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The Changing Rationale for European University Research Funding: Are There Negative Unintended Consequences?

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In recent years there has been wide-ranging debate on the advantages and drawbacks of the rationale for resource allocation to university research. The post–World War II rationale for public support of science has been challenged by a more contractual-oriented vision of how to support research. The academic debate has provided a diverse set of descriptions and explanations with some views strongly supporting the contractual-oriented rationale and others critical of it.[1] The debate transcends the academic circle, as illustrated by the large number of national government reports: for example, Commission Jacques Attali (1998) for France, House Committee on Science (1998) for the United States, and National Committee of Inquiry into Higher Education (1997) for the United Kingdom.[2]

This article examines how changes in the rationale for science funding might influence the behavior of universities in European Union (EU) countries and the USA.[3] The article begins by describing the changes in university research funding for a selected group of EU countries during the period 1981–1996 and goes on to analyze the contractual-oriented vision of university research funding and its consequences. The primary focus is on the negative unintended consequences of the new rationale. It is shown that the short-term efficiency gains resulting from the quasi-market incentive

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structure introduced by the new rationale could be counterbalanced by long-term disadvantages arising from unintended outcomes. This paper does not provide a quantitative comparison between long-run negative effects and expected short-term benefits because it is arduous, if not impossible, to exactly quantify these effects. Instead, the paper provides a critical analysis of the relevance of the negative unintended effects of the new contractual-oriented rationale for university research funding. Finally, national specificities in connection with university researchers that are relevant for national policy are subsumed, the purpose here being to create a comparative analysis.

In his original work on US universities, Veblen (1918) proposed economic explanations for the institutional behavior of universities, focusing particularly on the introduction of business principles into university policy. Since this seminal work, it is mainly historians, political economists, and sociologists who have been concerned with understanding the behavior of universities. From the 1960s onward, with the development of human capital theories, economists focused some of their research on the university (e.g., Becker 1975 and Schultz 1960). However, despite this new interest, it was mainly the educational aspects—the contribution of universities to the production of the human capital of graduates or others that leave the university to enter other sectors of the economy—that were taken into account, leaving aside the analysis of the overall behavior of the institution or its specific contribution to society's stock of scientific and technological knowledge. While this research endeavor led to the development of the economics of education, it did not equally promote the development of the economics of university-based research.[4]

At the beginning of the 1960s, Nelson 1959 and Arrow 1962 laid some of the foundations for the current economics of science.[5] These two papers underscore the fact that the properties of non-excludability and non-rivalry in consumption prevent the creator of scientific knowledge from fully appropriating the returns from investments in knowledge creation. Moreover, as the marginal costs of duplicating scientific knowledge are very low, scientific knowledge can be characterized as a public good, which prevents the producer from capturing the benefits stemming from the production of new knowledge. Therefore, market forces are inadequate to deliver the socially optimal level of scientific research. As a result of this market failure, private investment is socially insufficient and the state has a legitimate role in taking responsibility for the support of a sizeable fraction of scientific research.

Scholars in the economics of science have been mainly concerned with analysis of the behavior of the individual researcher.[6] With the exception of the works of P. Dasgupta and P. A. David (1987; 1994), the scholarly work in this area only marginally considers the issues related to the institution where the research is carried out and does not analyze the interactions among the various organizations forming the system of innovation.

Throughout the 1980s and 1990s, attention increasingly has been devoted to the institutional analysis. On one hand a large literature mainly within the framework of political economy, institutional economics, and national systems of innovation has

developed theoretical concepts in the broad area of the national systems of innovation useful for the understanding of university behavior.[7] On the other hand, a number of studies have focused on how different micro-decisions and micro-incentives generate perceptible differences in institutional behavior.[8] Most of them originated from, and referred to, the Anglo-American context. Recently, especially in countries such as the United States, the United Kingdom, and Australia, market forces and government-simulated market actions (via performance-based funding systems) have significantly influenced the behavior of universities (Geuna 1999; Massy 1996). These changes toward a stronger market orientation for higher education systems have stimulated further research on the economics of university-based research.

The remainder of this article extends the literature on the economics of the research conduct of universities by analyzing the behavior of European universities over the past fifteen years and proposing an interpretation of the possible unintended consequences of a more contractual-oriented rationale for the funding of university research. The second section analyzes the evolution of university research income in ten EU countries during the period 1981–1996. The third section briefly reviews the confrontation between the post World War II rationale and the developing new rationale for scientific funding and further pursues the analysis of the characteristics of the contractual-oriented rationale. The fourth section focuses on the long-term unintended consequences of the new rationale. The last section offers concluding comments.

Changes in University Research Funding

After World War II, the higher education systems of EU countries witnessed an impressive growth in the numbers of students and staff and in spending. For example, the number of students in the EU countries increased from about one million in 1960 to approximately nine million in 1990. In the same period, the gross enrollment ratio—i.e., total enrollment, regardless of age, divided by the population of the age group 20–24—grew from less than 10 percent to around 30 percent, depending on the EU country. This rapid growth was also connected with a rise in society's expectations of economic returns (Geuna 1998b).

These two phenomena have led to conflicting pressures on the institutional organization and role of the university. Examples of the tensions characterizing contemporary universities are (1) incompatibility between the demands of elite and mass higher education; (2) friction between curiosity-driven research aimed at the researcher-directed advancement of the knowledge frontier and targeted research driven by the needs of society; and (3) the different impacts of private and public financing. From the early 1980s onward, the policies and priorities of universities have been increasingly influenced both by the quest for nationally relevant university research and by the pressure for accountability and cost reduction. Although these

changes vary from country to country, they are driven by the same forces and have similar overall aims.

University Research Income

One of the most pertinent pieces of evidence highlighting these changes can be found in the changing structure of university income. University income stems from four main sources: general government grants or general university funds, direct government funds, internal funds, and the sale of academic services. By far the most important source of university funds in Europe is government funding. Depending on the country, the responsibility for the public funding of universities is attributable to different levels of government. It can be the responsibility mainly of central government (Austria, Finland, Denmark, France, Italy, Ireland, The Netherlands, United Kingdom), mainly of the regional government (Belgium, Germany), or shared between the central and regional governments (Spain) (OECD 1995).

Government funds to universities are funnelled through three different channels: incremental funding, formula funding, and contractual funding. In the first, funds are allocated on the basis of past expenditure levels with incremental resources made available for the development of new activities. This funding mechanism was the most prevalent in the expanding university systems until the early 1980s (OECD 1990b). Under formula funding, the budget of the institution is determined by some form of assessment of the actual institutional expenditure per student enrolled or expected to be enrolled. These funds are combined with general research funds according to a ratio of government funding for teaching compared with research, e.g., a 60:40 split. Research funds can also be determined by a formula system that allows the distribution of the funds in a selective way on the basis of research record. Contractual funding is applied via tender schemes. Public funding agencies issue targets in terms of student numbers or research and the various institutions apply for the funds to carry out specified tasks. There are different forms of contracting depending on the existence of fixed limits for the availability of funds and on the degree of specificity of the activity. In the case of limited funds and tightly specified targets, universities have to compete with one another for the resources. Although there is a high level of diversity in the mix of the different funding systems in the EU, recent years have seen an increasing reliance upon formula and contract funding (OECD 1990b).

