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The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm

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Abstract

This article examines recent developments in the role of the university in increasingly knowledge-based societies. Deploying the triple helix model (of academic–industry–government relations) recently developed elsewhere an emergent entrepreneurial paradigm is outlined in which the university plays an enhanced role in technological innovation. Governments encourage this academic transition as an economic development strategy that also reflects changes in the relationship between knowledge producers and users. It appears that the 'entrepreneurial university' is a global phenomenon with an isomorphic developmental path, despite different starting points and modes of expression.

Keywords: Triple helix; Entrepreneurial university; Knowledge dynamics; Institutional development

1. Introduction: back to the future

There is empirical evidence that identifying, creating and commercializing intellectual property have become institutional objectives in various academic systems. Coming from different academic and national traditions, the university appears to be arriving at a common entrepreneurial format in the late 20th century. The entrepreneurial university encompasses a 'third-mission' of economic development in addition to research and teaching, though the precise shape this takes might vary such that different scenarios of academic development can be projected (Readings, 1996).

This paper argues that this shift arises from both the internal development of the university and external influences on academic structures associated with the emergence of 'knowledge-based' innovation. Entrepreneurial activities are undertaken with the objective of improving regional or national economic performance as well as the university's financial advantage and that of its faculty. However, many

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academics and others view the entrepreneurial paradigm as a threat to the traditional integrity of the university (Pelikan, 1992). Some critics believe entrepreneurialism should be resisted (Brooks, 1993) or at least encapsulated in a special class of institutions of higher learning, fearing that an intensive pecuniary interest will cause the university to lose its role as independent critic of society (Krimsky, 1991).

Concomitantly, publication of research and production of graduates are held to be the most appropriate roles for an institution dedicated to the public good. Moreover, some companies, concerned about new firms emerging from academia as potential competitors, take a similar position, arguing that universities should confine themselves to traditional academic–industrial relationships such as consultation.

Despite such claims, as this paper will describe through comparative analysis, the momentum towards the emergence of an 'entrepreneurial university' is exceptionally strong, even if its development poses important institutional and governance questions for those involved. The concept of the entrepreneurial university envisions an academic structure and function that is revised through the alignment of economic development with research and teaching as academic missions.

The entrepreneurial paradigm is by no means confined to newly invented technologies or research intensive universities. It can be enacted at teaching as well as research universities through innovations in undergraduate education and continuing education. A two-way flow of influence is created between the university and an increasingly knowledge-based society as the distance among institutional spheres is reduced. The content and format for teaching, research and linkage itself are also affected.

The assumption of an active role in economic development leaves existing academic missions in place, but it also encourages them to be carried out in new ways. In addition to translating research into economic development through various forms of technology transfer, the traditional teaching role is reinterpreted as the university assists the modernization of low- and mid-tech firms. Thus, for example, student companies at the University of Sao Paulo and student interns from the University of Aveiro in Portugal creatively play an intermediary role in knowledge and technology transfer to local low-tech firms. Of course, like Sao Paulo and Aveiro, universities can combine research, teaching and economic development in a common framework.

The separation of teaching, research and business activities becomes less sustainable: ironically, some have suggested this is akin to a return to the medieval ideal of a common academic format that meets both the cultural and material needs of society (Geuna, 1998). Given centuries of divergence from an original unitary model, why is the university assuming an 'entrepreneurial' identity a millennium later? In this article, we set forth some features of the entrepreneurial paradigm that can be seen in various academic settings.

We explain the emergence of the entrepreneurial university as a response to the increasing importance of knowledge in national and regional innovation systems and the recognition that the university is a cost effective and creative inventor and transfer agent of both knowledge and technology. Despite industrial and academic systems at varying stages of development, governments in virtually all parts of the world are focusing on the potential of the university as a resource to enhance innovation environments and create a regime of science-based economic development.

2. The triple helix

One model through which we can interpret these changes is that of the 'triple-helix' (Etzkowitz and Leydesdorff, 1999). A triple helix of university–industry–government relations transcends previous models of institutional relationships, whether laissez-faire or socialist, in which either the economy or polity predominated, with the knowledge sector playing a subsidiary role. The triple helix model attempts to account for a new configuration of institutional forces emerging within innovation systems, whether through the decline of the total state or the opening of the insular corporation.

As knowledge becomes an increasingly important part of innovation, the university as a knowledge-producing and disseminating institution plays a larger role in industrial innovation. This was an activity formerly largely the preserve of either the industry or

government, or, depending upon the social system, it may have been a bilateral interaction between these two institutional spheres. Heretofore, industrial policies focused upon the government–business relationship, either by improving the 'business climate' with lower taxes or by influencing location decisions through subsidies. In a knowledge-based economy, the university becomes a key element of the innovation system both as human capital provider and seed-bed of new firms. Three institutional spheres (public, private and academic), that formerly operated at arms length in laissez faire societies, are increasingly interwoven with a spiral pattern of linkages emerging at various stages of the innovation and industrial policy-making processes.

There are four processes related to major changes in the production, exchange and use of knowledge which the triple helix model has identified: the first is internal transformation in each of the helices, such as the development of lateral ties among companies through strategic alliances or an assumption of an economic development mission by universities. The second is the influence of one institutional sphere upon another in bringing about transformation, for example government, in Sweden and the US, respectively, revising rules of intellectual property ownership to transfer rights from individuals or government to the universities. The third is the creation of a new overlay of trilateral linkages, networks, and organizations among the three helices, serving to institutionalize and reproduce interface as well as stimulate organizational creativity and regional cohesiveness. Groups such as the Knowledge Circle in Amsterdam, the New York Academy of Sciences and Joint Venture Silicon Valley encourage interaction among members of the three spheres, leading to new ideas and joint projects that might not otherwise have emerged from interaction within single spheres or from bilateral relations.

A fourth process is the recursive effect of these inter-institutional networks representing academia, industry and government both on their originating spheres and the larger society.

One such effect is on science itself as a result of internal changes within academia, strengthened and diffused by government policy. Given the increased participation of academics in entrepreneurial activities and the failure to define this new role as deviant, it can be concluded that the capitalization of knowledge appears to be taking increasing precedence over disinterestedness as a norm of science (Merton, 1942; Etzkowitz, 1998). Normative change has taken place not only as a result of the emergence of an entrepreneurial dynamic within academia but from the external influences on the university.

