

## The economic impact of Cardiff University: innovation, learning and job generation

*Huggins, Robert; Cooke, Philip; Centre for Advanced Studies, University of Wales, Cardiff, 33 Corbett Road, Cardiff CF1 3EB, Wales, UK*

Received March 1996; accepted November 1996

**Abstract:** This paper discusses two economic functions of the University of Wales Cardiff (Cardiff University) in relation to local and regional economic development. The first concerns its direct and indirect impact as an economic force in its own rights in the locality and the wider city-region of South East Wales. Through the application of impact analysis it is shown that the University is responsible for generating a gross local output of approximately £100 million a year and sustaining over 3,000 jobs. The second aspect of the paper concerns the knowledge impact of the University and its contribution to the development of regional industrial clusters in the automotive and electronics industries, and enhancing the 'learning capacity' of the locality.

### Introduction

The commonly held perception of universities as merely institutions of higher learning is gradually giving way to the view that universities are important engines of economic growth and development (Chrisman et al. 1995). Universities are increasingly considered to be an integral part of the city or regional network of public facilities that act as centres of attraction for individuals and enterprises, modifying the qualification structure of the labour market. Within this network universities stimulate job creation; encourage mobility; and have an intrinsic social and cultural effect of a kind which is more commonly described as 'quality of life' (OECD 1982). The city and regional setting of universities places them in a sphere that is often extremely dynamic, and offers a collective learning process that stimulates local creativity. An important element of this scenario consists of network concepts of development and the configurations of firms and service institutions aimed at achieving dynamic excellence (Nijkamp et al. 1994).

Batten's (1995) theoretical perspective of the 'network city', where co-operative mechanisms often resemble those of inter-firm networks, puts at its apex 'creative network cities' which place a higher priority on knowledge-based activities like research, education and the creative arts. In such cities, the 'urban player' is able to benefit from the synergies of interactive growth through reciprocity, knowledge

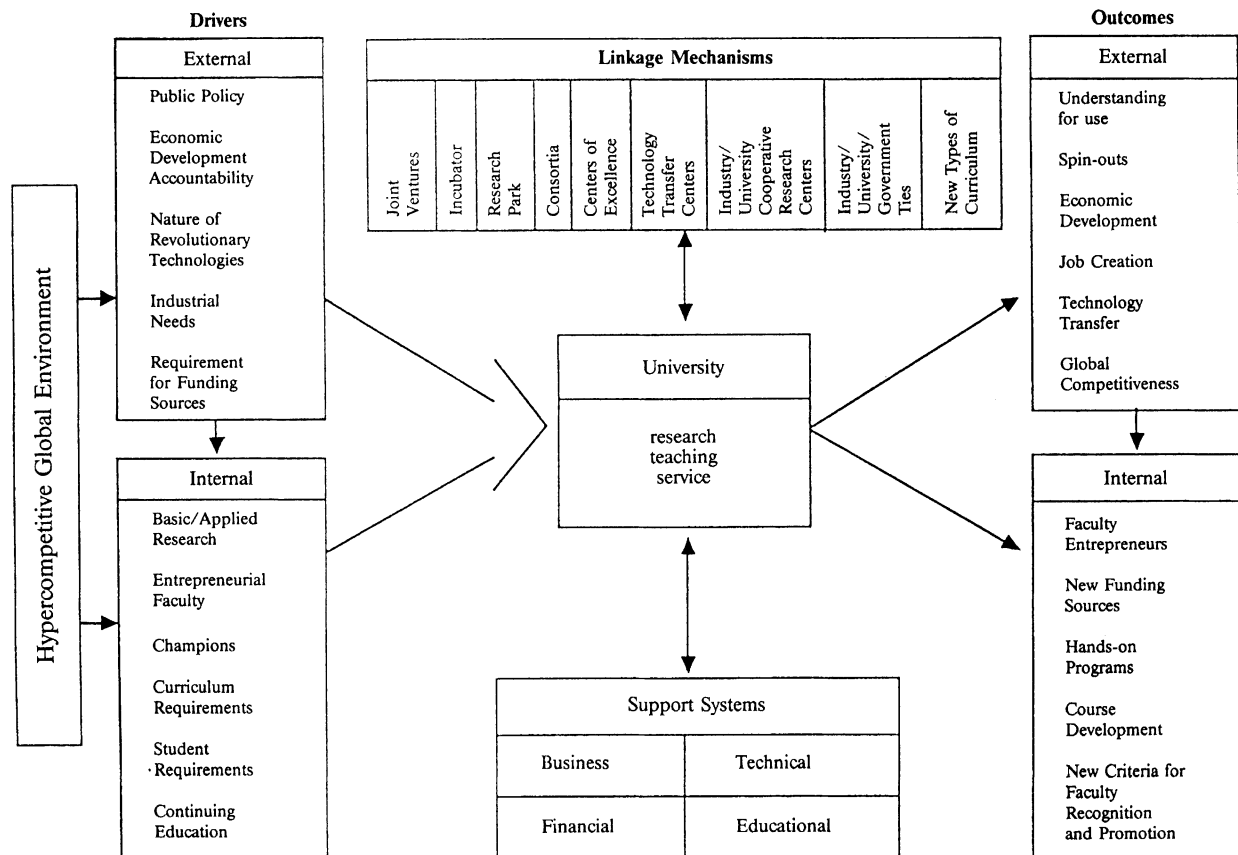
exchange and unexpected creativity. Batten points to the airport-university combination which he argues is one of the most synergistic factors currently contributing to faster and more prosperous urban growth in Sweden. Also, studies of urban regions in Europe indicate that those which have a stronger commitment to research-intensive activities and have access to modern communications, and international air transport, are expanding their employment and income base at a faster rate than other regions (Batten 1995). These successful regions offer economic development opportunities that are expressed in the development of employment, production and service linkages and linkages to local universities (Shachar and Felsenstein 1992). Production and service sector activities are increasingly knowledge-dependent and the organisation of firms reflects this transformation with firms connecting into regional knowledge networks. This changing locational configuration has meant that smaller regions or cities are often able to compete favourably with the large agglomerations due precisely to their networked nature. (Cooke 1996; Huggins 1996; Lambooy 1993).

Smilor et al. (1993) argue that in the United States, in particular, a new paradigm is emerging of the 'entrepreneurial university' which encompasses a more direct involvement in the commercialisation of research activities, and a more proactive approach to regional economic development. This paradigm emphasises that the environmental forces of a

hyper-competitive global environment are forcing a reassessment of external and internal forces which are resulting in linkage mechanisms and support systems that are altering the university's research, teaching and service missions (see Figure 1). According to Smilor et al. (1993) universities are now paying increasing attention to the value of more applied research, innovative and relevant teaching and service to the local, state and national public and private sectors. Such developments are usually facilitated through innovative linkages between the university and its external constituencies. The paradigm shift to a more entrepreneurial university appears to be a real one, not only in US universities but also the UK and other parts of Europe, particularly with regard to mechanisms for increasing technology transfer between universities and industry. These mechanisms include the introduction or expansion of university offices involved in licensing and patenting (seeking commercial applications for university research); small business development (providing technical or managerial assistance to entrepreneurs or small businesses); research and technology centres (operating or participating in facilities for the development of new technology); incubators (managing facilities in support of new

technology-based businesses); and investment/endowment offices (utilising the university's financial resources for equity in start-up businesses) (Dill 1995).