In the case of university research funding the OECD provides data for Higher Education Expenditures on Research and Development (HERD) that are approximately comparable across countries.[9] Table 1 shows the evolution of HERD intensity (HERD as a share of GDP) for the four main EU countries and for the EU countries together in the period 1981–1996. During the 1980s HERD intensity on the whole increased only slowly with some countries witnessing reducing intensity. The 1990s were characterized by contrasting tendencies; in the first half of the decade HERD

Table 1. HERD Intensity

		1981	1985	1989	1993	1996
HERD/GDP	Germany	0.38%	0.37%	0.41%	0.44%	0.41%
	France	0.32%	0.34%	0.35%	0.39%	0.39%
	UK	0.32%	0.33%	0.33%	0.37%	0.38%
	Italy	0.16%	0.22%	0.24%	0.28%	0.25%

Source: OECD 1998

intensity increased significantly, while in the second half decreasing or constant HERD intensities characterized all European countries. Over the last decade, HERD growth rate has continuously declined in almost all the countries, producing, especially in the second part of the 1990s, relative stagnation in constant prices of overall efforts (OECD 1998).

The R&D performed in the higher education system can be analyzed in relation to the different financial sources. The OECD classifies the funding sources for HERD into five main classes:

- Government, subdivided into *direct government funds (DGF)*—e.g., contracts and earmarked funds—and *general university funds* (GUF).
- *Business enterprises*—e.g., R&D contracts.
- *Abroad* (including foreign companies research contracting and EU research funds).
- *Private non-profit organizations (NPO).*
- *Higher education (HE)*, own funds—e.g., income from endowments.

Table 2. HERD Source of Funds for and Aggregate of Seven EU Countries (%)

	Total Gov.	GUF	DGF	Business	Abroad	NPO	HE
1983	94.0	68.3	25.7	2.9	0.6	1.5	1.1
1985	92.7	65.2	27.5	3.7	0.7	1.7	1.3
1989	89.9	60.2	29.7	5.4	1.4	2.1	1.2
1991	89.4	61.7	27.7	5.5	1.6	2.3	1.2
1993	87.7	60.1	27.6	5.8	2.5	2.7	1.4
1995	85.6	57.2	28.4	5.7	3.2	3.7	1.8

Source: Elaboration OECD data. The breakdown in GUF and DGF has been estimated for Italy.
The seven countries are Denmark, France, Germany, Italy, Ireland, The Netherlands, and the UK. Belgium, Greece, and Spain have been excluded due to missing or not-comparable data.

Table 3. HERD Funding Sources by Countries

		B*	D	F	G*	Gr	I**	Ir	Nl	S	UK*
	1981	39.4	10.9	45.1	18.7	10.5	0	14.9	5.7	13.0	20.5
Direct	1985	43.4	12.2	47.0	19.8	n.a.	0	11.5	7.1	24.1	25.0
Govern.	1989	25.5	20.6	48.1	22.4	12.0	0	19.0	7.8	27.7	27.6
%	1993	25.3	20.9	46.2	21.0	15.7	0	23.0	5.2	20.4	27.4
	1995	38.0	22.6	46.0	n.a.	13.3	0	20.0	6.3	30.1	29.9
	1981	46.8	85.6	52.6	75.6	89.5	96.2	67.6	91.1	87.0	64.8
GUF	1985	43.4	80.7	49.4	74.3	n.a.	98.0	66.0	88.1	74.7	57.2
%	1989	52.2	70.5	45.5	70.6	71.6	96.4	46.7	87.6	62.0	47.3
	1993	50.4	66.5	46.1	69.9	43.4	93.4	41.1	90.7	69.6	41.9
	1995	34.9	66.8	44.6	n.a.	59.1	92.0	42.0	79.3	40.3	37.8
	1981	2.9	0	0.9	0	0	0	0.4	0.3	0	3.8
HE	1985	2.7	0	1.4	0	n.a.	0	2.3	0.2	0	4.2
%	1989	5.6	0	1.0	0	0.3	0	4.2	0.1	0	4.8
	1993	3.4	0	2.3	0	5.9	0	4.4	0.1	0	4.3
	1995	6.8	0	4.0	0	4.1	0	4.5	0.3	13.7	4.2
	1981	9.3	0.7	1.3	5.7	0	2.7	7.1	0.3	0	3.1
Business	1985	8.7	1.0	1.9	5.9	n.a.	1.5	6.9	1.0	1.1	5.2
%	1989	12.6	1.5	4.6	7.0	6.2	2.6	9.2	1.1	9.2	7.7
	1993	14.6	1.8	3.3	8.1	3.8	4.8	7.1	1.5	5.9	7.6
	1995	10.6	1.8	3.3	7.9	5.6	5.6	6.9	4.0	8.3	6.2

	1981	0	1.6	0.1	0	0	0	2.6	2.3	0	5.6
NPO	1985	0	4.3	0.1	0	0	0	1.9	3.1	0	6.4
%	1989	0	4.4	0.1	0	0	0	1.8	2.9	0.5	8.4
	1993	0	5.0	0.2	0	0	0	2.1	2.2	0.6	12.2
	1995	1.0	4.5	0.5	0	1.0	0	2.5	6.5	0.5	14.1
	1981	1.6	1.3	0	0	0	1.1	7.3	0.3	0	2.2
Abroad	1985	1.8	1.8	0.1	0	n.a.	0.6	11.4	0.4	0.1	2.1
%	1989	4.1	3.0	0.7	0	10	1.0	19.1	0.5	0.7	4.1
	1993	6.2	5.8	1.9	0.9	31.1	1.8	22.3	0.3	3.5	6.5
	1995	8.7	4.2	1.6	1.2	17.0	2.4	24.0	3.5	7.0	7.8

Source: Elaboration OECD data.

*1983–1995.

**Italy does not supply a breakdown between direct government and GUF; the value refers to total government funds.

B = Belgium, D = Denmark, F = France, G = Germany, Gr = Greece, I = Italy, Ir = Ireland, Nl = The Netherlands, S = Spain, UK = United Kingdom.

GUF = General university funds, HE = Higher education (own funds), NPO = Private non-profit organization.

Due to the different ways of classifying the various funds, a zero value either refers to zero funds or the inclusion of the funding type in a different class. With the exception of Denmark, France, Italy, Ireland, and the UK, in all the other countries there are breaks in the series for a few sources of funds. Portugal is not included due to incomplete time series.

Table 2 presents the evolution of the relative share of the HERD funding sources for an aggregate of seven EU countries between 1983 and 1995 (see table 3 for a ten-country breakdown). These seven countries account for about 80 percent of total HERD performed in the EU countries throughout the period.[10]

In six of the ten countries considered, government funds account for more than four-fifths of total expenditures. Only Greece, Ireland, and the United Kingdom have lower shares of about 70 percent in 1995.[11] All countries, without exception, have witnessed a decrease in government funds. For example, in France the share of government funding decreased from 98 percent to 91 percent while in the United Kingdom it fell from 82 percent to 68 percent. These changes mask differences in the types of government funding. While general university funds tend to be allocated on the basis of incremental funding or some form of formula funding, direct government funds are principally funnelled through contractual funding—e.g., research funds from the research councils or ministries. In all the countries, the share of general university funds has substantially declined, while the share of direct government funds has increased, although not sufficiently to offset the decrease in the other components of government funding.

The declining share of government funding has been compensated for by a rise in the share of the other sources of funds. Where figures are available, abroad, private non-profit organizations, business, and higher education sources of funds show positive trends.

The growth in finance from abroad is particularly important. In the period under consideration, funding from a country other than that of the institution experienced a compound annual growth rate of 23 percent for the aggregate of the seven countries. Funding from abroad has become extremely important for the higher education systems of small less-advantaged countries, such as Greece, Ireland, and Portugal, accounting for over a quarter of total HERD in a few of the years under consideration. Particularly for these countries, but also for the other EU countries, a significant proportion of the funds received from abroad can be ascribed to the European Commission (Commission of the European Communities 1994; 1997), for example, through the structural funds and the framework programmes. Generally, the growth in foreign funding for R&D performed in the higher education sector is an indication of the increased internationalization (Europeanization) of university research (OECD 1998).