These latter cases have arisen from government polices such as the changes in the rules for disposition of intellectual property arising from federally funded research in the US. Similar restructuring of the ownership of academically generated intellectual property is under way in Japan and Sweden in order to enhance their utilization. Encouraged by technology transfer offices and the requirements of government granting programs for the support of research, scientists increasingly examine the results of their research for its technological and economic potential. A dual cognitive mode has emerged in academic science as researchers focus both on achieving fundamental advances in knowledge and inventions that can be patented and marketed.

3. The entrepreneurial academic paradigm

The effect of the four (inter-related) processes has been to encourage the emergence of an entrepreneurial culture within academia. Within the US, the academic scene has been, '' . . . characterized by decentralization, market competition, and institutional pluralism'' (Davis and Diamond, 1997). Rather than being encapsulated within a special class of universities that have special interests in applied research or professional disciplines, the introduction of entrepreneurialism into the academic scene affects the educational and research missions of all of institutions of higher learning, to a greater or lesser degree.

The entrepreneurial academic paradigm has normative as well as analytical components. To be active, rather than merely formal innovation agents, universities must undergo a first academic revolution, the incorporation of research as an academic mission (Jencks and Riesman, 1968). Academic institutions must also enter the second revolution, the assumption of a role in economic development through extensions of both their research and teach-

ing missions, but not necessarily in lockstep sequence. As we shall see, these transformations can occur simultaneously and even, to some extent, in reverse order.

The entrepreneurial university includes the following developmental mechanisms and emergent structures which can be tied to the four processes noted above. The implications, or corollary for each, are sketched out in summary form.

3.1. Internal transformation

Traditional academic tasks are redefined and expanded, according to the requirements of newly emerging functions. Thus, teaching was earlier affected by research during the 'first academic revolution' when teaching was expanded to include the methodologies for obtaining new knowledge as well as the passing on and reinterpretation of existing knowledge. Teaching is currently expanded by students testing their academic knowledge in 'real world situations' and acting as intermediaries between the university and other institutional spheres.

Corollary: Revision of existing tasks. Traditional functions and roles are reinterpreted and expanded in the light of new goals. For example, professors may identify opportunities for students to serve as interns in firms where their temporary apprentice role transcends the original educational intention.

As the university enlarges its role in innovation, controversies arise such as the propriety of the extension of the academic mission from dissemination to the capitalization of knowledge. Proponents and opponents of change debate these issues publicly and in governance structures within academia. Out of such controversies new rules and roles are defined and legitimated. Over time, the university reformulates its mission to incorporate the entrepreneurial paradigm.

3.2. Trans-institutional impact

The industrial and governmental spheres increasingly also develop similar intermediary capabilities. Thus, the imbalance between organizations and institutions that have such capabilities and those that lack them are redressed. A new equilibrium of overlapping institutional spheres is established in which collaborations and rules for interaction are more easily understood and negotiated.

Corollary: Stabilization. Formats for collaborative arrangements are institutionalized in legal and customary formats, e.g., the US Co-operative Research and Development Agreement (CRADA). Such contracts take a flexible form of finalized projects or networks with a fixed time frame and external as well as organizational funding.

3.3. Interface processes

The entrepreneurial university requires an enhanced capability for intelligence, monitoring and negotiation with other institutional spheres, especially industry and government. Beyond the ability of the top leadership of the university to engage with their counterparts in other institutional spheres, a mid-level organizational linkage capability gives the university the ability to identify confluence of interest between external organizations and their academic counterparts. Interface specialists make introductions, organize discussions, negotiate contracts, and otherwise act in an intermediary role to facilitate interaction with their counterparts and other potential partners in government and industry. Interface specialists emanating from various organizations and institutional spheres forge a common identity, independent of their employers. This is expressed organizationally in the creation of associations representing the emerging interface professions.

Corollary: Centralization/decentralization. Over time, as the entrepreneurial paradigm takes hold, interface capabilities spread throughout the university. Within academic departments and centres, faculty members and other technical personnel are assigned special responsibility to assess the commercial salience of research findings and encourage interaction with external partners. Centralized interface capabilities (e.g., technology transfer or university spin-off offices) play a leading role during the early stages of the introduction of an entrepreneurial

paradigm into academia but their role declines as it becomes institutionalized.

3.4. Recursive effects

Beyond establishing links with existing organizations, the university as entrepreneur also develops capabilities to assist the creation of new organizations. This may take various forms such as formation of firms based upon academic research, and leadership in forming regional organizations, bringing the various institutional spheres together for the common purpose of fostering innovation.

Corollary: Trilateral organizations. The existence of capacities for interface in various organizations increases the likelihood of collaboration in creating new cross-organizational and cross-institutional entities such as centres including investigators from several universities or from universities, companies and government laboratories. Joint ventures among companies provide a related instance emanating from the industrial sphere.

We have attempted here to define the essential characteristics of the entrepreneurial university and its process of emergence. In the sections that follow, we shall exemplify the propositions outlined above through case studies of academic development in Europe, Asia, South and North America. We will focus on the second element or process of the helix model, the influence of institutional spheres on each other, and in particular of government upon academia through a series of cross-national comparative case studies.

4. The mutual influence of institutional spheres

US universities have undergone two major transformations in the past century. We have elsewhere discussed the impetuses to the first academic revolution, an internal transformation of the university in the US in particular the effect of paucity of research funds in the mid-19th century in the context of the emergence of universities imbued with the research ideal (Etzkowitz, 2000). Under stringent financial conditions academics either had to give up their research plans or pursue entrepreneurial strategies to obtain research funding from internal and external sources. In the post-war era, while there were also similar pressures that were brought to bear on universities, so encouraging the need to secure additional income, the much wider, and more fundamental impact of the knowledge-based economy, as described in the triple helix model, ensured this process was of a qualitatively distinct order to that of the previous century.

Clearly, some sense of these changes were heralded earlier in the twentieth century in the first real steps then taken towards building academic–industrial links, notably those originated at MIT by Vannevar Bush and his colleagues at MIT. Similarly, the Research Corporation, founded by Frederick Cottrell a Professor of Chemistry at the University of California Berkeley, introduced the principle of utilizing income generated by patents to seed-fund new research. A potentially self-generating system of research funding was initiated that was subsequently expanded by government.