There is a dichotomy of the economic impact of universities between expenditure and knowledge impacts, the former being a result of the expenditures by the university, faculty and staff, students and visitors, which generate changes in regional income and employment. The knowledge impact refers to changes in the quality of production factors induced by the knowledge produced at universities, resulting from research and the accumulation of human capital plus effects related to the university's services to the community. The mechanisms underlying the knowledge impact of universities refers to the relationships between basic and applied research, and the subsequent diffusion of knowledge (Florax and Folmer 1992). Whilst econometric modelling approaches are useful in assessing expenditure impacts they are of less use in gauging knowledge impacts. For instance, there are numerous difficulties measuring quantitatively the extent to which technology-based firms rely on universities to provide R&D support, or the strength of university-industry technology transfer links (Robson et al. 1995).



Source: Smilor et al. (1993).

Figure 1. Entrepreneurial US university paradigm.

The expenditure impact can be calculated in terms of the direct and indirect jobs created and also the extra income within an economy that a university generates. Research by Durham University Business School suggests that the economic 'multiplier effect' of a university is greater than that of industry because of the structure of turnover, and the proportion of expenditure by staff and students likely to come directly to a locality. Some of the physical benefits of growth in universities come in the form of the development of new buildings, which in-fill and reclaim derelict industrial, residential or commercial areas, reshaping the built environment (Wright 1994). A university is often one of the biggest businesses in a city or region, with a number of different responsibilities to the local community (CVCP 1994). It delivers services to local citizens, as undergraduates, graduates or continuing education students, and to local employers. Also, as Schuller (1995) indicates, a university is a major employer, usually with an army of low-paid staff on cleaning and janitorial duties, and provides leisure and other facilities through its generally large property portfolio.

This paper assesses the local impact of universities through a case study of Cardiff University and its effects within the city of Cardiff and also the sub-regional economy of South East Wales; quantifying the expenditure impacts of the University through the use of an econometric model and evaluating the knowledge impacts via more qualitative methods. Such evaluations are increasingly becoming an important part of university policy making processes with regard to issues of accountability and the development of more socially responsible attitudes to the human and physical resources they are allocated; particularly the relationship between universities and the local community. In part this stems from the changing view of the role of education generally as government policy, particularly in the UK, has sought to encourage practical and vocational skills. One result of this has been that both universities and the 'outside world' have increasingly seen higher education as an economic resource (CVCP 1994).

### Local expenditure impact of universities

The methodologies used for assessing impact have generally become more sophisticated although most approaches are based on standard Keynesian multiplier theory with a university, like any other production activity, undertaking its business through the purchase of inputs which in turn produce outputs. The methodology used here is a development of models used in three previous university impact studies. It is a variant of a model used by Bleaney et al. (1992) in an impact study of Nottingham University, which was adopted in studies by Robson

et al. (1995) measuring the impact of universities in Greater Manchester, and also Armstrong et al.'s (1994) study of Lancaster University. These studies are based on the assumption that an injection of expenditure into a university leads to expenditure by that institution on staff salaries and goods and services, which together with spending by students coming into the local area raises output and hence income in the area. These (first-round) increases in income in the region lead to subsequent rounds of spending by those benefiting from the expenditure. It is this induced effect which is usually referred to as the Keynesian multiplier process, where expenditure by one individual is seen as representing income for someone else. Therefore, any increase in expenditure feeds its way through a number of sequential rounds with each round declining in size to reflect deductions from income in the form of taxation and social security payments, indirect taxes, and decisions between consumption and saving. There is also a leakage arising from that proportion of income spent on imports to the area (CVCP 1994).

The choice of a Keynesian multiplier approach enables Cardiff University to be valued in relation to its impact on income, expenditure, or employment. In this study two different measures of income will be used. Firstly, gross local output (GLO), which is the equivalent of what at a UK level would be called National Income or Gross Domestic Product (the terms 'income' and 'product' can be used interchangeably because of the way in which national income accounting is conducted). GLO measures the money value of all goods and services produced in the local economy. Since Cardiff University is part of the local economy and produces a product (educational services), it adds directly to gross output. It also stimulates production elsewhere in the local economy by buying other goods and services from local firms and through the local spending power of its staff and students (i.e. the local multiplier process). The second income measure produced is local disposable income (LDI), which is the remainder after taxes and other deductions (e.g. pension contributions and National Insurance).

The CVCP (1994) report on 'universities and communities' highlighted the need to concentrate on the production of the multiplicand (i.e. the initial exogenous change in income or expenditure in the local economy) which is seen as the sum of the following:

- gross expenditure by the University on staff living in the locality/region being considered (including employees pensions and National Insurance contributions);
- an estimate of spending in the locality by the staff of the University who live outside the locality;
- non-staff expenditure of the University which is spent in the locality;
- expenditure in the locality by students drawn into

or retained in the locality by the presence of the University;

- gross expenditure by the University Student Union in the locality.

As far as possible the Cardiff study incorporated the above coefficients into its analysis and sought to follow the CVCP (1994) guidelines relating to data collection and estimation. Before undertaking the study it was important to be precise about the local area upon which impact is being analysed. In this case it consists of the city of Cardiff at one level, and on a second level the three counties of South Glamorgan, Mid Glamorgan and Gwent, which constitute South East Wales. The study is for the financial year 1994–95 and throughout the study a conservative approach has been adopted, using lower case estimates and assumptions in calculating impact effects. The results of the study should therefore be interpreted as minimum estimates of the impact of the University.

Multiplier values derived in the study are comparable with those of other contemporary impact studies based on Keynesian multiplier theory. It is considered that such multipliers generate conservative estimates of the economic impact of Cardiff University on its region. A recent study by McNicoll (1995) into the impact of the Scottish higher education sector on the economy of Scotland generated considerably larger multipliers. However, in McNicoll's (1995) study multiplier values are derived from an input-output model and it is therefore difficult to draw conclusions about the accuracy of multipliers from direct comparison.

### Expenditure impact of Cardiff University

The analysis is confined to a single base year, 1994–95, and reflects the latest University accounting data. It is important to note that while the analysis is based on data for a single year, the full impact of any expenditure injection is likely to occur over a number of years. Separate estimates are calculated for gross local output (Y) and local disposable income (D). Table 1 sets out the main components of expenditure associated with the annual operation of the University in 1994–95.

