing environment, for instance), aid might largely go to low-productivity industries or firms. In this sense, one cannot say that state aid is exogenous with respect to productivity growth. We thus have to distinguish the effect of state aid on productivity growth from the correlation between these two variables, which follows from the objective of awarding aid in the first place. Hence, instrumental variables are used

8 To give a few examples: state aid case NN15/2000 – UK, Civil Aircraft Research and Technology Demonstration Programme is considered a horizontal R&D measure although directed exclusively at the civil aviation industry; state aid case N443/1999 – Germany, R&D Aid to Institut für Solare Technologien, GmbH is classified as R&D aid and is exclusively awarded to support research of photovoltaics technology; state aid case N74/2005 – Sweden, Environmental Aid to Volvo Truck Corporation is classified as environmental aid and is exclusively awarded to foster environmental measures in the motor vehicles industry; state aid case XS118/2003 – Germany, Polenbürgschaft is classified as an SME block exemption case; however, it is exclusively awarded to the industrial machinery sector in Brandenburg, Eastern Germany.

to estimate the effect of state aid on productivity growth, controlling for the fact that productivity growth may itself determine the amount of aid.

We have used two types of instruments. First, political-economy variables have been used, as political characteristics of a country are likely to determine the willingness to extend aid to particular sectors – either because some political parties care more about equity/efficiency than others or because certain governmental structures are more prone to capture by interest groups. Second, state aid to other sectors have been used, as the willingness to grant aid can also be inferred from the observation of the level of aid granted to other sectors of the economy. These aids are correlated with aid to manufacturing and awarded independently of the productivity of the manufacturing sector. They are thus good potential instruments.

4. Estimation results

4.1 Some descriptive statistics

The computation of MFP levels and growth rates according to the methodology described in Box 1 yields the results summarised in Table 1. We also present the sample means of the state aid variables.

As Table 1 illustrates, among EU-15 countries, France is closest to the technological frontier in the manufacturing sector, which is determined by Canada and the United States during the sample period. The group of countries farthest away from the frontier include Italy, Denmark, and Spain. Nordic countries experienced the highest MFP growth rates, whereas Spain and the United Kingdom show average MFP growth close to zero.

Among EU-15 countries, France is closest to the technological frontier in the manufacturing sector.

Table 1. Descriptive statistics on MFP, MFP growth, and state aid

	MFP growth (%)		Distance to frontier (% of technology level of leading country)		Vertical state aid to manufacturing (% of value added)		Total state aid to manufacturing (% of value added)	
	Mean	St. Deviation	Mean	St. Deviation	Mean	St. Deviation	Mean	St. Deviation
Austria	1.73	0.0244	75.1	0.0142	0.10	0.0015	1.37	0.0019
Belgium	1.60	0.0231	82.3	0.0214	0.28	0.0043	2.23	0.0054
Denmark	1.47	0.0430	63.8	0.0186	0.07	0.0011	4.49	0.0101
Finland	5.35	0.0325	75.7	0.0819	0.08	0.0013	1.75	0.0038
France	2.61	0.0232	90.8	0.0321	0.39	0.0026	2.10	0.0050
Germany	1.36	0.0236	77.1	0.0215	1.18	0.0115	3.65	0.0117
Greece	n.a.	n.a.	n.a.	n.a.	0.78	0.0146	7.18	0.0444
Ireland	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Italy	0.56	0.0293	67.1	0.0324	0.68	0.0071	4.58	0.0241
Luxembourg	n.a.	n.a.	n.a.	n.a.	0.00	0.0000	2.56	0.0087
Netherlands	0.45	0.0290	82.4	0.0380	0.08	0.0005	1.23	0.0017
Portugal	n.a.	n.a.	n.a.	n.a.	0.63	0.0075	1.86	0.0077
Spain	0.24	0.0135	63.5	0.0348	1.08	0.0098	2.74	0.0088
Sweden	3.49	0.0371	86.4	0.0520	0.00	0.0000	0.77	0.0059
UK	0.11	0.0210	86.9	0.0786	0.01	0.0002	0.79	0.0015

Notes: Based on 1992-2003 data (1995-2003 for state aid data for Austria, Finland, and Sweden); Mean = period average; n.a. = not available due to missing data either on capital stocks or value added.