This was in contrast to many European, Asian and Latin American countries where basic and even applied research was pursued in government institutes. This created a different set of problems than in the US. As long as funding is expanding, an Institute system with technology transfer mechanisms is a viable support structure to the industry. However, such entities tend to ossify under conditions of financial stringency since the recruitment of personnel with new ideas slows. Moreover, in Latin America, Institutes tended to operate as independent entities and lacked technology transfer capabilities. Moreover, like their German counterparts, the Institutes were expensive structures with full time researchers, unlike universities where professors are supported by teaching duties and students, as apprentice researchers, were low-paid or paid for their research training through government or parental subvention.

4.1. The diffusion of academic technology transfer in the US

In the US, underneath the cover of an ‘endless frontier’ ideology of government funding without strings attached, linkages appeared in fits and starts

to overcome gaps among the institutional spheres that had been only temporarily elided during the Second World War. When blockages to interaction appeared, they were resolved through a political process that was given impetus by the industrial crisis that arose from increased international competition for the US industry in the 1960s and 1970s.

The build-up of research results in academia, without sufficient mechanisms to transfer practical outcomes to the industry, was not seen as a problem at first. It became recognized as an issue only when an innovation gap in the US industry became apparent due to the rise of competition. Well in advance of this crisis, a few patent attorneys at NIH and NSF became concerned about the perceived difficulties in translating research into economic activity. Acting largely at their own initiative, they established administrative procedures to allow universities to acquire patent rights to federally funded research on the condition that universities create professional in house technology transfer capacities to arrange patenting and licensing.

Short-term practical uses were not expected from government research grants but eventual utility was part of the post-war 'social contract' between scientists and government. The premise was that the billions of dollars of research funds supplied to the universities contained significant unrealized potential for technology development. Nevertheless, there was significant opposition in Congress, and from persons in the executive branch who believed that patenting of government funded research was illegitimate privatization of what should be a free public good. Despite these difficulties, academic technology transfer was successfully promoted within the federal government until an opponent, HEW Secretary Califano, in the Johnson administration, shut down the informal administrative procedures that had been created by government proponents of tech-transfer.

Proponents of technology transfer within the executive branch of the government proposed to overcome this blockage with a new law based upon a coalition between the universities and small business. Washington representation groups of both interests consulted on its provisions. For example, the language of the Bill and the administrative regulations worked out after its passage had to be adjusted to allow sufficient time to report inventions without interfering with professors' publication plans. Similarly, small business was concerned with keeping access open to so-called 'background inventions'.

A lobbying campaign culminated in a new legal framework for the translation into use of the fruits of federally funded research. The 1980 Bayh–Dole Act gave ownership of intellectual property, arising from federally funded research, to the universities. Nevertheless, the outcome was also a balance between traditional professorial rights and the institutional interests of the university. In the universities at least, innovators, by tradition, and soon by law, were guaranteed at least 15% of the returns on their invention.

Under the law, universities were obligated to make an effort to commercialize these rights. Universities lacking a technology transfer office soon established one, by hiring an industrial scientist in a field in which the university had potentially research or by giving the responsibility to an attorney on its staff. Some professors resisted academic involvement in technology transfer, believing that the university should devote itself to research and teaching. Other professors, who were already working with the industry, argued that the interposition of an administrative office in between themselves and their corporate sponsors would impede industrial relations.

These divisive issues were largely resolved by dividing the financial results of research among the investigator, the investigator's department and the university as a whole. The 'one-third rule', taking into account the general interest of the university and the particular interests of entrepreneurial faculty, was acceptable to both faculty groups and was widely adopted. Academia helped supply the industry with improved technology as a result of this low-key, indirect, federal innovation strategy that, with no direct appropriation of funds, changed the rules of the game.

Universities such as MIT and Stanford, which had been anomalies within the US academic system, now became the models for other universities to emulate. Other schools such as Columbia, which previously viewed themselves as playing a policy and service role in supplying faculty members going to Washington to serve temporarily in government, now found themselves trying to establish new ties with the industry, often in their local region.

Universities gradually extended their activities deeper into the technology transfer process, identifying and filling gaps in the technology 'push' process, establishing incubators to assist the formation of firms from campus research and venture capital arms to fill gaps in the availability of 'seed' funding. Government programs, such as the Small Business Innovation Research (SBIR) Program also increasingly play the role of 'public entrepreneur' in assisting the financing of new firms (Etzkowitz et al., 2000).

In addition, lateral connections appeared as national professional associations of technology transfer officials were organized within university, government and industry sectors, the Association of University Technology Managers, the Federal Technology Transfer Executives and the Licensing Executives Society, respectively. Over time, these intermediary groups increasingly overlapped in their membership, although regular meetings and conferences brought university and government laboratory technology transfer officers together with industry scouts to facilitate the transfer process.

Technology transfer activities are now a significant source of income for a few universities where significant technologies originated. Others are still gearing up their offices or waiting for technologies to receive health and safety approvals, so that the royalty flow to the university and its faculty can begin. In any event, a trilateral network of innovation has been put in place through these increasingly complex ties as, for example, companies donate intellectual property that falls outside of their core competencies to universities and thereby facilitate its development (Technology Access Report, 1999).

In 1862, the Morill Act assigned government-owned land to a special class of universities to support the development of agriculture. In 1980, the Bayh–Dole Act turned over intellectual property rights emanating from federally funded research to all universities as a virtual equivalent of a land grant. As the dividends in technology transfer and formation of new firms grows from Bayh–Dole, it may eventually come to be seen to be as significant to US innovation and economic development as the Morill Act.

Our account of the situation in the US suggests a gradual transformation over time of the institutional character of the university sector, but it is also clear, we hope, that these changes accelerate as a result of the qualitatively new dynamics of the knowledge society, such as the appearance of trilateral networks which create their own institutional configuration and institutional space. Similar structural shifts can be seen outside of the US, but limitations of space mean that we cannot tell a similar story for each. Instead, we focus our attention on the more recent developments of the past two decades.

4.2. The university and wealth creation in the UK

Public funding for university research in the UK has become dependent on the perception of whether it will make a direct contribution to the economy. The reduction of research funding has forced public sector institutions, especially universities, to undertake activities that either attract industrial funding or generate income. In part responding to government policies (both conservative and most recently labour), universities have become involved in exchange activities such as licensing patents and establishing innovation centres. At the same time, changing relations between knowledge producer/user links through outsourcing, the arrival of transorganizationally dependent technologies (such as bioinformatics) and the rapid growth of information sourcing, created, as in other advanced countries, the re-configuration of institutional relations. For universities, this has meant that we are beginning to see a shift from a grant to an exchange economy in higher education. This has required new institutional orderings and modified academic regimes that govern and reward entrepreneurialism.