In 1994–95 the University purchased goods and services to the value of £36,013,000 from more than 400 suppliers in the UK, Europe and the rest of the world. In order to assess the extent of purchasing in Cardiff, South East Wales and elsewhere, a sample survey representing some £9,310,210 or 25.9% of expenditure was conducted. A total of 1,657 invoices were examined in the survey to determine the value of the goods or services and the location of the supplier. Although some studies have adopted a different approach setting a lower cut-off point (for individual invoices) in order to avoid examining

**Table 1.** Direct Expenditure by Cardiff University 1994–95

	£ 000
<i>University staff salaries and wages</i>	
Academic and related staff	45,666
Non-academic staff	10,117
Total salaries and wages	55,783
<i>Non-wage expenditure</i>	
Residences, catering and conferences	5,284
Consumables and laboratory expenditure	6,960
Books and periodicals	1,267
Fellowships, scholarships and prizes	388
Heat, light, water and power	1,811
Repairs and general maintenance	1,308
Provision for long-term maintenance	1,450
Grants to university students' union	1,323
Research grants and contracts	4,904
Other services rendered	1,653
Cost of early retirements	813
Other provisions	2,563
Rents	30
Auditors' remuneration	28
Auditors' remuneration in respect of non-audit services	79
Other expenses	6,152
Total non-wage expenditure	36,013
Interest payable	9
Depreciation	10,010
Total expenditure by Cardiff University	101,815

Source: Financial Statements 1994–95.

many thousands of lower value purchases the Cardiff survey revealed that this approach may lead to inaccuracy. These findings support those of Armstrong et al. (1994) which suggests that universities make a very substantial number of purchases in the £1–500 range, many of which are placed with local businesses.

The survey revealed that approximately 31.9% of goods and services were purchased in Cardiff, 39.7% in South East Wales (including Cardiff), and 58.1% elsewhere. The survey also indicated that South East Wales, and particularly Cardiff, accounts for a large proportion of catering, foodstuffs, and building services whilst computer, scientific and technical equipment tended to be purchased from suppliers outside the region. Despite the generally lower value of goods and services purchased in South East Wales and Cardiff, in comparison with those purchased outside South East Wales, there was found to be a considerably large number of suppliers in the Cardiff area who were benefiting from University business.

In order to establish the economic impact of staff employment and spending in South East Wales and Cardiff, staff details on grade, post town and salary were extracted from personnel databases. The six categories of staff identified were: academic;

academic related (e.g. librarians, administrators); research, clerical; technicians and manual. Analysis revealed that 98.4% of all University staff reside within South East Wales. The academic and technician staff groups showed the greatest propensity to commute to and from work from areas outside Cardiff. Among academic staff, only 55% reside in Cardiff while a further 42% live in the rest of South East Wales. In addition, 3% of academic staff reside in areas outside South East Wales. The situation is similar for technicians with only 55% residing in Cardiff itself, while 44% reside within areas of South East Wales other than Cardiff. Research and manual staff have the highest propensity to live in Cardiff. Taking academic and academic related staff together (i.e. those with the highest earnings), 57.7% live in Cardiff and 97% live in South East Wales (including Cardiff).

In 1994–95 there were 13,935 students at the University whose expenditure made a significant contribution to the service sector in Cardiff and South East Wales. Of these some 11,035 students were undergraduates residing in Cardiff for a minimum of 30 weeks of the year, while 2,146 were full-time postgraduates who resided in Cardiff for a minimum of 40 weeks per year. In addition to local authority grants, a total of 5,060 students, or 57% of 8,847 students who were eligible, took up loans under the Governments Student Loans Scheme to supplement their grants during the 1994–95 academic year. The total value of these loans was £5,201,588 with the average amount per student approximately £1,028 per annum. A significant proportion of this extra income will represent expenditure benefiting the South East Wales economy.

In order to assess student expenditure in Cardiff and South Wales a questionnaire survey of 500 students was undertaken. The survey yielded 258 usable responses (a more than acceptable response rate of 51.6%). The survey showed that the average total weekly expenditure of students during term time was £81.17 per student and that only 9.6% of this took place outside of Cardiff or South East Wales. The survey also found that among students living in private accommodation, 14.4% of their spending took place within the University. For those living in University halls and other University owned residences 59.9% of their spending took place within the University. The term-time residential location of students was established with reference to the students database record system. Undergraduate students were strongly concentrated within the Cardiff district, in particular the central area of the city.

The model is basically an extension of the one introduced by Bleaney et al. (1992), which was further refined by both Armstrong et al. (1994) and Robson et al. (1995). Armstrong et al. (1994) introduced some particular refinements which have been adapted for use in the Cardiff case.

### *Initial Injection (Expenditure Base)*

The model involves a number of stages. At the outset this simply involves estimating the size of the initial monetary injection into the local economy.

This expenditure base is given as:

$$E = L + G \quad (1)$$

where  $E$  = expenditure base,  $L$  = labour services bought by the University,  $G$  = goods and services bought from outside by the University.  $E$  excludes pensions (though not employees pensions contributions.), depreciation, self-financing operations (e.g. residences, catering and farms, where the effect will be seen through student expenditure).

### *First-round Gross Local Output (GLO)*

$$Y_1 = L + A + hG \text{ measured at market prices} \quad (2)$$

where  $Y_1$  = first-round GLO,  $h$  = the proportion of  $G$  generated locally,  $A$  = the additional labour incomes of University employees.

### *First-round Local Disposable Income*

This is given as:

$$D_1 = (1 - t)(Y_1 - hiG) \quad (3)$$

where  $D_1$  = first round impact on disposable incomes of local residents,  $i$  = indirect tax rate (e.g. VAT),  $t$  = a direct tax rate (which allows for reduced unemployment benefits as well as income taxation).

### *Second-round Gross Local Output*

This is given as:

$$Y_2 = vZ + wcD_1 \quad (4)$$

where  $Z$  = total spending by students,  $v$  = proportion of student expenditures made on local produced goods and services,  $w$  = proportion of staff spending on locally produced goods and services,  $c$  = proportion of additional staff income consumed (the remainder being saved) – the marginal propensity to consume.

### *Second-round Disposable Income*

This is given as:

$$D_2 = (1 - t)(1 - i)Y_2 \quad (5)$$

### *The Full Multiplier for GLO (all rounds)*

This is given as:

$$\begin{aligned} Y_f/Y_1 &= (Y_1 + Y_2 + Y_3 + \dots)/Y_1 \\ &= 1 + (1 + wc(1 - t)(1 - i) + \dots)Y_2/Y_1 \\ &= 1 + Y_2/[1 - wc(1 - t)(1 - i)]Y_1 \end{aligned} \quad (6)$$

$Y_f$  = the final GLO (after all rounds of the multiplier process).