Germany and Spain grant most vertical state aid in relation to manufacturing value added.

Germany and Spain stand out as the countries granting most vertical state aid in relation to value added in the manufacturing sector. Given their moderate total state aid, it seems that these two countries award a large part of state aid to manufacturing through vertical instruments. By contrast, Denmark awards the majority of its state aid, which is considerable, in the form of horizontal aid. Finally, Sweden and the United Kingdom appear to support their manufacturing sectors least among the sample.

It is also helpful to examine the correlation between state aid and MFP growth rates across the different countries. The correlation coefficients are shown in Table 2. With regard to vertical aid, correlation coefficients show both positive and negative relationships. Overall, however, there seems to be a weak positive correlation between vertical state aid and the growth rate of MFP in the next period for the countries extending significant amounts of vertical aid. This positive relationship is a little more obvious for total state aid, though it is still negative for countries with low levels of total state aid. Spain stands out as the single case of high levels of total state aid associated with a negative correlation with MFP growth.

Table 2. Correlation between state aid in a year and MFP growth in the following year

	Vertical state aid	Total state aid
Austria	0.0126	0.1913
Belgium	0.4009	0.5515
Denmark	-0.0818	0.2509
Finland	-0.2368	0.0323
France	0.5225	0.3284
Germany	0.1881	0.2946
Italy	0.5116	0.3192
Netherlands	-0.3249	-0.2859
Spain	-0.2403	-0.1820
Sweden	--	-0.2373
United Kingdom	0.0098	-0.3163

Note: Correlation between state aid at time *t-1* and MFP growth in *t*.

4.2 Results

Table 3 presents the results of the baseline specification of the model[9]. When the error correction model is estimated without controlling for any of the possible alternative determinants of MFP

9 As the estimation of an error correction model presupposes the existence of a cointegrating relationship between the levels of MFP in each country and the frontier country, one needs to test for cointegration. However, the test would require knowledge of the absolute levels of MFP, which we do not observe, since only levels relative to other countries can be computed. As a less formal test, we performed unit root tests on the MFP growth series and report serial correlation tests for the error terms of the regressions. In addition, we performed Levin-Lin and Im-Shin unit root tests for panel data on the MFP growth of the non-frontier countries. The presence of a unit root was rejected in both tests at the 1-percent level. For the frontier, we used the Dickey-Fuller test with a MacKinnon p-value of 0.073.

growth (column 1), the estimated coefficient (β_2 in equation (3)) for the technological gap (i.e., *RMFP*) is negative as expected, but statistically not significant. On the other hand, technological diffusion, β_1 in equation (3), from the frontier country (i.e., $\Delta MFP_{Frontier}$) appears to be strong and statistically significant.

Fixed effects (introduced in column 2), which control for any unspecified and country-specific variables, are significant for only some countries, with the reference country being the United Kingdom.

Column (3) shows the results when including the output gap (*Output gap EU*), R&D intensity (*R&D/VA*), and the growth of public capital (*gkpub*)**.** With this specification, the coefficient of the technological gap becomes significant and increases (in absolute terms) to -0.175; the technological diffusion coefficient increases and remains significant. We can also see the direct effects of the control variables: R&D intensity appears to have a positive, statistically significant impact on MFP growth, while the impact of the output gap and of public capital is negative – although for the latter control variable, the estimated coefficient is not statistically significant. Fixed effects for Finland and Sweden become insignificant, while a negative fixed effect for Denmark appears significant at the 5-percent level. This may indicate that Finland and Sweden were able to maintain higher MFP growth rates with respect to the United Kingdom due to relatively higher levels of R&D intensity.

Column (4) shows estimation results when we allow for interaction between R&D intensity and the technological gap. The coefficient is negative, suggesting that the effect of R&D spending is the stronger the farther away a country is from the technological frontier. However, contrary to Griffith *et al*. (2001), we cannot find any evidence for this interaction term being significant. This also implies that in our estimates R&D does not affect the speed of convergence.