The anxiety felt over the need to exploit scientific research has contributed to the formation of number of commercialization policies. In 1985, UK universities were given the right and responsibility to exploit their intellectual property by securing property rights to ensure publicly funded work was transferred to the private sector. From the government's perspective, the devolution of rights from the state-agency British Technology Group (BTG) to universities was intended to both help universities generate income for themselves and contribute to national wealth creation. The decentralization of technology transfer

and the privatization of BTG represented a turning point in the evolution of the entrepreneurial university in the UK.

Academic entrepreneurs are encouraged to secure formal rights on their intellectual property as a key step towards the successful commercialization of their research. The new institutional vehicles that facilitate this process — such as industrial liaison offices and incubator firms — create new forms through which knowledge can be appropriated. This new activity has also affected the traditional academic reward system. Thus, the UK Higher Education Funding Council which is the principal state agency that supports universities has requested that patents held by academics should be regarded as evidence of 'quality research' in the national Research Assessment Exercise, and have, thereby, some equivalence to conventional academic output such as journal papers. Patents held by academics seem, therefore, to be able to provide evaluative measures in two distinct regimes of appropriation — the market and the academic — at the same time.

Nevertheless, it is important to recognize that universities have not found it easy to construct new regimes that can handle the commercialization of research. An in-depth study of universities' industrial liaison offices found these universities IPR policies confused and often ignored by academics. There was as much disorder as order from the perspective of those attempting to build the entrepreneurial university. How entrepreneurial activities will be integrated with traditional academic tasks is still under debate. It is quite likely that in the UK privately funded contract research will form the primary links between academia and industry. At the same time, in the UK as elsewhere in Europe, the growth of university spin-off firms (USOs) has increased steadily in response to the pressure towards commercializing the science base or developing knowledge-based services for larger firms that subcontract R&D activities such as experimental testing.

A recently completed study of USOs in the materials, scientific instruments and information technology sectors, differentiated these firms according to four distinct types (Webster and Rappert, 1997; Rappert and Webster, 1998; Rappert et al., 1999). The 'independent firm' (54% of the sample) is a firm which has broken away from the university, where contact is relatively modest, especially when compared with links to other firms. The hybrid firm (17%) is a firm that is likely to be still located within the university and dependent on the university for a degree of administrative and financial support. Intellectual property rights are shared with academic research groups and the firm's staff occupies both academic and company positions simultaneously. Hybrids do, however, seek the growth that will take them to full independent status.

The shell firm (21%) is sometimes but not always located within a wider university holding company. Such a firm is designed primarily to pull in research income for a university department. The founders see the establishing of a shell company as merely one mechanism among a range of industry liaison and contractual arrangements. Finally, the virtual firm (8%) brings together research staff from a number of academic sites across the UK, developing new embryonic product ideas unlikely to be found within a single university department for third parties who go on to take them through to market.

In the wider ecology of commercialized public sector activities, these different types of firms can be seen to be variants of change associated with the first and third of our processes associated with the triple helix model, that is, internal transformation and the arrival of new interface structures bridging academia and industry. The firms have varying capacities for growth and make different demands over time on their host university. This in turn reflects the sector they are in, the sort of knowledge needs they have, and the time-to-market of their products. The materials companies, for example, are much more likely to depend on core science knowledge inputs from university departments over a number of years as the new materials science is still (compared with instruments and IT) at an early stage of development, and new products some way off.

The growth of a USO can also reflect their role in relation to the parent university. Shell firms, which earn modest (though occasionally high) levels of income for university departments will be likely to be less exposed to financial risk because of the buffer provided by the university. On the other hand, such firms may also have restricted growth patterns as centres for employment because of internal changes in research staff, research foci and structural

constraints associated with university Departmental procedures to which the shell firm is subject.

This brief discussion of USO illustrates the process of 'institution formation' noted above. These new organizations can have quite distinct linkage and growth characteristics. Notwithstanding this, however, it is still likely to be the case that whatever the cultural setting — whether in Germany or the UK — the wider processes at work in the knowledge system will encourage universities to construct structures which maximize their capacity for innovation. The common features of the entrepreneurial university mapped out earlier do not necessarily mean a uniform set of institutional structures has to be set in place. Nevertheless, many of the same organizational forms identified in the UK were earlier constructed in the US for much the same reasons.

4.3. The emergence of the entrepreneurial university in continental Europe, Latin America and Asia [1]

As the case of the UK indicates, the entrepreneurial university can emerge in academic systems with little or no previous history, and even a strongly antagonistic attitude toward the capitalization of knowledge. Clearly, pressure from the Thatcher government during the 1980s towards greater 'enterprise', not least through new policies on intellectual property that mirrored similar shifts in the US, was important. Nevertheless, as in the US, it is quite likely that the wider institutional changes wrought by the emergence of knowledge-based innovation would have prompted such changes in the medium term. In both the UK and US, however, the relative independence of the university sector (as corporate institutions) from the state meant that the capacity for flexible response to the new circumstances was high (even though in some cases it could also enable some institutions to continue to act, at least for a short time, as they always had done).

On the European Continent and in Latin America, academic institutions were traditionally creatures of the state. Under such conditions, part of the process of creating entrepreneurial academic institutions has been their attaining a significant degree of independence from controlling bureaucratic institutions such as a Ministry of Education, Culture or Science. For example, French universities only attained independent status in 1972 as an indirect outcome of the student revolts of 1968 (Musselin, 1998).

A gradual shift can be identified in Continental Europe and Latin America towards an increasing autonomy of the university from the state, on the one hand, and closer engagement with the industry, on the other. The transition to an entrepreneurial university is encouraged by European Union funding programmes that provide resources to create intermediary mechanisms such as liaison offices to interface with small- and medium-sized firms (SMEs). Abandonment of protectionism and associated plans to develop entirely new industrial sectors autochthonously, based on government R&D have been downscaled into more modest, less costly programmes to subsidize Latin American universities to take up the task of enhancing industrial technology. Should these trends continue, European and Latin American universities would find a new balance in their relationship with government and industry, moving apart from the former and closer to the latter.