*The Full Multiplier for Local Disposable Income*

This is given as:

$$\begin{aligned} D_f/D_1 &= (D_1 + D_2 + D_3 + \dots)/D_1 \\ &= 1 + (1-t)(1-i)(1+wc(1-t)(1-i) + \dots)Y_2/D_1 \\ &= 1 + (1-t)(1-i)Y_2/[1-wc(1-t)(1-i)]D_1 \end{aligned} \quad (7)$$

$D_f$  = the final disposable income (after all rounds in the multiplier process).

*Application of the Model*

The application of the model consists of using the multiplicand coefficients and variables generated from other sources as listed. All data refers to £000s.

*Initial Injection*

$$\begin{aligned} E &= L + G \\ L &= \text{total labour costs} - \text{pensions} \\ &= 55,783 - 5,994 = 49,789 \\ G &= \text{expenditure on goods and services} \\ &\quad - \text{depreciation} \\ &= 36,013 \\ E &= 49,789 + 36,013 = \underline{85,802} \end{aligned}$$

*(1a) First-round gross local output (GLO)*

$$Y_1 = L + A + hG \text{ measured at market prices}$$

$h$  = the proportion of  $G$  generated locally = 0.319 for Cardiff and 0.397 for South East Wales.  $A$  = the additional labour incomes of University employees, a coefficient of 0.075 has been used for estimating a proportion of academic and academic related salaries (the mean of the coefficients used by Bleaney et al. (1992) and Armstrong et al. (1994)).

$$\begin{aligned} Y_1 &= (49,789) + (0.075) (39,898) \\ &\quad + (0.319) (36,013) \\ &= \underline{64,269 \text{ for Cardiff}} \\ Y_1 &= (49,789) + (0.075) (39,898) \\ &\quad + (0.397) (36,013) \\ &= \underline{67,079 \text{ for SE Wales}} \end{aligned}$$

*(1b) First-round Local Disposable Income*

$$D_1 = (1-t)(Y_1 - hiG)$$

$t$  = a direct tax rate (which allows for reduced unemployment benefits as well as income taxation) = total takes-offs as a proportion of total related expenditure =  $(22,097)/(52,457) = 0.42$  (taken from University internal financial data).  $i$  = indirect tax rate = 0.14 (taken from UK national accounts).

Therefore:

$$\begin{aligned} D_1 &= (1-0.42) ((64,269 \\ &\quad - (0.319) (0.14) (36,013)) \\ &= \underline{36,343 \text{ for Cardiff}} \\ D_1 &= (1-0.42) ((67,079 \\ &\quad - (0.397) (0.14) (36,013)) \\ &= \underline{37,745 \text{ for SE Wales}} \end{aligned}$$

*(2a) Second-round Gross Local Output*

$$Y_2 = vZ + wcD_1$$

$Z$  = total spending by students. Weekly student spending = £81.17 per student, also there are 11,035 undergraduates (in residence for 30 weeks) 2,146 full-time postgraduates (in residence for approximately 40 weeks). For the purposes of this study part-time postgraduates are excluded as it assumed that most are from the locality and would already be in residence. Therefore  $Z = [(81.17) (30) (11,035)] + [(81.17) (40) (2,146)] = 33,839$  (approx.).

$v$  = proportion of student expenditures on goods and services in the locality. Of total student expenditure only 9.6% took place outside of Cardiff or South East Wales, and in general it is safe to assume that  $v$  for both Cardiff and South East Wales will be the same as almost all student spending in the region takes place within Cardiff. As well as spending outside the region, spending within the University must also be deducted in order to avoid double counting. For 60% of students (those living in private accommodation) this equalled 14.4%. For the 40% of students living in University-owned accommodation this rose to 59.9%. Hence a weighted average of the two =  $[(60) (14.4) + (40) (59.9)]/(100) = 32.6\%$ . Therefore  $v = 1 - \text{spending outside the locality} - \text{spending within the University} = 1 - 0.096 - 0.326 = 0.58$ .

$w$  = the proportion of staff spending on locally produced goods and services. Values for these have been derived using retention factors generated by Robson et al. (1995), who estimate a mean retention rate of 0.24 for the city and 0.32 for the region. However we estimate that approximately double (66.0% compared to 32.7%) the amount of staff live in Cardiff (who are employed by Cardiff University, compared with the staff of Manchester's universities and who live in the city of Manchester). On the other hand while almost 100% of the staff of Manchester's universities live in the North West region, this falls to 98.4% for South East Wales. It therefore appears that there should be a slight convergence of the retention rates for the Cardiff case. Hence for the Cardiff locality we estimate  $w = (0.24) + \{[(0.327)/(0.660)] (0.32 - 0.24)\} = 0.28$ . For South East Wales  $w = (0.984) (0.32) = 0.31$  (approx.).

$c$  = the marginal propensity to consume = from the Family Expenditure Survey this is estimated to be 0.90.

Therefore:

$$\begin{aligned} Y_2 &= ((0.58) (33,839)) + ((0.28) (0.9) (36,343)) \\ &= \underline{28,785 \text{ for Cardiff}} \\ Y_2 &= ((0.58) (33,839)) + ((0.31) (0.9) (37,745)) \\ &= \underline{30,157 \text{ for SE Wales}} \end{aligned}$$

*(2b) Second-round Disposable Income*

$$D_2 = (1-t)(1-i)Y_2$$

$$D_2 = (1 - 0.42) (1 - 0.14) (28,785) \\ = \underline{14,358 \text{ for Cardiff}}$$

$$D_2 = (1 - 0.42) (1 - 0.14) (30,157) \\ = \underline{15,042 \text{ for SE Wales}}$$

(3a) Third-round Gross Local Output

$$Y_3 = wcD_2 \\ Y_3 = (0.28) (0.90) (14,358) \\ = \underline{3,618 \text{ for Cardiff}}$$

$$Y_3 = (0.31) (0.90) (15,042) \\ = \underline{4,197 \text{ for SE Wales}}$$

(3b) Third-round Disposable Income

$$D_3 = (1 - t) (1 - i)Y_3 \\ D_3 = (1 - 0.42) (1 - 0.14) (3,618) \\ = \underline{1,805 \text{ for Cardiff}}$$

$$D_3 = (1 - 0.42) (1 - 0.14) (4,197) \\ = \underline{2,093 \text{ for SE Wales}}$$

(4a) Fourth-round Gross Local Output

$$Y_4 = wcD_3 \\ Y_4 = (0.28) (0.9) (1,805) = \underline{455 \text{ for Cardiff}} \\ Y_4 = (0.31) (0.9) (2,093) = \underline{584 \text{ for SE Wales}}$$