When compared to other studies, our estimates of the diffusion and convergence parameters appear somewhat higher, especially the diffusion estimate. In particular, the diffusion coefficient as estimated by Griffith *et al*. (2001) is around 0.13 and that of Scarpetta and Tressel (2002) is not significant for manufacturing industries. This compares to our estimate of around 0.5 to 0.6, which hold across the specifications presented in the different tables. The estimates for the convergence parameter vary between -0.07 and -0.097 in Griffith *et al*.[10] and between -0.02 and -0.05 for the manufacturing sectors in Scarpetta and Tressel. In our study, the estimate is about -0.175 for the baseline specification. Those two studies use industry-level data and estimate the same parameters for all industries. Our study uses aggregate manufacturing data, and this implies that the parameter estimate is like an unweighted average of the effects of specific industries, and may incorporate diffusion effects across industries.

This study suggests somewhat faster technology diffusion and productivity convergence than some earlier studies.

10 The estimate decreases to around -0.02 when interaction terms with other variables are included.

Table 3. Baseline specifications of the MFP growth model

Variable	(1)	(2)	(3)	(4)
Austria		0.0069	0.0000	0.0000
Belgium		0.0095	0.0045	0.0045
Denmark		-0.0012	-0.0373**	-0.0373 **
Finland		0.0340***	0.0192	0.0192
France		0.0234***	0.0271**	0.0271 **
Germany		0.0045	-0.0144	-0.0144
Italy		-0.0082	-0.0168	-0.0168
Netherlands		-0.0011	0.0014	0.0014
Spain		-0.0123	-0.0181	-0.0181
Sweden		0.0252**	-0.0034	-0.0033
$\Delta MFP_{Frontier,t}$	0.5171***	0.5348***	0.6260***	0.6259 ***
$RMFP_{i,t-1}$	-0.0008	-0.0414	-0.1751***	-0.1748
Output gap EU			-0.0079**	-0.0079 **
$R\&D/VA_{i,t-1}$			0.6873**	0.6864
$R\&D/VA_{i,t-1}$ x RMFP				-0.0040
gkpub			-0.3151	-0.3154
_cons	0.007	-0.0115	-0.0770***	-0.0769 **
Statistics				
Observations	131	131	100 (b)	100 (b)
Adjusted R^2	0.239	0.363	0.455	0.448
Serial correlation		2.183	2.252	2.443

Notes: Robust standard errors are used due to presence of heteroscedasticity. Serial correlation is Bhargava *et al.* modified DW for balanced panels (b) and Baltagi-WU LBI for unbalanced panels. *** (**) [*] indicates that the coefficient is significant at the 1% (5%) [10%] confidence level.

Next, we analyse the effect of state aid on manufacturing MFP. As discussed earlier, total state aid to manufacturing includes aid awarded to R&D objectives and, thus, estimated coefficients are likely to be biased. To mitigate the possible bias in the coefficients, we have replaced R&D intensity by privately funded R&D. Table 4 shows the estimation results for the effect of vertical state aid, as classified by the European Commission (that is, for sectoral state aid). Three different specifications are estimated, for which we present both weighted OLS and instrumental variables GMM estimates.

We considered two possible sets of instruments: political economy variables and state aid intensities in other sectors of the economy. The political variables we considered as potentially correlated with state aid were the number of years in office for the political party of the head of government, the ideology of the party in office (left-wing, right-wing, or centre), a measure of the strength of the government (where weaker governments are considered to be those formed by a large number of parties with few seats in the parliament), the number of seats of the government in the parliament, a measure of the strength of the opposition (defined as in the case of the governing majority), and the number of seats of the opposition. With respect to aid to other sectors of the economy, we considered state aid awarded to coal, financial services, transport, other non-manufacturing sectors, and to other services.

State aid to other sectors does not affect aid to manufacturing.

State aid to other sectors of the economy do not seem to explain state aid to manufacturing given the rest of exogenous regressors; first stage regression results yield insignificant coefficients for these instruments. Only aid to other non-manufacturing sectors seems to be significant. Nevertheless, it loses its significance once the other political economy variables are added to the estimation. Therefore, state aid to other sectors of the economy cannot provide any new relevant information to explain the intensity of state aid to manufacturing over and above what is provided by political variables.