4.3.1. Europe

In Europe, the 'stadium generale' played a common unifying role of cultural reproduction during the medieval period. Nevertheless, the medieval universities of Paris and Bologna, one a corporation of students, the other of masters, exemplified two contrasting models of academic governance (Rashdall, 1936). It appears, that the belief that teaching and the acquisition of broad knowledge which is followed by a specific company training as the true task of universities overshadows the emergence of an institutional renewal according to the needs of a knowledge-based society.

There are a variety of European circumstances that have made for stronger or weaker links between

[1] The US, Latin America and Japan sections are partly based on interviews reported in Technology Access Report, Novato, CA; e-mail: info@techaccess.com. See: Etzkowitz, H. ''From Brazil's 'Endless Frontier' Strategy to Tech Transfer'' (November/December 1997), ''Tech Transfer Cornerstone: The Pre-History of the Bayh–Dole Act I'' (June 1998), ''Tech Transfer Cornerstone: Passing the Bayh–Dole Act II'' (December 1998) and ''Is the US an Appropriate Model for Japanese Tech Transfer?'' (January 1999).

academic and corporate sectors. Yet, the European Commission regards ''fruitful co-operation between universities and industries as one of the strongest engines of economic growth for Europe'' (ESTA, 1997, p. 10), confirming the importance given to universities in relation to their role in economic development in the late 20th/early 21st centuries. The possibility of playing such a role does, however, vary by region and country, reflecting differences in the way both the industry and academia have developed over this past century, and in this sense it would be wrong to presume a single European model, either of linkage, or of the university per se. We can sketch out some of these differences, and similarities, by focusing on a few European countries here.

4.3.2. Italy

Italy's success in trying to overcome the conservatism of classical teaching universities seems to be stalled by the ongoing struggle to cope with administrative and budgetary problems. However, the financial crisis of the universities resulting from severe cut backs in public funding has, since the 1980s, led to the introduction of new laws allowing universities the right to obtain private funding. Yet, the financial crisis of the public sector has left universities with a new autonomy without providing the managerial knowledge necessary to organize a for-profit range of activities. While public universities are blamed for mismanagement, inappropriate education schemes and inefficiency in matters of research, the polytechnics are more successful in finding industrial partners. The most famous ones, located in Milan and Turin, were originally set up by Olivetti and Fiat respectively to secure the recruitment of engineers for these same firms.

In recent years, the *confindustria*, the powerful industrial association of Lombardy, has had a major influence in shaping the university course system covering the natural sciences. Further, the *progetti finalizzati* (finalized projects), funded by the central authority of research and development (CNR) which has been in existence since the 1970s, have encouraged an increased level of research activity at some universities. These changes are, however, modest in real terms, since the percentage of industrial funded research remains low and universities have not reached the point of being accepted as a partner in the innovation process. Italian universities, such as the Bocconi in Milan, are in the throes of the first academic revolution. A new generation of scholars, often with PhDs from abroad, are in discord with an older generation hewing to a traditional scholarly orientation that is less concentrated on research and publication.

As in a number of other European countries, the 'second revolution' is being led by new initiatives that are centred on highly regarded research institutes, such as the National Institute for the Physics of Matter (INFM). INFM has established two strategic research laboratories in liaison with Italian semi-conductor firms, whose interest lies in research that delivers good quality control measures. Both researchers and students develop strong links with the participating companies. It is quite likely then that only by diffusing this strategy across other firms and sectors will the impact of the INFM initiative become significant. The financial capacity of the European Commission might help to compensate for the chronic financial shortage of national sources and the reluctance of companies to establish and finance institutionalized networks rather than to engage professors for a personalized form of consultation.

4.3.3. Germany

During the last century, traditional German teaching universities adopted a differentiated approach to research and teaching. Some universities took up application oriented research (similar to that carried out in the Fraunhofer institutions) while more basic research was located within the Max Planck Institutes (MPI). Educational programs, of shorter and of more practical relevance, were established within the Fachhochschulen (polytechnics).

While these changes brought positive effects, notably in terms of the very great success of the Fraunhofer contract research organization, they had their downside: the MPI fostered an ivory tower culture, while the Fachhochschulen set only low entrance requirements for students and has been said to reflect a lower standard of teaching. Moreover, the applications orientation and a dependency on industrial funding, and the more immediate concerns of the industry, have worked against competence building in high technology fields. While the concern of

policy-makers initially was to keep up with the US and to build up a competitive academic system which is free and open to everybody it soon turned out that idea had been a too costly mission. It became clear that it was impossible to proceed in this direction in times of recession and the financial crisis of the public sector.

High unemployment made the university a parking lot for young people looking for a job. Readily available social security and free education as well as the social status very often were the reason for the attractiveness of the institution. The result was the loss of reputation of many, so called, mass universities. Yet, another problem became more and more prevalent at the end of the 1980s. German universities are within the legal domain of the Bundeslander in the federal system. Constitutional law places the financial responsibility for the maintenance of these institutions within both regional and federal government — a characteristic in the German system that became notorious as the 'joint decision trap' (Scharpf, 1985). Since revenues from industrial taxes have tended to decrease for the Bundeslander, universities become a growing burden for them rather than an instrument for stimulating regional development.

Some initiatives have been taken to deal with this problem through revision of the Hochschulrahmengesetz, the legal framework of universities in the purview of the national government. Universities will be allowed to establish entrance examinations, shorten educational schemes, install flexible contracts for university staff (formerly, life long employees), charge tuition and pool forces with other universities in their region. Thus, a modicum of institutional independence has been granted. Additionally, the administrative system of the university itself is undergoing an evaluation process according to standards used in for-profit organizations. New accounting methods, emphasizing cost efficiency, with penalties exacted for inefficient use of budgets will be installed. The excessive number of administrative staff is in question and some tasks are being outsourced to private organizations. Government is setting in motion a process to encourage universities to look after their own needs, encouraging them to become independent actors, once again demonstrating the importance of public initiatives in creating the conditions for the emergence of entrepreneurial universities (Gebhardt, 1997).