(4b) Fourth-round Disposable Income

$$D_4 = (1 - t) (1 - i)Y_4 \\ D_4 = (1 - 0.42) (1 - 0.14) (455) \\ = \underline{227 \text{ for Cardiff}}$$

$$D_4 = (1 - 0.42) (1 - 0.14) (584) \\ = \underline{291 \text{ for SE Wales}}$$

(5a) Fifth-round Gross Local Output

$$Y_5 = wcD_4 \\ Y_5 = (0.28) (0.9) (227) = \underline{57 \text{ for Cardiff}} \\ Y_5 = (0.31) (0.9) (291) = \underline{82 \text{ for SE Wales}}$$

(5b) Fifth-round Disposable Income

$$D_5 = (1 - t) (1 - i)Y_5 \\ D_5 = (1 - 0.42) (1 - 0.14) (57) \\ = \underline{28 \text{ for Cardiff}}$$

$$D_5 = (1 - 0.42) (1 - 0.14) (82) \\ = \underline{41 \text{ for SE Wales}}$$

(6a) Sixth-round Gross Local Output

$$Y_6 = wcD_5 \\ Y_6 = (0.28) (0.9) (28) = \underline{7 \text{ for Cardiff}} \\ Y_6 = (0.31) (0.9) (41) = \underline{11 \text{ for SE Wales}}$$

(6b) Sixth-round Disposable Income

$$D_6 = (1 - t) (1 - i)Y_6 \\ D_6 = (1 - 0.42) (1 - 0.14) (7) = \underline{3 \text{ for Cardiff}} \\ D_6 = (1 - 0.42) (1 - 0.14) (11) = \underline{5 \text{ for SE Wales}}$$

(7a) Seventh-round Gross Local Output

$$Y_7 = wcD_6 \\ Y_7 = (0.28) (0.9) (3) = \underline{1 \text{ (approx.) for Cardiff}} \\ Y_7 = (0.31) (0.9) (5) = \underline{1 \text{ (approx.) for SE Wales}}$$

(7b) Seventh-round Disposable Income

$$D_7 = (1 - t)(1 - i)Y_7 \\ D_7 = \underline{0 \text{ for Cardiff}} \\ D_7 = \underline{0 \text{ for SE Wales}}$$

Total Gross Local Output 1994–95

Total Gross Local Output (GLO) is to equal to the sum of the outputs for each round of spending, and is shown by Table 2.

**Table 2.** Estimated gross local output for Cardiff and South East Wales (£ 000)

	Cardiff	South East Wales
Round 1	64,269	67,079
Round 2	28,785	30,157
Round 3	3,618	4,197
Round 4	455	584
Round 5	57	82
Round 6	7	11
Round 7	1	1
Total	97,192	102,111

Therefore Cardiff University has the effect of generating a gross local output in Cardiff of £97.19 million and £102.11 million in South East Wales.

Total Local Disposable Income 1994–95

Total Local Disposable Income (LDI) is to equal to the sum of the incomes for each round of spending, and is shown by Table 3.

**Table 3.** Estimated local disposable income for Cardiff and South East Wales (£ 000)

	Cardiff	South East Wales
Round 1	36,343	37,745
Round 2	14,358	15,052
Round 3	1,805	2,093
Round 4	227	291
Round 5	28	41
Round 6	3	5
Round 7	0	0
Total	52,764	55,227

Therefore Cardiff University has the effect of generating local disposable income in Cardiff of £52.76 million and £55.23 million in South East Wales.

**Full Multiplier for GLO**

This is given as:

$$\begin{aligned} Y_f/Y_1 &= 1 + Y_2/[1 - wc(1 - t)(1 - i)]Y_1 \\ &= 1 + 28,785/[1 - (0.28)(0.9)(1 - 0.42) \\ &\quad (1 - 0.14)] 64,269 = \underline{1.51 \text{ for Cardiff}} \\ &= 1 + 30,157/[1 - (0.31)(0.9)(1 - 0.42) \\ &\quad (1 - 0.14)] 67,079 = \underline{1.52 \text{ for SE Wales}} \end{aligned}$$

where all terms are as previously defined, and  $Y_f$  = the final GLO (after all rounds of the multiplier process).

**Full Multiplier for LDI**

This is given as:

$$\begin{aligned} D_f/D_1 &= \frac{1 + (1 - t)(1 - i)Y_2}{[1 - wc(1 - t)(1 - i)]D_1} \\ &= 1 + (1 - 0.42)(1 - 0.14)(28,785)/[1 - (0.28) \\ &\quad (0.90)(1 - 0.42)(1 - 0.14)] 36,343 \\ &= \underline{1.45 \text{ for Cardiff}} \\ &= 1 + (1 - 0.42)(1 - 0.14)(30,157)/[1 - (0.31) \\ &\quad (0.90)(1 - 0.42)(1 - 0.14)] 37,745 \\ &= \underline{1.46 \text{ for SE Wales}} \end{aligned}$$

Table 4 summarises the main financial effects of the operation of Cardiff University with regard to Cardiff and South East Wales.

**Table 4.** The Effect of the Operation of Cardiff University on the City of Cardiff and South East Wales (£ 000)

	Cardiff	South East Wales
Expenditure base ( $E$ )	85,802	85,802
First round GLO ( $Y_1$ )	64,269	67,079
First round LDI ( $D_1$ )	36,343	37,745
Second round GLO ( $Y_2$ )	28,785	30,157
Second round LDI ( $D_2$ )	14,358	15,042
Final GLO ( $Y_f$ )	97,192	102,111
Final LDI ( $D_f$ )	52,764	55,227
Expenditure base multiplier (GLO) ( $Y_f/E$ )	1.13 (factor)	1.19 (factor)
Expenditure base multiplier (LDI) ( $D_f/E$ )	0.61	0.64

The local expenditure impact analysis can be extended in a manner which allows the generation of employment figures, which although fairly robust must be regarded as less accurate than the income effects on which they are based. The first stage involves the estimation of direct employment ( $E_d$ ) associated with the University. For Cardiff University in 1994–95 this is estimated as: 2,665 University employees plus 82 Students Union staff. i.e.  $E_d = 2,747$ . As Table 5 indicates this puts the University amongst the top ten employers in Wales.

**Table 5.** Largest Employers in Wales

1. South Wales Electricity	6,658
2. Welsh Water Group	6,600
3. Tesco	5,045
4. Asda	4,500
5. Sony	3,500
6. British Gas	3,000
7. Cardiff University	2,747
8. Ford	2,500
9. Lloyds Bank	2,500
10. Barclays Bank Cymru	2,400

Source: Adapted from Western Mail, 11 October 1995.