Table 4. The effect of vertical state aid on MFP growth

Variable	Specification (1) WLS	Specification (1) IV GMM	Specification (2) WLS	Specification (2) IV GMM	Specification (3) WLS	Specification (3) IV GMM
Austria	0.0000	…	0.0000	…	0.0000	…
Belgium	-0.0045	-0.0067	0.0000	…	0.0263	0.0241
Denmark	-0.0351	-0.0319	-0.0505**	-0.0462**	-0.0274	-0.0262
Finland	0.0072	0.0050	0.0019	0.0002	0.0167	0.0119
France	0.0210	0.0163	0.0192	0.0164*	0.0539**	0.0497**
Germany	-0.0308*	-0.0404**	-0.0328**	-0.0371***	-0.0078	-0.0106
Italy	-0.0194	-0.0236	-0.0270	-0.0256	0.0000	…
Netherlands	-0.0018	-0.0047	-0.0320*	-0.0338**	-0.0087	-0.0144
Spain	-0.0216	-0.0316	-0.0510*	-0.0541**	-0.014	-0.0176
Sweden	-0.0125	-0.0128	-0.0468*	-0.0468*	-0.0067	-0.0124
$\Delta MFP_{Frontier,\ t}$	0.5576***	0.5411***	0.5144***	0.4987***	0.5420***	0.5252***
$RMFP_{i,\ t-1}$	-0.1425**	-0.1346**	-0.1508**	-0.1401***	-0.1421**	-0.1374**
$R\&D/VA_{i,\ t-1}$	0.8347**	0.8100**	0.8771***	0.8748***	0.8134**	0.8396***
gkpub	-0.4038	-0.3339	-0.3202	-0.2042	-0.3841	-0.2660
Output gap EU	-0.0053	-0.0035	-0.0001	0.0009	-0.0029	-0.0024
$AIDV/VA_{i,\ t-1}$	0.8280*	1.5728**	0.4918	0.9051	0.8684**	0.8679*
EPL_{t-1}			0.0289**	0.0272***		
ADMIN			-0.0260**	-0.0252***	-0.0249	-0.0253
EPL_{t-1} (med)					0.0318	0.0336
EPL_{t-1} (high)					0.0525	0.0559
_cons	-0.0645***	-0.0616***	-0.0694***	-0.0663***	-0.0501**	-0.0496***
Statistics						
Observations	88	88	88	88	88	88
Adjusted R^2	0.354	0.333	0.407	0.399	0.380	0.369
Serial correlation	2.500	2.500	2.558	2.558	2.525	2.525

Notes: See notes to Table 3. Note further that the instrumental variables (IV) used are: (i) the number of years the party of the chief executive of the government has been in office; (ii) the composition of the government; and (iii) the ideology of the party dominating the government.

Political variables appear then to be the most suitable instruments. Among them, those that appear to jointly better explain the level of state aid, while being uncorrelated with MFP growth[11], are the following: the number of years in office for the political party of the head of government (positive effect), the composition of the government (weaker governments awarding higher levels of aid), and the ideology of the party dominating the government (centrist parties awarding less aid than

11 Shea partial R^2 of the excluded instruments ranges between 0.26 and 0.38, depending on the specification. This is a measure of the adequacy of the instruments to explain the endogenous variable. The absence of correlation between the instruments and MFP growth was assessed through over-identifying restriction tests. All specifications presented in the tables passed the test, meaning that the hypothesis of exogeneity of the instruments could not be rejected.

the rest). These results are in line with the characteristics of governments more prone to capture. The longer a party is in power, the higher is the probability of links with representatives of the different industries. At the same time, weaker governments are formed by small pivotal parties, which can have some lobbying power to implement the measures that please their electorate. Finally, centrist parties are perhaps those whose ideology is less oriented towards particular pressure groups.

Specification (1) shows the estimates obtained for the baseline model with the controls and the vertical state aid variable (*AIDV/VA*). Results show a positive and significant effect of vertical aid on manufacturing productivity: an extra percentage point of vertical state aid generates approximately 0.83 percentage points (0.0083 = 0.828 * 0.01) of MFP growth in the manufacturing sector. It also turns out that when political variables are included as instruments, the magnitude of the vertical-aid coefficient more than doubles. This result holds also for total state aids (see Annex Table A1).