Funds from private non-profit organizations (usually private foundations such as charities) have continuously increased throughout the period under consideration.[12] In the European context, in contrast to the United States, private foundations did not play a significant role in the funding of university research until the end of the 1980s. Although at the aggregate level NPO funds account for only 3.7 percent of total higher education expenditures on R&D, in countries such as the United Kingdom, The Netherlands, and Denmark private non-profit organizations had become the second most important source of funding by the end of the period.

The share of HERD financed by business showed positive growth rates in all EU countries during the 1980s. This increase has been particularly important for the nations that started from a low share, while countries such as Germany and Ireland, which already had relatively high values, witnessed only a moderate rise. The case of Belgium is peculiar. Although Belgium had the highest share of HERD financed by business enterprises in 1983, significant growth continued throughout the period under consideration so that industrial funding was responsible for about 10 percent of HERD performed in Belgian institutions by 1995. From 1989 onward, at the aggregate level (seven countries combined), the share of business enterprise funding remained almost constant. However, at country level different tendencies can be highlighted. The countries with high levels of industrial funding for university research witnessed constant or decreasing shares of business funds (for certain countries there was a reduction in real amounts of funding), while most of the nations that had started from a low share showed positive growth rates.

In the thirteen years under consideration, the share of HERD financed by government decreased by about eight percentage points. Two periods can be identified. In the first, up to circa 1989, increased industrial funding accounted for most of the difference. In the second period, during the 1990s, other sources of funds, such as private foundations and the European Commission, contributed significantly to the funding of higher education expenditures on R&D, while business funding stagnated or, in certain cases, even decreased.

Although industrial funding of university research showed indications of stabilization during the 1990s, its share of total HERD was about 6 percent at the end of the period under study, representing the second most important source of funds (in some countries such as Germany, Ireland, Spain, and the United Kingdom, it reached about 7 percent).[13] Most of these funds are channelled to universities via contract research or co-operative R&D projects with industry. Although these links may be of various types, they are all characterized by an exchange of knowledge among participants, with the university usually being the most important supplier of knowledge.[14] These collaborations are also the result of policies aimed at raising the apparent economic returns from publicly financed research by stimulating interactions between universities and industry. The goal is to increase the transfer of knowledge from the university. An example is the LINK program to promote collaboration between university and industry in the United Kingdom.

The Changing Rationale for University Research Funding

This section, after briefly reviewing the confrontation between the post–World War II rationale and the developing new rationale for scientific funding, analyzes the objectives, resource allocation mechanisms, and implicit assumptions of the new rationale.[15] On the basis of this analysis, the following section shows that the potential

advantages of the contractual-oriented approach could be counterbalanced by long-term disadvantages arising from unintended outcomes of the new rationale.

The Rationale for University Funding

The move toward indirect control of university behavior via financial incentives and government push for increased co-operation between universities and industry are just two of the outcomes of a re-examination of the rationale for resource allocation to university research that is taking place not only in the United Kingdom but, to varying degrees, throughout continental Europe as well.

The canonical model of university research funding, arising from the dual considerations of expanding student enrollment and the building of greater university research activity, developed after World War II. It related academic quality to the level of funding. The increase in public funding was grounded on the premise that the proportional rise in academic quality (for both teaching and research) would foster the welfare of society. Crucial to this view are the following two assumptions. First, the transfer of knowledge from basic research to commercialization is seen as a linear process. In this linear model, basic research (mainly carried out at the university) leads to applied research and development and then to commercialization.[16] Second, knowledge is a public good with important positive externalities and hence there is a need for public funding to reach a socially more appropriate level of investment. As education is characterized by positive externalities, this reasoning is also applicable. On the basis of this model, governments, first in the United States and then in the European countries, regarded scientific research as a source of future welfare and directed a large amount of financial resources toward university research.

In the post–World War II rationale, resource allocation to universities, as compared with other publicly funded sectors such as health care, was mainly based on an ex-ante judgement of research promises and therefore was influenced by the priorities of the academic community. Two main reasons justified the self-determination of priorities by the university community. First, as the research output (and the value of education) is difficult to measure, the people in the best position to evaluate it are the practitioners, that is, the academic staff. Second, the strong conviction that the internal social organization of the university was the most appropriate means for managing university activities supported the claim of autonomy in the definition and control of university behavior.

Based on these premises, a predominant post–World War II rationale for university research funding was to fund research considered by the academic community to be most worthy. Grant allocation via the peer review system, and allocation of block funds to the university on an incremental or formula basis, the most common practice in the European countries, were the mechanisms used. In return, scientists were producing new knowledge that, due to its "public goods" nature, would enter into other

knowledge production processes within and outside the university. This system was paralleled by public procurement which, although less comprehensive than that developed in the United States, supported university research to support the state, such as in the case of the French *grandes écoles* or the reliance on universities for defense research in the United Kingdom.

The economic crises in the late 1970s and the rise in inflation put national budgets under strain. Although the scale of university activity continued to increase, lobbying from other publicly funded sectors such as health and social security for reduced public budgets put increasing pressures on university research funding. In the same period in most European countries universities were going through a phase of increasing bureaucratization and massification and consequent loss of prestige in the eyes of the public. These phenomena opened the way to a more direct intervention of government in the guiding of the research enterprise. From the early 1980s onward there has been a transition from the post–World War II rationale for scientific funding to what can be referred to as the contractual-oriented approach to university research funding. During the 1990s, also due to government budget constraints resulting from the enforcement of the Maastricht criteria for joining the common European currency (the EURO), science funding shifted from a period of continuous budgetary expansion to one of constant or shrinking budgets as shown in the previous section.

Two main features characterize a contractual-oriented approach to university research funding. First, the university is required to support aims that are intended to enhance national economic development and the strengthening of competitiveness. Second, to obtain this result and to increase the short-term efficiency of the institution, the government makes increasing use of competitive mechanisms for resource allocation. These two points are discussed below.

The Role of the University in the New Rationale for Resource Allocation

A new government vision of the role of the university characterizes the contractual-oriented approach to university research funding. Although there are some differences in the views of various European nations, the following can be considered to be the principal social goals for the university system as defined by governments:[17]

- To reproduce existing levels of knowledge.
- To improve the critical reasoning capabilities and specific skills of individuals (1) as an input into their public and private work activity and (2) as an input into the development of a democratic, civilized, inclusive society.
- To increase the knowledge base (1) by pursuing knowledge for its own sake and (2) by pursuing knowledge and its application for the creation of wealth.
- To serve the specific training and more general research support needs of the knowledge-based economy at local, regional, and national levels.