In addition to the direct employment associated with the University, the income multiplier effects generate additional jobs elsewhere in Cardiff and South East Wales. Robson et al. (1995) again make use of retention factors to produce employment multipliers of 1.158 for the city and 1.383 for the region. Although these multipliers cannot be directly applied to the Cardiff example it is possible to make adjustments through calculating differences in the relevant consumption profiles of Cardiff-Manchester and South East Wales-North West England. This is best estimated via a calibration of the multipliers to take account of local consumption of goods and services by Cardiff University using the following:

$$\begin{aligned} \text{Cardiff Employment Multiplier} \\ &= C_m = M_m + [(C_1/M_1)(M_m)]/100 \end{aligned}$$

$$\begin{aligned} \text{SE Wales Employment Multiplier} \\ &= S_m = C_m + \{[(S_1 - C_1)/C_1](C_m - 1)\} \end{aligned}$$

Where:

$$\text{Manchester local spend factor} = M_1 = 0.056$$

$$\text{Cardiff local spend factor} = C_1 = 0.319$$

$$\text{South East Wales local spend factor} = S_1 = 0.397$$

$$\text{Manchester Employment Multiplier} = M_m = 1.158$$

Therefore:

$$C_m = 1.158 + [0.319/0.056](1.158)/100 = 1.22$$

$$\begin{aligned} S_m &= 1.22 + \{[(0.397 - 0.319)/0.319](1.22 - 1) \\ &= 1.24 \end{aligned}$$

To determine total employment (direct, indirect, induced) is simply a matter of applying the multiplier to total direct employment.

$$\begin{aligned} \text{Therefore total University related employment in} \\ \text{Cardiff} &= (E_d)(C_m) = (2,747)(1.22) = \underline{3,351} \end{aligned}$$

$$\begin{aligned} \text{Total University related employment in South East} \\ \text{Wales} &= (E_d)(S_m) = (2,747)(1.24) = \underline{3,406} \end{aligned}$$

Therefore, as well as sustaining 2,747 direct employees, Cardiff University is responsible for creating and sustaining some 604 additional jobs in Cardiff and a further 55 in the rest of South East Wales. This suggests that Cardiff University accounts for approximately 2.1% of Cardiff's total local labour market.



The income multiplier values of 1.46 – 1.52 generated by the methodology are relatively high compared to the overall variety of multipliers produced by other higher education impact studies undertaken in the UK. Table 6 highlights the varying range of multipliers from the different methodological interpretations applied. However, a further analysis of the figures indicate that the Cardiff multipliers are of a relatively similar value to those produced for establishments within urban areas, e.g. Yorkshire & Humberside (Leeds, Bradford and Hull), Liverpool, Lanchester (Coventry) and Strathclyde (Glasgow).

**Table 6.** Multiplier values used in other UK higher education impact studies

Study	Multiplier value
Bolton	3.00
Bristol Polytechnic	1.15
Lancaster	1.15–1.25
Lanchester Polytechnic	1.50
Liverpool	1.45
Manchester	1.17–1.25
Nottingham University	1.059
South Shields	1.30
Southampton University	1.197
Stirling	1.24–1.54
Strathclyde University	1.66–2.15
University of East Anglia	1.20
Wolverhampton Polytechnic	1.027–1.103
Yorkshire & Humberside	1.30

Source: CVCP (1994).

### Knowledge impact of universities

Knowledge, and access to knowledge, are becoming one of the most important success factors in urban and regional development policies. Consequently, the concept of a knowledge network has increasingly come to the fore as an instrument in development strategies. These knowledge networks generate, collect and transfer scientific information through a multitude of channels. The presence of a knowledge network is increasingly regarded as a primary locational factor as it allows entrepreneurs to benefit from the availability of new information, while at the same time linkage to a knowledge and information node provides access to larger national and international networks (Nijkamp et al., 1994). Universities, along with other research institutes, are increasingly represented as an important resource and node in knowledge networks that can be tapped in order to promote growth.

The urban and industrial make-up of a locality is a crucial factor in shaping university-industry links, particularly the strength of the high-tech and start-up firms sector, which are known to be much more

dependent on research and knowledge transfer than mature-sector firms. Also, while large firms are often self-supporting with regard to R&D, small (technology-based) firms are often highly dependent on external sources of research. Therefore, as the diffusion of knowledge proliferates, it is usually high-tech and starting firms that tend to cluster around universities (Florax and Folmer 1992). Access to a high quality knowledge-base offers opportunities for creative and new decisions in the strategies of these firms. These opportunities often come in the form of access to what are called 'learning principles', i.e. learning-by-examining, learning-by-doing and learning-by-using, which are becoming a critical competitive tool (Nijkamp et al. 1994). Those universities with long-standing industrial ties have obviously progressed further down the path towards developing a range of formal and informal technology transfer related services and facilities. They will usually have better evolved systems for disseminating information with a marketing strategy directed inwards at their own members and outwards at potential firm sponsors. According to Bower (1992), Cornell, MIT and Stanford in the US and UMIST, Imperial College and Edinburgh in the UK are among the institutions which fall into this category. Others institutions have tended to borrow the practices of these pioneer institutions. The recent trend has been to adopt the 'science park model' of technology transfer which in the UK, in particular, has been influenced by the keenness of government to foster universities as incubators of growth.

Universities were among the first founders of science parks seeking to develop stronger links between industry and higher education institutes. The vision was one of a location with a critical mass of scientifically sophisticated individuals generating new technologies and innovative ideas often produced in universities and channelled and diffused by new commercial ventures located in-purpose-built units in close proximity to the university (Westhead and Storey 1995). There has been much debate as to whether or not science parks have contributed significantly to local economic development. The science park movement is founded on the belief that the process of developing innovative technologies and products places special requirements on inputs that are often not available within an individual company's own establishment (Bower 1992). However, although usually presented as a key element in technology transfer policy, science parks are increasingly accused of being essentially real estate developments, where beyond a small number of special cases it is the quality of the buildings and the environment rather than a university's research inputs that sells the space (CVCP 1994).

A number of studies exist which indicate that for investments in buildings, close proximity to universities is not an important location factor. These

studies show very few benefits arising from the agglomeration of industry close to university, and a lack of empirical evidence of meaningful linkages between university and technology-based companies in their vicinity (Florax and Folmer 1992; Shachar and Felsenstein 1992). In addition, evidence suggests that few science parks act as a growth pole in the urban context or nor a catalyst for high technology development (Shachar and Felsenstein 1992). However, although the direct economic benefits have not always been impressive the generative effects of these knowledge centres are seen as important cornerstones of urban and regional strategies (Nijkamp et al. 1994). Robson et al. (1995) argue that the sheer number of university-owned science parks demonstrates that they are certainly of some benefit to the institutions themselves. A recent study by Westhead and Storey (1995) to ascertain 'added-value' of science park location in the UK, measured the formal and informal links developed with local higher education institutions by independent science park firms, compared with the links made by a comparable group of independent high technology firms not located on a park. The survey revealed that a link with a local higher education institute is correlated with firm survival. However, the survey also revealed that the vast majority of links developed with local institutes are generally informal ones.