Recall that the OLS estimate of the aid coefficient is the sum of the true parameter plus a bias term, whose sign is given by the covariance between the lagged values of vertical aid and the error term in the equation describing MFP growth. Taking the coefficient of the IV estimates as a consistent approximation of the true coefficient, we conclude that the OLS estimate is biased downwards and, hence, the covariance is negative. We would like to infer from this covariance the sign of the MFP growth parameter in the equation determining the level of vertical aid: that is, whether aid goes to 'winning' or 'losing' sectors. Unfortunately, this is not possible without estimating a model for state aid. Although the expression for the covariance depends on the particular specification of this model, both positive and negative values of the coefficient are compatible with a negative covariance.[12]

The effect of vertical state aid on manufacturing productivity appears positive.

Specification (2) adds to the model the indicator on employment protection legislation (EPL) and that of administrative regulation (ADMIN), which proxies product market regulations. The effect of vertical state aid is again estimated to be positive, but becomes insignificant even after correcting for endogeneity. Administrative regulations have a negative and significant effect on MFP growth. However, we also find a positive and significant effect of employment protection, contrary to the findings of Scarpetta and Tressel (2002). A categorisation of the EPL indicator into three possible levels[13], taken into account by specification (3), seems to suggest that the positive effect of employment protection comes from countries with higher levels of employment protection[14], though the results are not statistically significant. Vertical state aid becomes again significant with this specification, although its magnitude and the bias of the OLS estimate seem to be smaller and almost negligible.

We estimated yet another specification with a categorisation of vertical state aid into low, medium, and high. More specifically, countries with no vertical state aid were classified as having low vertical aid. Countries with a level of vertical aid one standard deviation above the mean were classified as high-vertical-aid countries. The categorisation was time varying, and we took advantage of the fact that there are countries in the sample with no vertical aid in some years and a positive level in other years. Unfortunately, the correlation of the instruments at hand with the outcome of this

12 Consider, for example, the following linear specification for state aid: $AIDV_t = \mu\ AIDV_{t-1} + \alpha\ political_t + \delta\ gMFP_t + u_t$. The expression for the covariance between $AIDV_{t-1}$ (which appears in equation (3)) and the error term ε_t in equation (3) then is: $Cov(AIDV_{t-1}, \varepsilon_t) = -[\delta/(\mu+\delta\beta_3)]\ Var(\varepsilon_t)$. We can see that a negative covariance is compatible with positive and negative values of δ depending on the magnitudes of the other parameters in the equation. However, if we assume that $0<\mu<1$, it is easily seen that the true sign of β_3 is inversely related to the sign of the covariance, which means that not taking into account the endogeneity leads to underestimates of the true parameter.

13 Low-EPL (high-EPL) countries are those with an EPL indicator more than one standard deviation below (above) the sample mean; the remaining countries have been categorised as intermediate-EPL countries.

14 High employment protection could favour MFP growth if protection fosters workers' investment in firm-specific knowledge and skills.

categorisation was not significant. Hence, instrumental variable estimation was not possible for this specification. While we do not show even the results of the OLS estimation, suffice it to mention that these results pointed to a negative effect of vertical aid on MFP growth for medium levels of vertical aid, but a positive effect for high aid levels. Nevertheless, none of the estimates was significant and we cannot exclude the possibility that the bias of the OLS coefficients is underestimating a positive effect in both categories.

The effect of total state aid on manufacturing productivity is also positive.

A similar exercise has been performed using total state aid to manufacturing rather than only vertical aid. The results are presented in detail in Annex Table A1. Suffice it to note here that they are similar to those for vertical state aid. However, the significance of the results is stronger – possibly because total state aid to manufacturing has not fallen, thus avoiding a downward trend in the data that hinders identification. What is more, except for specification (1), i.e., the one that does not control for product market regulation and employment protection legislation, the impact of total aid to manufacturing on MFP growth appears to be higher than the impact of vertical aid. Depending on the specification, an extra percentage point of total state aid intensity yields between 0.76 and 1.05 percentage points of MFP growth.