The German story is then one of a mixture of redefining the university system to be both more active in regional development while being required to be prepared to generate higher levels of income through commercializing its teaching and research activity. The division between the pure research of the MPI and the more applied work of traditional universities is unlikely to persist in the future in practice since new networks linking basic and applied R&D that cut across institutional structures are developing. In response to the Hoechst's US$50 million dollar contract with Massachusetts General Hospital in 1980, Germany, founded the 'Genecentrum' research centres, in Cologne, Munich, Heidelberg, and Berlin. The objective was to create a critical mass of research activity in molecular biology, a field in which Germany lagged, despite or perhaps because of its strong commitment to biochemistry.

Almost two decades later, this initiative has borne fruit as participating scientists have begun to organize biotechnology firms, with as many as 12 founded in 1997. Generally, there is a tendency to adopt US methods to establish links with industries. Internships sponsored by companies and alumni organizations are getting more and more popular. On the other hand, larger companies like Daimler–Chrysler or Bertelsmann are planning to set up their own universities in order to avoid a long and difficult innovation process in the co-operation with university administrations.

4.3.4. Latin America

The classic Latin American University is undergoing rapid, if discontinuous change, spurred by shifting relations among industry and government. Traditional educational curricula designed to fit graduates into existing large bureaucratic organizations, whether governmental or industrial, are less relevant in an era when there is a premium on people with the varied skills necessary to work in new organizations and through networks. The emerging Latin American academic pattern could, then, in these terms be characterized as undergoing simultaneously what we referred to earlier as the 'first' and 'second academic revolutions'.

Efforts to reconfigure national and regional innovation systems play a significant part in the restructuring of universities. For example, in the state of Rio de Janiero, government has offered incentives for companies and universities to collaborate in revising rigid academic structures, in order to make undergraduate education both more interdisciplinary and more responsive to the needs of employers. A traditional focus on undergraduate education, primarily taught by part-time professors is being displaced by a full time professorate with a greater focus on research and the emergence of connections to industry through research as well as training of students. An unintended consequence of the creation of a full time professorate is the weakening of the traditional integration of academia with society, through the former model of the professional as professor.

Science policy in Brazil, and elsewhere in Latin America, has traditionally emphasized the primary role of the national government. Indeed, major technology-based industries and universities were creatures of the state. The classic Latin American theory of science, industry and government, the eponymous 'Sabato triangle', postulated that the national state could play the leading role in restructuring their relationship. Thus, following the triangle model, the technology for milk production in Columbia is analyzed by looking at government economic policy for the milk industry, the productive structure of milk products and how the science and technological infrastructure deals with milk problems. Sabato and his colleagues, having formulated the triangle as a radical strategy to overcome dependency and underdevelopment, founded the Service of Technical Assistance to Industry in 1962 to address Argentina's industrial problems. When military regimes took power they reinterpreted the thesis of a leading role for government in innovation as a mandate to create new industrial sectors such as a computer industry in Brazil, both to enhance national autonomy and as a technological underpinning for the armed forces.

As in Eastern Europe and the former Soviet Union, having universities and industry as part of the same institutional sphere under the aegis of government was expected to facilitate technology transfer. However, in practice, there was often a gap rather than a close working relationship between developers and users (Mello et al., 1998). Government supported research agencies had to guess what potentially useful areas of R&D would be helpful to industrial enterprises. Not surprisingly, they often missed the mark of what would work in a product.

Reformers who recognized the inadequacy of the traditional Latin American academic model for economic development posited alternative top-down 'populist' and 'elitist' theses of university reform, such as those in Brazil, emphasizing the application of biotechnology to local underutilized resources such as sugar bagasse, on the one hand, and to creating mid-sized basic research facilities such as a synchrotron, with industrial research capacities, on the other. In the medium term, perhaps the most significant event both for university reform and university–industry linkage is the 'bottom-up' incubator movement in municipalities and universities across the country such as the facility at the State University of Rio de Janeiro branch campus in Friburgo where incubator hosted consulting firms infuse traditional companies in the region with advanced technologies and knowledge.

Innovative efforts are also underway to utilize the resources of the university for social as well as economic development. For example, COPPETEC, the industrial relations arm of the engineering school of the Federal University of Rio de Janiero has begun a program to organize cooperatives. Rather than focusing on high-tech ventures, the program seeks out entrepreneurially oriented residents of poor neighbourhoods (favelas), typically with little previous formal education and provides them with basic training in formation of a small business. Groups formulate their projects, develop their leadership and test their ideas, such as bakeries and cleaning services, often finding their initial customer within the university before venturing out into the larger economy. The initial success of this project has led to its being taken up at the national level for replication elsewhere (Ulla, 1998).

4.3.5. Japan

During the post-war era, the Japanese university mainly focused on training students for corporate and government employment. Currently there is a shift toward research, especially longer term research with potential commercial implications. In anticipation of useful results, the protection of intellectual

property originating in academia has become an issue. Since ownership resides in the individual professor, the concern is whether academics are willing or able to protect and commercialize their discoveries.

Some Japanese academics, fitfully encouraged by government, seek to reorient their universities to capture intellectual property rights from academic research (Kneller, 1999). They wish to return, in a different way, to an earlier, more formal, system of academic industry relations. In the pre-war era, some professors prototyped technology for industrial production. In the early post-war, formal ties between academia and industry were cut, in part due to the connection between universities and the armament industry. Similar ties can be identified in the US in the development of the aircraft industry in the inter-war period. When the Japanese lost the war academic ties with the industry and the military were broken as part of the restructuring of Japanese universities and other institutions by the US occupation.

When formal ties were ended, academic industry relations shifted to an informal mode. When Japanese professors produced useful ideas during the post-war era they were typically transferred to industry through informal relations to existing companies. When a company became interested in an academic research topic or when a firm faced a problem on which it needed outside research assistance, an industrial research would be sent on a visit to a relevant professors research group. If the industrial researcher interested the academic in the problem, research support could be forthcoming, The industrial researcher might arrange for a longer stay. A parallel research effort would be established in the company lab, pursuing the more practical aspects of the topic. In these relationships, the academic researcher turned over the potential intellectual property to the company to patent. In turn, the academic received modest research support.

It is tempting to assume that informal relations among academia and industry are a special Japanese cultural characteristic in comparison to more legalistic and contractual models in the US. However, the informal system was in part the result of the suppression of pre-war close connections between academia and industry in support of military projects. These ties built upon a tradition dating from at least the early twentieth century of engineering professors designing products that would then be manufactured by firms. At that time, academia substituted for an industrial research capacity that had not yet been created.