The first two aims correspond to the traditional role of the university as an institution for the preservation and the transmission, through education, of knowledge, culture, and social values. The third social goal, although referring to the traditional role of the university as a site where knowledge is produced through scholarship and research, defines the action of the university in a broader sense and changes the "control" of the research agenda. Scholarship and research should be pursued at the university for the production of knowledge for its own sake and for the production of a stock of useful knowledge that might be applied at other sites resulting in benefits to society. Moreover, university research should also aim at the direct production of applied knowledge for the creation of wealth. Finally, the fourth social goal assigns a new role to the university. Universities are seen as direct actors in the process of economic development. In this new role, the university has to satisfy the knowledge needs, in terms of teaching and research, for economic development at local, regional, and national levels.[18]

Two streams of thought are at the basis of the new government vision of the role of the university. Although both have been highly criticized, analysis of the debate is beyond the scope of this article. On one hand, on the basis of the laissez-faire philosophy and due to the process of globalization and resulting increased international competition, a number of politicians and industrialists have begun to perceive the contribution of universities to wealth creation and national competitiveness as being insufficient. From this point of view, public funding of university research is expected to result in more concrete and direct returns. Hence, university research should reflect more closely the scientific and technological needs of society, and universities should co-operate with firms, becoming the suppliers of applied knowledge that can be readily transformed into innovations that increase the competitiveness of national industries.[19]

On the other hand, the increased complexity of scientific research and the development of cross-field research, for example, information technologies and molecular biology, underscore the relevance of knowledge production based on cross-disciplinary and cross-institutional collaborations. On the basis of this observation, it has been claimed that the nature of the scientific investigation process is changing from the search for new knowledge in a single discipline to a search process that cuts across disciplines, institutions, and methods. In this highly controversial view of a changing process of scientific discovery[20] the university ceases to be the leading player in the process of knowledge creation and becomes only one of the possible sites where knowledge is produced (Gibbons et al., 1994). From this perspective, the structure of the university is not suited to the new process of scientific discovery and, therefore, without radical structural changes, it cannot claim the current level of public resources.

Competitive Mechanisms for Resource Allocation

The contractual-oriented approach to university research funding is based on the use of financial incentives to control university research behavior indirectly. Quasi-market incentive schemes are applied to steer university research behavior toward the accomplishment of new objectives and to increase the short-term efficiency of the institution. Policies are implemented to increase the concentration and selectivity of research funds and, more generally, to improve accountability and reduce costs. Although direct competition is not permitted, government attempts to simulate market actions by adjusting its demand for university services in response to absolute or relative institutional performance (Massy 1996). To implement a system that enables the evaluation of performance a series of administrative measures would need to be to be created.

The clearest example of the contractual-oriented approach in Europe is the market-steering model developed in the United Kingdom. This has two main thrusts. First, as a result of budget constraints and competition for funds from other publicly funded sectors, the overall government contribution to the total research incomes of universities is reduced or maintained unchanged in nominal terms. This strategy is pursued not only to stimulate cost-minimizing behavior in the universities but also to create incentives for the development of research activities that might receive funding support from non-government sources such as firms and foundations. Second, a reallocation in government funds is implemented with a decrease in general university funds and an increase in direct government funds. A larger allocation of resources through specific grants allows government to develop policies aimed at a more purpose-directed allocation of research effort and at the creation of quasi-market incentive structures that permit indirect control of university research behavior.

Other European countries, such as The Netherlands, Finland, Hungary, Poland, and Portugal, have started to implement similar approaches to university funding (Geuna, Hidayat, and Martin 1999). F. A. Van Vught (1997), for instance, suggested that the new government strategy toward higher education in The Netherlands is the outcome of both government planning and market coordination. In other countries, such as France and Italy, government proposals for changing the organization of the higher education system are currently under discussion.

National policies aimed at concentration and selectivity of research funds may be further reinforced by the research actions of the EU. The four Framework Programmes of the Commission of the European Communities in support of R&D co-operative projects have been characterized by a highly competitive approach to research funding. Universities have increasingly taken part in these co-operative R&D projects and have become the largest single type of institution in the Fourth Framework Programme both in terms of the number of times they have participated in an EU-funded R&D co-operative project and in terms of funds received (Geuna 1998a, 1999).

Given national differences, the core of the new resource allocation system resides in an ex-post evaluation of university research performance via market forces or simulated market actions. First, most non-government sources of university research funding, especially industry funding, are characterized by a high level of competition and by a continuous short-term evaluation of research outputs. Second, direct government funds are allocated through competitive mechanisms, such as tenders with specific targets and limited budgets, on the basis of the past performance of the applicants and the "excellence" of the proposal, and involve repeated evaluation of the outputs. Finally, an increasing share of general university funds is granted through simulated market actions such as the case of research funding being allocated to universities in proportion with their previous research performance.

The contractual-oriented approach to university research funding is based upon the following main assumptions:

- That it is possible to evaluate the quality of the research output accurately.
- That it is possible to identify the most promising research avenues.
- That cost reductions can be achieved without any decrease in the quality of the output.
- That due to the existence of scale and scope economies, the concentration of scientific capabilities increases the research output of the system.
- That the administrative costs of assessment and evaluation, for both government and universities, linked to the implementation of a competitive system, are small compared with the cost savings.

The Unintended Consequences of the New Rationale for Resource Allocation

This section assumes that the new rationale stimulates cost-efficient behavior from universities insofar as it creates incentives for productivity increases and cost minimization, and explores whether or not the negative unintended consequences of the new rationale might prevail in the long run over its assumed advantages. More specifically, the analysis focuses on the long-term implications of a strong reliance on quasi-market mechanisms for public funding and of increased industry funding for university research. In this connection, the following four issues are examined: (1) increased concentration of resources, (2) disproportionate incentives for a short-term foreseeable research endeavor, (3) changing incentive structures, and (4) exacerbation of the impact of cumulative and self reinforcement phenomena and, in particular, of the Matthew effect.[21]

Increased Concentration of Resources

One of the aims of the allocation of government funds via the simulation of market conditions is to obtain a higher concentration and selectivity of research funds, which will permit the exploitation of economies of scale and scope present in the research production process, and to orient the research toward the needs of society.

First, it is important to notice that the existence of scale and scope economies in university production is an assumption for which there is no strong empirical evidence. Indeed, the literature concerned with scale and scope economies in university production offers a blurred picture. There are two main approaches. The first evaluates economies of scale and scope for the joint production of teaching and research using econometric cost function estimates (Cohn, Rhine, and Santos 1989; Johnes 1997).[22] The second studies the relationship between size and research performance applying statistical-descriptive tools (Martin et al. 1993; Johnston 1994). Neither approach provides unequivocal answers. While there is some general consensus on the existence of scale economies in teaching and administration, when research production is included the empirical evidence in favor of scale and scope economies is more mixed, with cases in which department size and scientific research productivity have no or only weak negative correlation.

Furthermore, uncoordinated multiple sources of research funding might result in negative unintended consequences that could offset the potential positive effects of the contractual-oriented approach. This could occur both at the national level, as a result of the existence of diversified competitive national sources of funds, and at the European level, as a result of the existence of national and EU funding sources. For example, due to its competitive character, industrial funding will tend to be mainly funnelled toward the top universities, which, via simulated market actions, also receive the largest share of public funding.[23] In the United Kingdom, 33 percent of the total university research income from industry was accounted for by only 6 percent of the institutions (seven institutions) in 1996–97 (HEFCE, 1998). On the other hand, multiple sources of funding may help to offset the danger of scientific sclerosis in established ideas that can occur when only one agency in a monopsony position allocates funds relying on an established group of peer reviewers.

An overlap of industrial funding with increasingly selective public funding may create an increased concentration of resources. The following are the unintended consequences of this situation. First, given the fiscal limits of the public sector, the trends toward increasingly selective funding will reduce the availability of non-competitive public funds—i.e., funds allocated in a proportional way. The allocation of resources on a basis other than merit enables human resources and research organizations to develop and express their potential in ways of their own choosing, and hence allows the public agency to collect information about research potentials. The distributive allocation of funds also offers the possibility for researchers and research organizations of unknown "quality" to perform research outside the programmatic agenda.