From this empirical evidence Westhead and Storey (1995) suggest that the role of industrial liaison officers within higher education institutes needs to be strengthened, particularly their relationships with science park managers which enable the further establishment of systems which actively link individuals in firms with individuals in appropriate university departments. Despite the perception of science parks as property-based initiatives that just happen to be located adjacent to a university (which itself is often seen by tenant firms as an overstuffed bureaucracy funding from rental payments), Westhead and Storey (1995) suggest that a happy medium could be reached through a central unit managing the property aspects of universities and acting as an effective conduit to the knowledge resources of institutes. This centrality of access to some universities is an issue raised by MacNamara et al. (1995) who argue that many universities lack a recognisable 'front door' for enquiries, with SMEs, potential inward investors and intermediaries often finding it difficult to identify the most appropriate source of help. Therefore the introduction of a co-ordinated gateway for both local and international enquiries needs to be coupled with increasing knowledge management by universities.

### **Cardiff University: a knowledge node of regional industrial clusters**

The transformation of Welsh industry towards a higher-skill, high GDP and low unit labour costs, engineering-led manufacturing economy has been associated with the development of industrial complexes in automotive and electronics engineering, which display most of the key characteristics of the ideal innovative regional cluster. Cardiff University has played a part in the development of these clusters acting as a local host for joint research and development programmes with automotive companies such as Lucas and Rover in which industry-relevant R&D is conducted for clients inside and beyond the region. The automotive sector R&D undertaken by the University has mainly concentrated on systems engineering, new materials and robotics. In addition the University, together with other Welsh higher education institutes, has conducted research for electronics companies in IT, semiconductors and magnetics. Overall, universities in Wales conduct some £6 million of industrial research per year, of which £2 million is basic research. To some extent this figure has been boosted by the fact that there are scarcely any free-standing public research institutes and relatively few basic research consultancies in Wales.

The emergence of these industrial clusters in Wales suggests a more systematic co-ordination to regional economic development, driven by the hierarchical relationship between globally successful inward investors and local supplier companies, but animated in a relatively non-hierarchic, networked manner by a variety of local bodies, including Cardiff University. Researchers at the University have increasingly been drawn into new 'heterarchic' relationships that have begun to develop. Initially, this has often been through day-schools or seminars at which academic expertise has been shared and refined in discussion with company managers. Later, small research projects have been commissioned with a focus on relaying knowledge about global best-practice on such new management tools as 'lean production', 'business process re-engineering' and 'value analysis' back to both large foreign and smaller indigenous firms in the region. Technical research in the engineering departments of the University has, in any case, been partly industry-funded for many years but now there is an incentive to apply it in the context of the emergent engineering economy.

Despite the commonly held view that industry regard the commercial awareness of academics with a degree of scepticism, a survey by Cooke, Davies and Huggins (1995) of 200 technology-based firms in South Wales illustrated that over 30% of companies in the locality use the technical services of higher education or further education colleges.

Furthermore, Cardiff University was cited almost twice as often as any other institution. The survey also highlighted that the significant majority of links with universities and higher education institutes are at a local or regional level, rather than national or international. This is undoubtedly due to a number of factors, one of which is that a lack of resources among many SMEs in the region means they are often over-dependent on their own contacts and knowledge which are usually highly localised. This ultimately means they are not aware of the wider range of R&D services available or any complementary R&D that has been undertaken elsewhere. Also, respondents felt that more importance needed to be attached to selecting the right partner to assist in the development of the innovation, with the general view that some form of intermediary is required to effect such partnerships, i.e. individual firms need not be solely left to themselves organise collaborative ventures. This issue, mentioned earlier by MacNamara et al. (1995), has resulted in many South Wales firms having little knowledge of whether potential partners had the degree of understanding and awareness which they were looking for. Problems were also encountered regarding the amount of time and resources needed to identify and secure a potential partner, particularly in the SME sector.

Dissemination of the results of the Cooke, Davies and Huggins (1995) survey, and the subsequent raising of awareness of some of the collaborative problems faced by firms, has led to the setting-up of the Cardiff University Innovation Network (CUIN), which is an attempt by the University to not only capitalise on this success, but also to promote networking concepts within the locality. The CUIN was launched in March 1996 to focus on all aspects of innovation, i.e. turning creative ideas into successful commercial products. The Network seeks to incorporate the best practice networking activities of some of the larger, often foreign-owned firms within the locality which deliberately build internal and external networks. Therefore, the Network will act as a facilitator and encourager of networking between companies, and between companies and the University.

The Network, the first of its kind to be introduced in Wales, will provide support for industrial innovation and will mean that the University as a whole will be able to more effectively contribute to wealth creation. As one of its long-term goals the CUIN is attempting to build links with one of the largest science parks in Wales, that of Imperial Park near Newport. However, there has been some criticism that the University has failed to forge a good relationship with a science park/technology centre situated adjacent to its own main 'campus'. The Cardiff Business & Technology Centre (CBTC) was created in 1987 with the purpose of providing

business units on land owned by Cardiff University, that would be available for use by newly created companies and small scale businesses which fulfilled a set of general objectives. These objectives consisted of helping:

- new innovative firms to establish and grow;
- existing SMEs to modernise and diversify;
- to promote technology transfer.

Companies particularly targeted to set-up in the Centre were specialist software companies, computer and communication companies, and medical companies involved in R&D. Another prime target was the University projects in various departments which could be spun out as small enterprises. In recent years there had been the addition of companies involved in the food marketing sector and basic computer skills training for members of the public, which has diffused the 'technology image' of the Centre.

A recent survey, (Griffiths and Hampson 1995), of the Centre's tenants revealed that closeness to the University was only relatively important to 37.5% of the sample. The survey also revealed that although networking activity within the Centre was virtually non-existent, 63% of companies gave contracts to University departments to perform work for them, or to use the University's facilities. These companies did place a particular value on their relationships with the University, especially the 37.5% of companies which originally were spin-outs. Griffiths and Hampson (1995) conclude their survey by stating that CBTC does not appear to have fulfilled one of its original objectives very well, particularly the encouragement of enterprises from higher education institutions. Although part of this problem may be attributed to the University failing to encourage worthwhile links with the Centre, the majority of the blame must lie with the Centre's management team who have failed to bring in 'value-added' tenants that would thrive on the environmental synergies that such a centre is able to create. This confirms the view that although such centres and parks have a desirability in terms of the quality of buildings and surroundings, there is an apathy from management of centres towards acting as intermediaries for interaction between firms and universities.

## Conclusions

This study, using a previously developed and refined model, has shown that it is possible to estimate fairly accurately the economic impact of Cardiff University on its locality and sub-region. This analysis suggests that in the 1994–1995 period the University had the effect of creating a total local income of £97.19 million in Cardiff and £102.11 million in South East Wales as a whole. When taxes, pension contributions, national insurance, etc. are taken into consideration the remainder amounts to a local disposable income

of £52.76 million in Cardiff and £55.23 million in South East Wales. The modelling exercise also suggests that as well as supporting 2,747 direct employees, its consumption patterns generate a further 604 indirect jobs in Cardiff and 55 in the rest of South East Wales. As well as expenditure effects account has also been taken of the knowledge role of the University in enhancing the 'learning capacity' of the locality. Cardiff University is attempting to make the most of opportunities with regard to its industrial departments and the links that can be (and are being) made with firms in the locality, particularly through collaboration with firms in the automotive and electronics sectors who are gradually upgrading the technical nature of operations. The introduction of the innovation network will increase the creative force engendered through university-industry links. The network will create a gateway or 'technoport' for knowledge acquisition and dissemination both locally and globally.