As a final step in the analysis, we return to the impact of vertical aid on MFP growth and consider specifications where the potential effect of aid depends not only on the level of aid, but also on the distance of any particular country from the technological frontier. Technically, this implies interacting the regressors *RMFP* and *AIDV/VA*. Unfortunately, the limited sample size implies that such a more elaborated specification is harder to estimate precisely. The results we obtain (not shown) add therefore little information to our main conclusions.

To summarise the main findings discussed in this section, our results point to a positive effect of pure vertical state aid on productivity growth in manufacturing. This effect cannot be attributed to the possibility that governments might tend to extend aid to sectors with higher productivity, as we have accounted for any endogeneity there may be between productivity and aid. Nevertheless, independently of the rule followed by governments, there is some evidence that productivity has grown faster the more aid was extended in the previous period. It is also possible that the effect of state aid lasts longer than a single period. However, the short dimension of our panel prevents us from exploring a richer structure for the lagged effects of state aid.

The effect of vertical aid, as classified by the European Commission, provides an estimate for the worst-case scenario since efficiency arguments in favour of such aid are weak. This estimate is positive and significant for the majority of specifications. In turn, total state aid data provides the best-case scenario, given that it includes aid that can be justified on efficiency grounds. In this case, the results are more significant and seem to indicate that the positive effects are reinforced, possibly through a positive impact of state aid on R&D intensity.

With regard to the model proposed, it yields robust estimates for the diffusion of technology (0.5), for the speed of convergence (around -0.15), and for R&D (0.8). The estimated aid coefficient is not as robust, varying in magnitude and significance with different measures of employment protection legislation (EPL). In general, when controlling for EPL, the effect of state aids decreases (becoming non-significant for some specifications). Aid, EPL, and PMR all measure different aspects of state intervention, and a challenge for further work will be to more clearly separate out the impact of aid from other intervention. This would surely call for a structural analysis of the joint determination of the allocation rule for state aid and productivity growth.

Our results have to be interpreted with caution, however, given the short dimension of our panel. Better estimates for private capital stocks should enable us to use the information on state aid for all EU-15 countries. This would include Ireland and Portugal, two countries where the share of vertical state aid in total aid is among the highest in the sample. Moreover, a longer time series would allow us to better capture the influence of common shocks through the use of time dummies and to define a better lag structure for the state aid variable.

5. Conclusions

Sectoral aid and aid for rescue and restructuring are two examples of vertical state aid, that is, aid extended to specific firms or industries. Horizontal state aid, in contrast, is in principle extended in support of broad economic goals (such as R&D, environmental protection, energy savings, promotion of SMEs, and so on) independently of sector. Similarly, regional aid aims at supporting all activities in lagging regions. The European Commission has recognised that vertical aid is "likely to distort competition more than aid for horizontal objectives and also tend to favour objectives other than identified market failures" (European Commission 2005, p.20). As a consequence, the Commission is encouraging Member States to reduce this type of aid.

Existing evidence concerning the effectiveness of vertical state aid is scarce and points to vertical aid resulting in rent shifting in the short term. With respect to rescue and restructuring aid, the only study existing to our knowledge indicates that firms in difficulty seem to partly close the productivity gap *vis-à-vis* other firms. Some studies using a broader definition of aid suggest that state aid may raise the productivity of subsidised firms in the short-term compared to that of non-subsidised ones. However, in the medium- to long run, the effect becomes negative.

Using a model of productivity convergence across countries, we have assessed the effects of vertical state aid in the manufacturing sector. There are several variables that could be used as a measure of performance on which to assess the effects of state aid. However, productivity appears to be the most important given the ultimate relationship between productivity and economic growth. We focus on the manufacturing sector because of the measurement problems that characterise non-manufacturing industries. Moreover, manufacturing is footloose in nature and thus more likely to receive vertical state aid.

Overall, the results point to a positive, significant effect of vertical state aid on productivity growth.