Their success or otherwise in producing relevant results from the research funded in this way is a source of information about their capabilities that can be used in future allocations of finance by the funding agency. The scientific capabilities of a researcher (or research organization) tend to be uncertain in the early phases of her/his career. In acknowledging this situation, the Social Science and Humanities Research Council of Canada (SSHRCC) weights the proposals from young scientists more heavily than their CVs in the evaluation of research applications (the reverse of the normal evaluation procedure). Competitive allocation mechanisms that concentrate funds in a few highly productive institutions generate less observable experience with research performance by other institutions and individuals. Thus, the selective funding approach, although efficient in the short term (the most productive universities/research organizations are those that receive the largest share of the funds), could have negative long-run consequences for society in preventing new scientists who have bright ideas, but work in less esteemed institutions, from developing their potential. Indeed, only a fraction of human resources and research institutions are able to express their quality, leaving research potentials unexploited.

Second, the local positive externalities and the scale and scope economies produced by the geographical concentration of scientific capabilities and the concentration of a large part of research resources in a few universities could be offset by the negative externalities imposed on the universities that are marginalized by this process. For example, the knowledge of researchers at institutions with few or no resources to conduct fundamental research will tend to become stale or obsolete, preventing them from teaching and carrying out targeted research in a way that is effective in terms of social needs (Dresch 1995).

Third, quasi-market allocation mechanisms for public funding and increased industry funding of university research push universities to reduce the "price" of their services. It is economically rational to set these prices at levels below the amount required to maintain the portion of the university that is not "fully employed." The costs of the institutional and research infrastructure, such as the library, may be only partially covered depending on whether the competitive conditions support the attribution of these to research contracts. Moreover, universities are ill prepared to account for the real opportunity costs of the involvement of their scarce resources in contract research for industry. Professors or other researchers are likely to set prices based upon the incremental costs of an activity rather than at levels that will permit reproduction of their intellectual assets. In effect, individual researchers are unlikely to have a realistic idea of the depreciation of their own intellectual capital or will take the view that in the long run (when they retire) the university will have had to make investments in younger researchers to retain the competencies of the institution. Industrial contracts enlarge the dimension of the laboratory with an increase in the number of junior staff, but they rarely cover the costs of the involvement of senior faculty, or the increasing organizational costs and the use of the infrastructure, which is only marginally covered by overheads. The adaptation to the new funding system requires a pro-

cess of learning that may take several years.[24] Hence, contract research for industry may result in a form of public subsidy for particular industries for the type of research that firms would otherwise have had to finance on a full-cost basis. This situation is particularly important for universities with very low research receipts from government, which are thus pushed to rely more heavily on industrial funding. Being in a weak financial situation, they find themselves in an asymmetric bargaining relationship with industry. This in turn can result in a large amount of these universities' research resources being tied up in routine contract work for industry. Researchers, technicians, and the scientific instrumentation of these universities are thus employed to develop a type of research that translates public support of universities into subsidies for specific firms in the private sector.

Disproportionate Incentives for Short-Term Research

The push toward tighter interaction between university and industry, with the aim of possibly fostering national competitiveness and economic development, and the use of ex-post evaluations of university research performance via market forces or simulated market actions, could create disproportionate incentives for short-term research. In such circumstances, university research will tend to respond to the short-term concerns of industry and, in addition, the ex-post evaluation approach emphasizes the recent quantifiable outputs of the institution without taking into account work in progress or the long-term development of projects or capabilities. As a result, projects with a long-term horizon will be less likely to be performed. The contractual-oriented approach creates disincentives for researchers to become engaged in this type of project as they do not produce quantifiable outputs at the time of evaluation. This is the case with the Research Assessment Exercise in the United Kingdom, which evaluates the four best publications produced in a window of 4/5 years. Hence, with this incentive structure, application-oriented short-term research will substitute for long-term research in the university research activity portfolio, dismantling what was the core activity and the source of comparative advantage for the university. Furthermore, the lack of incentives for path-breaking, and consequently more risky, research decreases the probability of scientific novelty, potentially reducing the new knowledge base from which new technological innovations can emerge.[25]

Conflicting Incentive Structures

Different competitive research-funding sources create diverse incentive structures. Researchers and, in general, research organizations face different incentives and constraints depending on the source of the funds upon which they rely. In a very schematic way, a researcher is paid on the basis of the teaching she/he does, the non-con-

tractual research she/he carries out (general or fundamental research), the contract research she/he is involved in, and the administrative and other duties she/he performs. However, in practice, research and teaching activities overlap at least partially, so the research activities carried out at the university cannot easily be allocated to the sources of funds. Hence, the behavior of the research organization (sum of researchers' behaviors) is the result of the interaction among various incentives and constraints originated by different research-funding sources. In the case in which the incentive structures lead to conflicting behavior, tensions would characterize the organization of university research. For example, secrecy and applicability of research results are cases in which incentives and constraints created by industrial funding conflict with the more traditional university research behavior (David, Foray, and Steinmueller 1999). To the extent that the practice of secrecy or delay in publication is typical of contract research carried out for industry, this conflicts with the incentives to publish that originate in the scientific reward system based on priority claims and reputation building typical of traditional university research (Dasgupta and David 1994). A striking example is the case of scientific research in chemistry where, increasingly, papers cite patents not because the technological innovation patented was produced before the paper but because the researcher, being financed by industry, had to wait for approval of the patent application before being allowed to publish her/his research.[26]

Furthermore, in certain cases, the impact of the various incentive structures is proportional to the support provided, while in others it can be more or less important. In the former instance, where there are multiple sources of funds equally weighted, university behavior is driven toward accomplishing diverse aims depending on the weight of the various incomes in the total research budget of the university. In the latter instance, the incentives associated with one subsidiary source of funds may dominate university research behavior, distorting the role played by the university and thus reducing the social benefits of the allocation of public resources to university research. This is more likely to occur when general government research funds are fully utilized. In these circumstances, new research activities should be supported by other funds; hence the incentive structure stimulated by these funds may have an impact on university research behavior disproportionate to the level of resources supplied (OECD 1990b).

Cumulative and Self-Reinforcement Phenomena

The increased reliance on quasi-market incentive schemes in university research funding and the existence of diversified non co-ordinated competitive funding sources may exacerbate the importance of the cumulative and self-reinforcement phenomena present in the process of scientific production. Since the seminal work of R. K. Merton on the Matthew effect (1968), it has been recognized that the organization and resource allocation structure of science tends to reward successful individuals and

groups with access to means that increase their probability of being successful in the future. The new economics of science has elaborated this concept in terms of path-dependence and self-reinforcing mechanisms.[27] The reputation of a researcher (group) derives in some measure from prior success, but this may be due to good luck and not to "real" innate abilities. On one hand, a lucky researcher may have an early success that feeds subsequent performances, putting her/him on a high productivity path. On the other hand, an unlucky, but possibly talented researcher, may have problems in getting work published, leading to decreased means to fund further research and reduced self-motivation that will drive her/him onto a low productivity path. An extreme case of government trying to maximize the return on R&D investment can be modelled as a multi-armed bandit situation with each researcher being an arm. Eventually one researcher gets all the money (Cowan 1991). The same mechanisms can be applied to groups, with the additional problem that groups, especially disciplinary departments, may be more long-lived than individuals.

In this situation, quasi-market allocation mechanisms based on ex-post accountability not only produce a biased evaluation of real scientific capabilities but also, due to their mechanistic accounting, tend to reinforce the virtuous and vicious circles described above. Moreover, the existence of diversified noncoordinated sources may further reinforce the cumulative process.[28] In fact, on one hand, the concentration of public funding in a few institutions because of competitive resource allocation augments the probability of attracting other competitive research funds for these universities and, on the other hand, decreases the attractiveness of the less supported institutions to external providers of funds. As pointed out above, this latter type of university will be pushed to carry out routine contract research to attract money from industry. This in turn may lead to a reduction in the quality of scientific output, which will further reduce the probability of attracting research funds targeted to high-quality research.