Japanese universities once mainly confined to the traditional industrial relations task of preparing students for jobs in Japanese firms have taken a new task. Formerly, companies wished to mainly hire persons with BA degrees, preferring to give specific training internally to ensure that it was in line with company goals. Japanese industrialists are rethinking this strategy. Universities are now expected to prepare more persons with advanced degrees. These persons will move into an environment with a higher degree of mobility among companies, within academia, and between academia and industry. Indeed an increasing number of Japanese universities now have high-level administrators who arrived from industrial research positions. In short we are beginning to see a much greater formalization of academic–industry ties in Japan.

The academic sphere in Japan is returning to its pre-war prominence as a major source of economic development. This time the expectation is that academic resources will be used to infuse civilian industry with new products and even firms. Japan is currently taking stock of its innovation system, identifying flaws and moving to emulate a post-war US system of innovation characterized by start-up firms, often based on intellectual property emanating from academic research. Just as the US looked to Japan to learn TQM and just in time production, Japan now looks to the US to determine how to establish start-ups and translate academic research into new technologies and production processes. Indeed, the Japanese industrial policy agency MITI, that initiated consortia of companies and regulated the inflow and out flow of companies from ‘sunset’ to ‘sunrise’ industries has recently installed a program of grants to universities in imitation of the US NSF.

5. Evolution of ivory tower to entrepreneurial paradigm

The developments sketched out above suggest that Schumpeter’s model of the entrepreneur has been creatively extended beyond the sphere of busi-

ness into education and government. It has also expanded from the individual to the collectivity. Indeed, Schumpeter himself adumbrated this latter thesis in his discussion of the historic role of the US Department of Agriculture as 'public entrepreneur', instigating innovation among farmers (Schumpeter, 1949).

Nevertheless, we should not underestimate the significance of funding shortages pushing academia in this direction. This latter factor has been most acute in Eastern European countries where support for research institutes fell like a stone within the space of a few years during the early 1990s. It was much less a matter of the insistent demands of a knowledge-based innovation that prompted change (although blockages to innovation were an underlying cause of economic collapse) but the insistent demands of survival prompted by financial crisis (Kwiatkowski and Edvinsson, 1999).

In other countries, including the US and the UK, entrepreneurship is sometimes grafted on to academic structures whose leadership often still articulates monastic values in their public presentation of self. Columbia University in the City of New York is identified by the New York Academy of Sciences as leading 'the regional royalties pack' in the greater New York area, earning 'over US$50 million in royalties from its intellectual property' (Raymond, 1999). At the same time, George Rupp, the President of Columbia, in a public lecture on the heritage of the university said that ''it is essential that the values from our 'monastic' and 'scholastic' educational traditions be stressed equally in undergraduate education.'' Rupp further argued for the application of this critical tradition to 'our forms of market capitalism', intending this remark for the larger society (Gale, 1998).

The contemporary university is an amalgam of teaching and research, applied and basic, entrepreneurial and scholastic interests. These elements exist in a creative tension that periodically come into conflict. Conflict typically results in compromise and normative change in which different and even seemingly opposed ideological elements such as entrepreneurship and the extension of knowledge are reconciled.

Some observers (such as Ziman, 1991) posit that academic involvement with the industry is an indicator of a transformation of the university into a bureaucratic mode in which academic research will mimic its industrial counterparts, controlling the decisions about how to do research but having lost control over the research agenda to external influences. The key issue is how far it is possible for academic scientists to combine Mertonian and entrepreneurial values in an ethos of entrepreneurial science in which the extension and capitalization of knowledge are made compatible. There are continuing tensions between mobilizing knowledge as a public good (and maintaining the incentives to do this), and controlling its value as a private good (Arrow, 1962; David and Foray, 1995; Foray, 1997).

6. Conclusion: the future of the university and the university of the future

The comparative evidence summarized in this paper suggest that a pattern of transformation toward an entrepreneurial university is emerging, from different bases, in the US, Latin America, Europe and Asia. At least two major trends can be identified that affect the future role of the entrepreneurial university: one is the shift to ever greater dependence of the economy on knowledge production (Stehr, 1994) and, the second, the attempt to identify and guide future trends in knowledge production and their implications for society.

There is a shift underway from the economics of the production function to the socio-economic processes of the contemporary innovation system — with universities part of a new knowledge infrastructure. This transformation has been analyzed by Lundvall (1997) in his work on the advent of the 'learning economy', and by Smith (1997) on the role of University R&D in the ' knowledge infrastructure' for production. Within the context of today's knowledge-based innovation and the associated role played by knowledge-based networking, the model of the university centre as a vehicle for technology transfer has become organizationally and institutionally more complex, acting as a conduit through which knowledge exchange and exploitation is made more effective.

Each institutional sphere fills gaps with inputs from the other, even as they also take on some of the

role of the other. Consortia to develop new technologies may include corporate R&D units, university centres and government laboratories. Sometimes, each of these entities subcontracts part of their work to a unit in another sphere, say a university to a start-up firm or a corporate lab to an academic research group. Often assisted by national and multinational funding programs, these developments, further push innovation activities into network formats. Increasing complexity also leads to the emergence of a new layer of consortia managers and 'interface specialists' often located in the non-profit sector.

The emergence of new structures such as these within and between universities reflects the changing division of labour in innovation systems which encourages new patterns of mobility of both knowledge and researchers. These processes are not, of course, uniform across all discipline areas, suggesting that any current mapping of the socio-economic structure of research will find areas of research that can be classified as more 'open' or more 'restrictive' in terms of public access to the knowledge they produce.

We saw, however, that local circumstances — whether in developing or advanced industrial countries — can act as constraints on the speed at which the new institutional structures can be built. This problem is especially relevant for newly industrializing countries within which the knowledge infrastructure is more unevenly developed. Nevertheless, it is likely that in the future the traditional distinctions between public and private will break down, while the knowledge system itself grows in complexity and becomes much more difficult to manage. For example, firms in new technology areas, such as biotechnology or telemedicine, find it much more difficult to position themselves in these since, as McKelvey (1997) notes, ''the search space for economic innovations is ill-defined'' (p. 210).

Nevertheless, a viable search strategy for technological evolution can be defined that may result in both useful unintended consequences and 'conscious mutation' possibilities. For example, Venezuela is concentrating academic and governmental R&D on oil and Finland, building upon the previous application of electronics to its wood processing niche, utilized this 'second order resource' to create the Nokia mobile telephony success.