Following our discussion about the possible use of horizontal aid to extend what is *de facto* vertical aid, we consider vertical aid as representing the worst-case scenario of the effects of state aid on productivity. Total state aid, on the other hand, is considered to represent the best-case scenario. Overall, our results point to a positive, significant effect of vertical state aid on productivity growth. The best-case estimates are even more significant, which seems to indicate that the positive effect is reinforced, possibly through a favourable impact of state aid on R&D intensity. Nevertheless, given the correlation with other state interventions, further research on a structural model of state aids seems worthwhile.

Although our results have to be interpreted with caution, they seem to contradict the view that the efficiency justification for sectoral and rescue aid is weak. Indeed, they support the task of the European Commission to focus monitoring efforts on potentially distortionary state aid.

Annex

Data sources

Since state aid data are available on an aggregate basis, the manufacturing sector has to be modelled as a whole. Panel data are used for 11 EU Member States[15] for 1992-2003. The data set is unbalanced due to missing observations and because Austria, Finland, and Sweden entered the EU only in 1995.

Output. We use value added figures from the OECD STAN database (Vol. 2005) for the manufacturing sector. It is customary to use a value added concept for output in the convergence literature since the analysis includes industries with different levels of vertical integration (Schreyer and Pilat 2001).

Capital stock. We use fixed capital stock data from the OECD STAN database (Vol. 2005) for the manufacturing sector. Where data were missing, the fixed capital stock series were estimated with the help of gross fixed capital formation data using the perpetual inventory method.[16] The impact of capital utilisation on the measurement of MFP convergence is an issue in the convergence literature. Griffith *et al*. (2001) adjust capital stock for utilisation by using a smoothed output series, but find no significant impact on their results. Hence, we use unadjusted capital stock.

Labour input. Following Griffith *et al*. (2001) we use the number of people employed from the OECD STAN database (Vol. 2005) as a base measure. We also use total hours worked from the ILO database. Griffith *et al*. (2001) and Scarpetta and Tressel (2002) test for the robustness of their findings using hours worked instead of the number of people employed. They also make adjustments for different skill levels among countries and industries. However, neither modification has a significant impact on their results.

Purchasing power parity. A measure of purchasing power parity (PPP) is needed to convert the value of production into common units while taking into account differences in the purchasing power of each country's currency. To take into account that relative prices might evolve differently across countries, the most recent convergence literature uses industry-specific expenditure PPPs rather than GDP PPPs[17]. However, Scarpetta and Tressel (2002) run a sensitivity analysis on the use of GDP PPPs and find that their results are not significantly altered. Since we are only looking at the manufacturing sector as an aggregate and in a rather homogenous set of countries (EU-15), our baseline estimate uses GDP PPPs taken from the OECD.

Labour share in value added. Data on the labour share in value added are taken from the OECD STAN INDICATORS database.

State aid. Data on state aid are reported as aid to the manufacturing sector in percent of value added. They have been taken from the online version of the State Aid Scoreboard of the European Commission.

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15 Ireland, Luxembourg, and Portugal were dropped from the EU-15 sample due to the short series on gross capital stock formation, which yielded poor estimates of their private capital stocks.

16 See Scarpetta and Tressel (2003) and OECD (1999) for a description of the perpetual inventory estimation method. For estimating average service lives (ASL), data in OECD (1999) were used, taken from OECD (1993). For countries where no ASL data were available, the average of similar neighbouring countries was considered an adequate proxy.

17 See for example Griffith *et al.* (2001), Nicoletti and Scarpetta (2003), and Scarpetta and Tressel (2002). Kolasa and Zólkiewski (2004) use GDP PPPs when analysing the determinants of MFP for Poland and estimating convergence towards Germany.

R&D. Data on R&D intensity are drawn from the OECD ANBERD (Vol. 2004) database. R&D intensity is defined as the ratio of Business Expenditure in Research and Development (BERD) to value added. This database, combined with information from the Main Science and Technology Indicators (MSTI), also from the OECD, enables us to divide the business expenditure on R&D into privately financed and publicly financed.

Public capital. Data on public capital are taken from Kamps (2005). The data covers the period 1960-2001 for 22 OECD countries.