Conclusions

EU countries implement different approaches to public university research funding, forming a continuum of possible funding configurations. On one hand, countries such as the UK tend to rely most heavily on mission-oriented and selective policies, while in countries such as Italy proportional allocation policies (distributive policies) are still dominant. Nonetheless, recently there has been a move from the traditional model of university research funding toward the contractual-oriented approach in all the EU countries as indicated by funding patterns. Policy justification or rationalization exists for both canonical models. However, there has been too little analysis of the potential adverse consequences of the new contractual-oriented model.

As a result of these changes, university research has been increasingly supported by sources of finance other than traditional government funding. Nonetheless, govern-

ment funding is still crucial and industrial funding has not substituted for public funding. For university departments the importance of business funding, non-profit organizations, and funding sources from abroad has increased. The rapid rise in the share of university R&D financed by business during the 1980s has been followed by a period in which other sources of funds, such as private foundations and the European Commission, have contributed significantly to the funding of university research, while industrial funding has stagnated or even decreased. Foundations are increasingly playing an important role in the funding of university research. Thus, focusing only on university-industry relationships can paint a misleading picture of the changes in public research.

This article has analyzed how changes in the rationale for, and composition of, university funding could influence the behavior of these institutions. In particular, the unintended consequences of the re-examination and modification of resource allocation to universities have been examined. It has been shown that problems arise due to (1) increased concentration of resources, (2) disproportionate incentives for short-term foreseeable research endeavor, (3) conflicting incentive structures, and (4) exacerbation of the impact of cumulative and self-reinforcement phenomena present in the process of scientific production. These problems result in the negative unintended consequences that may prevail over the predicted advantages of the new rationale in the long run.

To test the behavioral hypotheses set out here would require time-series data on funding and research outputs at the institutional level, which are not available at the cross-country level in Europe. Nonetheless, many of the implications of these hypotheses can be tested by using cross-section data at a specific moment in time, while others can be verified for a single country or for a particular type of competitive funding.

More generally, the result of the analysis indicates the need for a better balance between allocation mechanisms based on quasi-market schemes and more distributive approaches. In this way, the short-term benefits of the new system might be obtained while minimizing the long-term negative consequences. Also, institutional innovation is required to mitigate the potential negative consequences of the contractual-oriented model. Finally, universities need to more actively promote their role in society and mobilize political support on their behalf so that they can exercise countervailing power against purely commercial and short-term interests.

Notes

1. For examples of the diverse approaches to the analysis of the changes in the rationale for public support of science, see, among others, David 1997, Dill 1997, Gibbons et al. 1994, Guston and Keniston 1994, Kealey 1996, Pavitt 1996, Slaughter and Rhoades 1996, Sommer 1995, Vavakova 1998, and Ziman 1994.
2. See also the survey by *The Economist* (1997).
3. In particular, the analysis developed in the last section of this paper is of relevance for both European and US universities.

4. See Blaug 1970 for an introduction to the economics of education and a review of the literature.
5. Prior to these works a large number of economists, sociologists, and philosophers have developed concepts and interpretations of relevance to the economics of science. Due to the confines of space and focus of this article on the economics of university-based research these works are not discussed in detail here. However, the work of Charles Saunders Peirce deserves particular mention. At the end of the nineteenth century Peirce put forward the idea of using an "economics of research" to analyze and affect the conduct and organization of scientific activity (1876). His original and subsequent developments of the economics of research can be considered the first contribution to the economics of science; see, for example, Wible 1994. (I am indebted to Professor Paul David and an anonymous referee for useful bibliographical suggestions.)
6. For a critical presentation of the main themes of the economics of science, see the survey articles by P. E. Stephan (1996) and A. M. Diamond (1996) and the survey on the new economics of science by P. A. David, D. Foray, and W. E. Steinmueller (1999). For examples of current research, see the special issue of the Revue d'Economie Industrielle edited by M. Callon and D. Foray (1997).
7. See, among others, Edquist 1997, Geiger 1993, Lundvall 1992, Nelson 1993 and Sommer 1995.
8. For examples of recent studies see Adams and Griliches 1996; Baldwin 1996; Cave, Dodsworth, and Thompson 1992; Garvin 1980; Geuna 1997, 1998a, and 1999; Hare and Wyatt 1988, 1992; Hoenack and Collins 1990; James 1986 and 1990; Johnes 1988, 1992, and 1997; Mansfield and Lee 1996; and Massy 1996.
9. In the Frascati manual, the basis for measuring R&D in OECD countries, the higher education sector is defined as "All universities, colleges of technology and other institutions of post-secondary education, whatever their source of finance or legal status. It also includes all research institutes, experimental stations and clinics operating under the direct control of, or administered by, or associated with, higher education establishments." This definition has been interpreted in different ways by the OECD member countries. Important differences are present in the way government-funded research institutions are classified. For example, while the Centre National de la Recherche Scientifique (CNRS) in France is classified in the higher education sector, the Consiglio Nazionale delle Ricerche (CNR) in Italy, which has broadly the same functions as the CNRS, is accounted for in the government sector. See the Frascati manual (OECD 1981) for a discussion of the shortcomings inherent in the measurement of HERD.
10. See Kyvik 1997 for an analysis of university research funding in the four Nordic countries in the period 1981–1993.
11. Also Belgium and Spain had a low share of government funds in 1995; however, the figures for the last year are a break in the series and, therefore, are not discussed here.
12. For example, in the biomedical area from cancer charities such as the Imperial Cancer Research Fund in the United Kingdom and the Dutch Cancer Society (Queen Wilhelmina Fund/KWF) in The Netherlands or the Association Française contre les Myopathies (AFM) in France.
13. Recently released OECD figures on the share of HERD financed by industry in 1997 are almost identical to the 1995 figures, with an average EU share at 5.7 percent.
14. A large body of literature has been devoted to the analysis of university-industry co-operations. For an analysis of the different types of linkages see, among others, Blume 1987, Malerba et al. 1991, and OECD 1984 and 1990a. For an analysis focused on the US context see, among others, Etzkowitz 1997, Geiger 1993, Mansfield and Lee 1996, and Nelson and Rosenberg 1994.