In the US there is much talk of reinventing universities but the Cardiff approach of a gradual evolution would seem to be quite successful, although it obviously has its problems, such as the technology park. This considered approach may offer the University more flexibility to adapt to a climate of economic development which is strongly based on the acquisition, analysis and transmission of information and on its application. In future, the University may even be forced to share, or even give up a part of its role as a repository of information and ideas (Hague 1991). The knowledge society will have a huge impact on working life and much of that impact will fall on the universities. Universities will increasingly need to adopt a more outgoing, market-led commercial attitude, plugging into and supporting the development of the local economy. Also, the large number of university impact studies being conducted is an indication of the increasing pressure on universities to show their 'worth' to local communities. However this accountability, i.e. the fact that public and the government have decided that universities are too important to be allowed to exist in ivory-towered isolation, should be seen as a two-way street (McInnis 1995). Communities should address what they see to be the benefits of the knowledge 'dispersal' of universities. Also, one should not forget the cultural and non-industrial nature of much academic research. Academics at Cardiff University, for instance, have for many years been involved in projects designed to upgrade and regenerate the local economy. These researchers often bring in certain local tacit knowledge which could not be obtained through consultants from elsewhere.

Finally, it is clear that universities are increasingly attempting to be recognised as significant 'stakeholders' in their own right within their localities (Robson et al. 1995). However, it is worth remembering Barzun's (1968) postulation that the number

of claims on a university is unlimited, and those that threaten fragmentation must be resisted. Therefore, university authorities must retain a balance between the change to market competition and their role as places of special competence and knowledge (OECD 1982; McInnis 1995).

## References

- Armstrong, H.; Darrall, J.; Grove-White, R.: Building Lancaster's future: the economic and environmental impacts of Lancaster University Expansion to 2001. Department of Economics and the Centre for the Study of Environmental Change, Lancaster University, 1994.
- Barzun, J.: *The American University: how it runs, where it is going*. Harper and Row, New York 1968.
- Batten, D.: Network cities: creative urban agglomerations for the 21st Century. *Urban Studies* 32(2), 313-327 (1995).
- Bleaney, M.; Binks, M.; Greenaway, D.; Reed, G.; Whyne, D.: What does a University add to its local economy?. *Applied Economics* 24, 305-311 (1992).
- Bower, D.: *Company and campus partnership: supporting technology transfer*. Routledge, London 1992.
- Chrisman, J.; Hynes, T.; Fraser, S.: Faculty entrepreneurship and economic-development: the case of the University-of-Calgary. *Journal Of Business Venturing* 10(4), 267-281 (1995).
- Cooke, P.: Reinventing the region: firms, clusters and networks in economic development. In: Daniels, P.; Lever, W. (eds.), *The Global Economy in Transition*. Longman, London 1996.
- Cooke, P.; Davies, S.; Huggins, R.: The South Wales technopole: customer survey and design of the network. Report to EU-DG13-SPRINT, CASS-UWCC, Cardiff 1995.
- CSO: Family spending: a report on the 1992 Family Expenditure Survey. HMSO, London 1993.
- CSO: United Kingdom National Accounts 'Blue Book'. HMSO, London 1994.
- CVCP: *Universities and Communities*, London, Committee of Vice-Chancellors and Principals of the Universities of the United Kingdom, 1994.
- Dill, D.: University-industry entrepreneurship: the organization and management of American-University Technology. *Higher Education* 29(4), 369-384 (1995).
- Florax, R.; Folmer, H.: Knowledge impacts of universities on industry: an aggregate simultaneous investment model. *Journal of Regional Science* 32(4), 437-466 (1992).
- Griffiths, C.; Hampson, D.: A tale of two science parks, 3rd Annual International Conference on 'High Technology Small Firms'. Manchester Business School, September, 1995.
- Hague, D.: *Beyond universities: a new republic of the intellect*. Institute of Economic Affairs, London 1991.
- Huggins, R.: Competitiveness and the global region. In: Simmie J. (ed.), *Innovation, Networks and Learning Regions*. Jessica Kingsley, London 1997.
- Lambooy, J.: The European city: from Carrefour to Organisational Nexus. *Tijdschrift voor Economische en Sociale Geographie* 84(4), 258-268 (1993).
- MacNamara, O.; Hamnett, A.; Vaughan, R.: The Knowledge House, 3rd Annual International Conference on 'High Technology Small Firms', Manchester Business School, September, 1995.
- McInnis, C.: Less control and more vocationalism: the Australian and New Zealand experience. In: Schuller T. (ed.), *The Changing University?*. The Society for Research into Higher Education, Open University Press, Buckingham 1995.
- McNicol, I.: The Impact of the Scottish Higher Education Sector on the Economy of Scotland, Glasgow, Committee of Scottish Higher Education Principals, 1995.
- Nijkamp, P., van Oirschoot, G.; Oosterman, A.: *Knowledge*

- networks, science parks and regional development: An international comparative analysis of critical success factors. In Cuadrado-Roura, J. R.; Nijkamp, P.; Salva, P. (eds.), *Moving Frontiers: Economic Restructuring, Regional Development and Emerging Networks*. Avebury, Aldershot 1994.
- OECD: *The university and the community: the problems of changing relationships*. Centre for Educational Research and Innovation, OECD, Paris 1982.
- Robson, B.; Deas, I.; Topham, N.; Twomey, J.: *The economic and social impact of Greater Manchester's Universities*, Centre for Urban Policy Studies, University of Manchester and Salford University Business Services Ltd, 1995.
- Schuller, T.: Introduction. In: Schuller, T. (ed.), *The Changing University?*, The Society for Research into Higher Education. Open University Press, Buckingham 1995.
- Shachar, A.; Felsenstein, D.: Urban economic development and high technology industry. *Urban Studies* 29(6), 839–855 (1992).
- Smilor, R.; Dietrich, G.; Gibson, D.: The entrepreneurial university: The role of higher education in the United States in technology commercialization and economic development. *International Social Science Journal* 45(1), 1–11 (1993).
- UWCC: *Publications, Grants and Statistics 1993–1994*. University of Wales College of Cardiff, Cardiff 1994b.
- UWCC: *Financial Statements 1995*. University of Wales College of Cardiff, Cardiff 1995.
- Westhead, P.; Storey, D.: Links between higher education institutions and high technology firms. *Omega* 23(4), 346–360 (1995).