Regulation indicators. Indicators on product market regulation and employment protection legislation are taken from Boylaud *et al*. (2000). We proxy product market regulation for the manufacturing sector using the economy-wide aggregate indicator of administrative regulations (ADMIN), following the reasoning in Scarpetta and Tressel (2002)[18]. The indicator of administrative regulations measures barriers to private entrepreneurial activities, such as administrative burdens for entrepreneurial activity as well as regulatory and administrative opacity (e.g., complexity of rules and procedures for licenses and permits). The indicator was calculated for 1998 and is assumed to be time constant. This probably underestimates efforts for European-wide harmonisation of rules and regulations; however, significant differences in their implementation and administrative processes still persist. For employment protection legislation (EPL), indicators are available for 1990 (for the late 1980s) and 1998; they include both regulations for regular and temporary contracts. The EPL indicator used in the econometric analysis is time varying (1990 and 1998); missing data have been estimated with the help of the compilation of changes in legislation reported in the table 'EPL time series breaking points', OECD Employment Outlook 2004, Chapter 2, Annex.

Output gap. Data on EU-15 potential output, and the output gap as the difference between actual and potential output, are from the AMECO database of the European Commission.

Political economy variables. We use the 2005 update of the DPI2004 database of Political Institutions compiled for the World Bank, which provides data for a large number of countries from 1975 to 2000. From 2000 onwards, data have been updated using the sources cited in the database when possible and official sources for parliamentary elections in European countries.

18 Scarpetta and Tressel (2002) choose this proxy "because it refers to norms and regulations that are applied to all industries, while the overall indicator also includes economic regulations some of which are more sector specific, and do not apply to the manufacturing industries" (footnote 13, p.15).

Table A1. The effect of total state aid on MFP growth

	Specification (1)		Specification (2)		Specification (3)	
Variable	WLS	IV GMM	WLS	IV GMM	WLS	IV GMM
Austria	0.0000	…	0.0000	…	0.0000	…
Belgium	-0.0065	-0.0116	0.0000	…	0.0363*	0.0403**
Denmark	-0.0519**	-0.0599***	-0.0620**	-0.0636***	-0.0413*	-0.0431**
Finland	0.0067	0.0078	0.0015	0.0081	0.0226	0.0214
France	0.0213	0.0128	0.0214*	0.0201**	0.0662***	0.0651***
Germany	-0.0297	-0.0409***	-0.0310**	-0.0346***	0.0036	-0.0016
Italy	-0.0351	-0.0552***	-0.0357**	-0.0463**	0.0000	…
Netherlands	-0.0036	-0.0036	-0.0335*	-0.0249	-0.0072	-0.0130
Spain	-0.0278	-0.0311	-0.0574**	-0.0481**	-0.0110	-0.0071
Sweden	0.0013	0.0053	-0.0358	-0.0223	0.0116	0.0048
$\Delta MFP_{Frontier,\ t}$	0.5623***	0.5032***	0.5298***	0.4831***	0.5498***	0.4913***
$RMFP_{i,\ t-1}$	-0.1592**	-0.1124*	-0.1746***	-0.1260**	-0.1589**	-0.1039*
$R\&D/VA_{i,\ t-1}$	0.7117**	0.5280	0.8140***	0.6299*	0.7233**	0.6564**
gkpub	-0.3631	-0.3663	-0.2746	-0.3278	-0.2973	-0.1764
Output gap EU	-0.0060	-0.0021	-0.0011	0.0015	-0.0039	-0.0004
$AID/VA_{i,\ t-1}$	0.3585	1.0458***	0.1366	0.7626**	0.3597	1.0071**
EPL_{t-1}			0.0290**	0.0233*		
ADMIN			-0.0265**	-0.0233**	-0.0307	-0.0406**
EPL_{t-1} (med)					0.0337	0.0485
EPL_{t-1} (high)					0.0493	0.0540
_cons	-0.0651***	-0.0544***	-0.0718***	-0.0591***	-0.0493**	-0.0373*
Statistics						
Observations	88	88	88	88	88	88
Adjusted R^2	0.375	0.302	0.424	0.368	0.392	0.339
Serial correlation	2.476	2.476	2.558	2.558	2.475	2.475

Notes: See notes to Table 4.

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