15. The situation in the EU countries is used as a reference in this analysis. For a discussion of the changes going on in the United States see, among others, Barrow 1996 and Slaughter and Rhoades 1996.
16. For a clear analysis of government expectations from scientific research generated by the successful use of scientific discoveries made during the World War II, see Brooks 1996 and Geiger 1993. For an early formulation of the rationale used to justify the public support of science, see Bush 1945.
17. See, among others, Commission Jacques Attali 1998, Ministero dell'Universita' e della Ricerca Scientifico Technologica 1997, and National Committee of Inquiry into Higher Education 1997.
18. For example, the report of the Commission Attali puts particular emphasis on the fact that the university has to act directly as a producer of innovation: *"les universités devront contribuer à la création d'entreprises et à leur développement. Pour cela, elles devront valoriser leur recherche, prendre des brevets, organiser des entreprises en leur sein"* (23).
19. For a criticism of this view on the contribution of university to the welfare of society see Vavakova 1998.
20. For an analysis supporting this view see, among others, Gibbons et al. 1994; for a criticism of the approach see, for example, David, Foray, and Steinmueller 1999 and Pestre 1997.
21. For the original definition of the Matthew effect in the sociology of science see Merton 1968. R. K. Merton (1968, 1973) and some of his students (see, for example, Cole and Cole 1973 and Zuckerman 1977) suggested that the organization and resource allocation structure of science tend to reward successful individuals and groups with access to means that increase their probability of being successful in the future. For an early analysis of the relationships between scientific productivity and cumulative effect see De Solla Price 1963 and 1976. For an economic analysis of the Matthew effect and its implications for resource allocation see Arora and Gambardella 1997, Dasgupta and David 1987 and 1994, and David 1994.
22. For a criticism of this approach see Getz, Siegfried, and Zhang 1991.
23. A. Arora and A. Gambardella (1997) showed that due to an information externality problem, firms have lower incentives than public agencies to fund scientists and institutions of unproven scientific capabilities. However, especially for small firms, the fact that universities are located nearby can become a factor as important as their scientific capabilities.
24. An interview with the manager of the transfer office of the Université Louis Pasteur of Strasbourg confirmed that, although the university has a long history of university-industry relationships, a large number of professors still have problems in correctly accounting for their opportunity costs.
25. The following two examples, among many others, are of relevance here. "When James Lovelock sought funds to study the distribution of CFCs in the atmosphere he was turned down, for making 'one of the most frivolous applications' the committee had heard. Years later his work proved a key to understanding the causes of ozone hole . . . Crystallography experts told Max Perutz and John Kendrew they were crazy to attempt to solve the structure of protein molecules using X-rays. For more than ten years 'they had no success at all' (Kendrew). It took over twenty years to achieve success" (cited from SBS).
26. The sources of information for this example are personal communications with directors of chemical and pharmaceutical laboratories at the Université Louis Pasteur of Strasbourg.
27. For the building blocks of this new theoretical approach to the organization of scientific production, see Dasgupta and David 1987 and 1994 and David 1994. For the original definition of path-dependence, see Arthur 1988 and David 1985.
28. Although it is possible to imagine some form of co-ordination that would reduce the negative unintended consequences of a diversified funding sources structure, co-ordination failures are likely to occur at both national and European levels.

References

Adams, J. D., and Z. Griliches. "Research Productivity in a System of Universities." *NBER Working Papers Series* No. 5833, 1996.

Arora, A., and A. Gambardella. "Public Policy towards Science: Picking Stars or Spreading Wealth?" *Revue d"Economie Industrielle* N. 79, 1er Trimestre (1997): 63–76.

Arrow, K. J. "Economic Welfare and the Allocation of Resources for Inventions." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, edited by R. Nelson. Princeton: Princeton University Press, 1962.

Arthur, W. B. "Competing Technologies: An Overview." In *Technical Change and Economic Theory*, edited by G. Dosi et al. London: Pinter, 1988.

Baldwin, W. L. "The US Research University and the Joint Venture: Evolution of an Institution." *Review of Industrial Organization* 11 (1996): 629–53.

Barrow, C. W. "The New Economy and Restructuring Higher Education." *Thought & Action* (spring 1996): 63–76. Also at <http://www.nea.org/he/tanda.html>.

Becker, G. S. 1975. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*, 2d Edition. Reprint, Midway, 1983.

Blaug, M. *An Introduction to the Economics of Education*. 1970. Reprint, Penguin Books, 1976.

Blume, S. "The Theoretical Significance of Co-operative Research." In *The Social Direction of the Public Sciences*, Sociology of the Sciences Yearbook XI, edited by S. Blume et al., 1987.

Brooks, H. "The Evolution of U.S. Science Policy." In *Technology, R&D, and the Economy*, edited by B. L. R. Smith and C. E. Barfield. Washington, D.C.: The Brookings Institution and American Enterprise Institute, 1996.

Bush, V. *Science: The Endless Frontier*. United States Government Printing Office, 1945. Also at <www.physic.uiuc.edu/ysn/docs/html_articles/vBush1945.html>.

Callon, M., and D. Foray, eds. "L'Economie Industrielle de la Science." Numéro Spécial of the *Revue d"Economie Industrielle* 79 (1997).

Cave, M., R. Dodsworth, and D. Thompson. "Regulatory Reform in Higher Education in the UK: Incentives for Efficiency and Product Quality." *Oxford Review of Economic Policy* 8 (1992): 79–102.

Cohn, E., S. L. W. Rhine, and M. C. Santos. "Institutions of Higher Education as Multi-Product Firms: Economies of Scale and Scope." *The Review of Economics and Statistics* 71 (1989): 284–90.

Cole, J., and S. Cole. *Social Stratification in Science*. Chicago, Ill.: Chicago University Press, 1973.

Commission of the European Communities. *Second European Report on S and T Indicators 1997*. Report EUR 17638 EN, 1997.

Commission of the European Communities. *The European Report on Science and Technological Indicators 1994*. Report EUR 15897 EN, 1994.

Commission Jacques Attali. *Pour un Modèle Européen d"Enseignement Supérieur*, 1998. Also at <http://www.education.gouv.fr/forum/attali.htm>.

Cowan, R. "Tortoises and Hares: Choice among Technologies of Unknown Merit." *Economic Journal* 101 (1991): 801–14.

Dasgupta, P., and P. A. David. "Toward a New Economics of Science." *Research Policy* 23 (1994): 487–521.

Dasgupta, P., and P. A. David. "Information Disclosure and the Economics of Science and Technology." In *Arrow and the Ascent of Modern Economic Theory*, edited by G. Feiwel. New York: New York University Press, 1987, ch.16.

David, P. A. "From Market Magic to Calypso Science Policy: A Review of Terence Kealey's 'The Economic Laws of Basic Research.'" *Research Policy* 26 (1997): 229–55.

David, P. A. "Positive Feedbacks and Research Productivity in Science: Reopening Another Black Box." In *The Economics of Technology*, edited by O. Granstand. Amsterdam: Elsevier Science Publisher, 1994.

David, P. A. "Clio and the Economics of QUERTY." *American Economic Review* 75 (1985): 332–37.

David, P. A., D. Foray, and W. E. Steinmueller. "The Research Network and the New Economics of Science: From Metaphors to Organisational Behaviors." In *The Organisation of Economic innovation in Europe*, edited by A. Gambardella and F. Malerba. Cambridge: Cambridge University Press, 1999.

Diamond Jr., A. M. "The Economics of Science." Special issue of *The International Journal of Knowledge Transfer and Utilization* 9 (1996): 3–49.

Dill, D. D. "Higher Education Markets and Public Policy." *Higher Education Policy* 10 (1997): 167–85.

Dresch, S. P. "The Economics of Fundamental Research." In *The Academy in Crisis,* edited by J. W. Sommer. Oakland: The Independent Institute, 1995.

Edquist, C., ed. "*Systems of Innovation.*" London: Pinter, 1997.

Etzkowitz, H. "The Entrepreneurial University and the Emergence of Democratic Corporatism." In *Universities and the Global Knowledge Economy,* edited by H. Etzkowitz and L. Leydesdorff. London: Pinter, 1997.

Garvin, D. A. *The Economics of University Behavior.* New York: Academic Press, 1980.

Geiger, R. L. *Research and Relevant Knowledge: American Research Universities since World War II.* Oxford: Oxford University Press, 1993.

———. "The Home of Scientists: A Perspective on University." In *The University Research System: The Public Policies of the Home of Scientists*, edited by B. Wittrock and A. Elzinga. Stockholm: Almqvist & Wiksell International, 1985.

Geuna, A. *The Economics of Knowledge Production: Funding and the Structure of University Research.* Cheltenham: Edward Elgar, 1999.

———. "Determinants of University Participation in EU-Funded R&D Cooperative Projects." *Research Policy* 26 (1998a): 677–87.

———. "The Internationalisation of European Universities: A Return to Medieval Roots." *Minerva A Review of Science, Learning and Policy* 36 (1998b): 253–70.