Firms, universities and governments who, individually and collectively, engage in 'bottom up' planning, 'roadmapping' and foresight exercises are more likely to reap future rewards than their peers focused on the short-term. Indeed, it was those US universities that made a bet on the emerging interdisciplinary field of molecular biology as early as the 1930s and 1940s who became the early hosts to industrial complexes in biotechnology during the 1970s and 1980s.

Although some observers have predicted that the university is in the process of being superseded by other more specialized organizational forms such as consulting firms, this is unlikely given an even greater need in a knowledge-based society for an institution of reproduction and generation of knowledge and skill through its teaching and learning role. In this information-based economy, knowledge can be a public and private good at one and the same time. Secrecy has been identified as part of the discovery strategy of investigators, even for research that is disseminated solely in classic academic fashion through journal publication.

The patent system is an exemplar of organizing knowledge as public and private at one and the same time. Concepts and technologies are made accessible to others even as 'rents' are accrued. Firms are also concerned with openness and secrecy as part of a potential common interest in creating broader markets. This is especially true in the IT sector (Byte Magazine, 1997). These developments suggest that as some firms act more like universities, in developing an interest in sharing, knowledge, universities have become more like firms in asserting a financial and proprietary interest in the potentially commercializable knowledge that they produce in the course of research and teaching activities.

In comparison to the university research system based upon relations with government, academic–industry relations are a relatively small phenomenon. Since the existing system still surpasses the emergent one, some observers suggest that technology transfer, academic patenting, royalty income and industrial sponsorship of academic research are not significant, even though it has expanded greatly in recent years. However, it is suggested here that linkages among sectors, drawing together different stages of the innovation process is an important change in an innovation environment comprising universities, national

Table 1
Summative chart of the university–industry–government relationship

University		Industry		Government	
Subjects	Keywords	Subjects	Keywords	Subjects	Keywords
Academic culture	· Academic autonomy	*Industry culture*	· Industry goal	*Public policy*	· Government goal strengthen economy
1. Quality 2. Freedom to publish · Revision of academic norms				1. Profit 2. Royalties · Revision of industry norms · Recognized economic	
Academic function: teaching, research and extension nputs: government funds and industry sponsorship Outputs: knowledge production		Industry function: national development Inputs: knowledge Outputs: new products		Development as academic (extension) and industry function	
· Time to research		· Generation of dynamism		· Give support to research directed to market	
· Commercialization of PSRS		· Larger and faster technological innovation		· Give support to technological innovation integrated to academic research	
1. Types of commercialization 2. Problems with commercialization 3. Results of the academic–industry technology transfer					
· Niches of market		· Niches of market		· Give support to university and industry identify niches of market	
· Exploitation of knowledge-based (academic expertise)		· Magnification of knowledge-based		· Economic development	
· Internal policy of patents		· Internal policy of patents		· Government policy of patents	
· Stability in the execution of research		· Sponsorship		· Give support to sponsored research	
· Use legal instruments to encourage cooperation		· Use fiscal incentives to encourage cooperation		· Give legal instruments and fiscal incentives to encourage cooperation	
· Evaluation of teachers that works with cooperation		· Evaluation of employees that work with cooperation		· Evaluation of university and industry results	
Intermediate offices	· Function: connect teaching, research and extension resources administration internal marketing and communication external marketing administration of the interaction process	*Agents*	· Function: connect in-home P&C with university P&D resources administration internal communication to evaluate possibilities of interaction and industry possibilities administration of the interaction process	*Politicians*	· Function: stimulate interaction university–industry
	· Organizational structure		· Organizational structure		
Relationship evaluation	· Typology	*Relationship evaluation*	· Typology	*Relationship evaluation*	· Typology
New University	· 21st century university 1. Entrepreneurial university 2. New university mission:	*New Industry*	· 21st century industry 1. Industry-based science 2. New industry mission	*New Government*	· 21st century government The new university and industry need a new

Table 1 (continued)

University		Industry		Government	
Subjects	Keywords	Subjects	Keywords	Subjects	Keywords
	economic development 3. New organizational structure: mixing disciplinary departments, interdisciplinary centers, new disciplines, self-generation institution, social space increased		3. New organizational structure: cooperation projects, entrepreneurial centers of high technology in the vicinity of universities		government administration where scientific and technological infra-structure are integrated to the productive structure

laboratories, laboratories of large corporations and, start up firms.

These organizations act, not separately as in the old linear model, but through various alliances and consortia, creating ties across the triad of helixes (academic, industrial and government) whose interconnections we have begun to model and map. A summative chart (Table 1) showing the evolution of these institutional spheres is shown above, denoting the issues within each sphere, processes of change and normative goals.

The transformation of academia from a 'secondary' to a 'primary' institution is a heretofore unexpected outcome of the institutional development of modern society (Mills, 1958). In consequence, ''the knowledge industry in modern societies is no longer a minor affair run by an intellectual elite, an activity that might be considered by pragmatic leaders as expendable; it is a mammoth enterprise on a par with heavy industry, and just as necessary to the country in which it is situated'' (Graham, 1998, p. 129). University development (forming a network of local Colleges in Scotland, recycling the old Pirelli works in Milan into a new campus, or building a shopping center and industrial park on the Stanford campus) is also central to regional development, both in 'less favored' rural and declining industrial regions.

The establishment of universities has always been a strategy for latecomers or lagging regions to build up industrial clusters and a collective identity. One element of the latecomer strategy is designing a new entrepreneurial university; it is also restructuring and reorganizing existing universities according to the MIT prototype. Thus, the call for '100 MITs' in Europe is part of a broader effort to create a more dynamic society, emphasizing entrepreneurship, firm-formation and risk-taking.

Rather than a transition to an assumed fixed point, such as a market economy in the east, we may be in a state of continuous transition. Rather than an end state as in the assumption of a transition to market, it is more likely given the dynamic, competitive nature of technology development in a global economy that there will be the continuous invention of new roles and relationships for static institutions. Certainly, the transition is not to a pure market since no country is giving up subsidies entirely and some are creating new ones. Rather the transition is toward a mixed system of market forces and government incentives. East/west, north/south: the interaction of government, industry and academia is shifting, from previous modes of separation or control, into a 'triple helix' of overlapping, yet relatively autonomous, spheres.

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