———. "Allocation of Funds and Research Output: The Case of UK Universities." *Revue d"Économie Industrielle*, N. 79, 1er Trimestre (1997): 143–62.

Geuna, A., D. Hidayat, and B. Martin. "Resource Allocation and Research Performance: The Assessment of Research." A study carried out for the Higher Education Funding Council for England, SPRU, University of Sussex, Brighton, 1999. Also at <http://www.sussex.ac.uk/Users/prff0/hefce.pdf>.

Getz, M., J. J. Siegfried, and H. Zhang. "Estimating Economies of Scale in Higher Education." *Economics Letters* 37 (1991): 203–8.

Gibbons, M., C. Limoges, H. Nowotny, S. Schwartzman, P. Scott, and M. Trow. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* London: Sage Publications, 1994.

Guston, H., and K. Keniston, eds. *The Fragile Contract.* Cambridge, Mass.: The MIT Press, 1994.

Hare, P., and G. Wyatt. "Economics of Academic Research and Its Implications for Higher Education." *Oxford Review of Economic Policy* 8 (1992): 48–66.

Hare, P., and G. Wyatt. "Modelling the Determination of Research Output in British Universities." *Research Policy* 17 (1988): 315–28.

HEFCE. *Industry-Academic Links in the UK.* HEFCE (1998) ref 98/70. Also at <http://www.niss.ac.uk/education/hefce/pub98/>.

Hoenack, S. A. "An Economist's Perspective on Costs within Higher Education Institutions." In *The Economics of American Universities: Management, Operations, and Fiscal Environment*, edited by S. A. Hoenack and E. L. Collins. Albany, N.Y.: State University of New York Press, 1990.

James, E. "Decision Processes and Priority in Higher Education." In *The Economics of American Universities: Management, Operations, and Fiscal Environment*, edited by S. A. Hoenack and E. L. Collins. Albany, N.Y.: State University of New York Press, 1990.

———. "The Private Nonprofit Provision of Education: A Theoretical Model and Application to Japan." *Journal of Comparative Economics* 10 (1986): 255–76.

Johnes, G. "Costs and Industrial Structure in Contemporary British Higher Education." *The Economic Journal* 107 (1997): 727–37.

———. "Performance Indicators in Higher Education: A Survey of Recent Work." *Oxford Review of Economic Policy* 8 (1992): 19–34.

———. "Determinants of Research Output in Economics Departments in British Universities." *Research Policy* 17 (1988): 171–78.

Johnston, R. "Effects of Resource Concentration on Research Performance." *Higher Education* 28 (1994): 25–37.

Kealey, T. *The Economic Laws of Basic Research*. London: Macmillan.

Kyvik, S. (1997) "Funding University Research in the Nordic Countries." *Science and Public Funding* 24 (1996): 233–44.

Lundvall, B. A., ed. *National Systems of Innovation*. London: Pinter, 1992.

Malerba, F., A. Morawetz, and G. Pasqui. *The Nascent Globalization of Universities and Public and Quasi-Public Research Organisations*. FAST Research in the framework of the MONITOR Programme, European Commission, 1991.

Mansfield, E., and J. Y. Lee. "The Modern University: Contributor to Industrial Innovation and Recipient of Industrial R&D Support." *Research Policy* 25 (1996): 1047–58.

Martin, B. R., et al. *The Effect of Size and Other Factors on the Research Performance of University Departments*. Brighton: SPRU, University of Sussex, 1993.

Massy, W. F., ed. *Resource Allocation in Higher Education*. Ann Arbor: The University of Michigan Press, 1996.

Merton, R. K. *The Sociology of Science: Theoretical and Empirical Investigations*. Chicago: Chicago University Press, 1973.

Merton, R. K. "The Matthew Effect in Science." *Science* 159 (1968): 56–63.

National Committee of Inquiry into Higher Education. *Higher Education in the Learning Society: Report of the National Committee*. Norwich: HMSO, 1997.

Nelson, R. R., ed. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press, 1993.

Nelson, R. R. "The Simple Economics of Basic Scientific Research." *Journal of Political Economy* 67 (1959): 297–306.

Nelson, R. R., and N. Rosemberg. "American Universities and Technical Advance in Industry." *Research Policy* 23 (1994): 323–48.

OECD. *University Research in Transition*. Paris: OECD, 1998.

———. *University-Enterprises Relations in OECD Member Countries*. Paris: OECD, 1990a.

———. *Financing Higher Education. Current Patterns*. Paris: OECD, 1990b.

———. *Industry and University: New Forms of Co-operation and Communication*. Paris: OECD, 1984.

———. *The Measurement of Scientific and Technological Activities. R&D Statistics and Output Measurement in the Higher Education Sector*. Paris: OECD, 1981.

Pavitt, K. "Road to Ruin." *New Scientist*, (3 August 1996): 32–5.

Peirce, C. S. "Note on the Theory of the Economy of Research: p.160 in Coast Survey Report." In *Writings of Charles S Peirce: A Chronological Edition, Vol. 3: 1872–1878*. Compiled by the editors of the Peirce Edition Project; edited by C. J. W. Kloesel. 1986. Bloomington, Ind., USA: Indiana University Press, 72–8.

Pestre, D. "La Production des Savoir Entre Académies et Marché—Une Relecture Historique du Livre : 'The Production of Knowledge' Édité par M. Gibbons." *Revue d'Économie Industrielle* 79, 1er Trimestre (1997): 163–74.

Price de Solla, D. J. *Little Science, Big Science*. New York: Columbia University Press, 1963.

Price de Solla, D. J. "A General Theory of Bibliometric and Other Cumulative Advantage Process." *Journal of the American Society of Information Science* 27 (1976): 292–306.

Schultz, T. W. "Capital Formation by Education." *Journal of Political Economy*, 68 (1960): 571–83.

Slaughter, S., and G. Rhoades. "The Emergence of a Competitiveness Research and Development Policy Coalition and the Commercialization of Academic Science and Technology." *Science, Technology, & Human Values* 21 (1996): 303–39.

Sommer, J. W., ed. *The Academy in Crisis*. Oakland: The Independent Institute, 1995.

Stephan, P. E. "The Economics of Science." *Journal of Economic Literature* 34 (1996): 1199–1235.

The Economist. "The Knowledge Factory." October 4, 1997.

Vavakova, B. "The New Social Contract: Governments, Universities, and Society. Has the Old One Failed?" *Minerva A Review of Science, Learning and Policy* 36 (1998): 209–28.

Veblen, T. *The Higher Learning in America: A Memorandum on the Conduct of Universities by Business Men*. 1918. Reprint, London: Routledge/Thoemmes Press, 1994.

Vught van, F. A. "Combining Planning and the Market: An Analysis of the Government Strategy towards Higher Education in The Netherlands." *Higher Education Policy* 10 (1997): 211–24.

Wible, J. R. "Charles Sanders Peirce's Economy of Research" *Journal of Economic Methodology* 1 (1994): 135–60.

Ziman, J. *Prometheus Bound: Science in a Dynamic Steady State*. Cambridge: Cambridge University Press, 1994.

Zuckerman, H. *The Scientific Elite: Nobel Laureates in the United States*. New York: The Free Press, 1977.

Internet

House Committee on Science. *Unlocking Our Future: Toward a New National Science Policy*. A report to the Congress, 1998. <http://www.house.gov/science/science_policy_report.htm>

Ministero dell "Universita" e della Ricerca Scientifico Technologica Linee per il riordino del sistema nazionale della ricerca scientific e technologica, 1997. <http://www.murst.it/Ricerca/ricerca.htm>