Research Imprint

- a New Approach to Citation Analysis

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Abstract

In this paper I present a method to allocate the welfare gains of an article to previous work on which the article builds. The method uses article to article citations and generates article specific impacts. To compile journal rankings the invariant method can be used. Articles written in the last t years transfer output to their references. The cited articles in turn transfer output to their own references. The transfer of output from one generation of articles to the previous one continues as long as citation data is available. The resulting values measure the articles' influence, or imprint, on research in the last t years.

1 Introduction

Over the past decade decision makers in academia have relied increasingly on research evaluations to allocate research funds. By doing so, decision makers hope to improve the efficiency of the research sector. At least in the German economics profession it seems that such assessments have led to an increase in academic output as measured by research evaluations. In this particular case, evaluations are successful in fostering the production of what they measure.

Research evaluations usually rely on journal rankings to control for research quality. The largest part of journal rankings is compiled using citation data. Citations indicate a contribution to the creation of knowledge, thus research evaluations assess the success in creating knowledge. But knowledge per se has no value. It is therefore questionable where present research evaluations are leading.

If the objective of decision makers is to increase welfare, research evaluations should try to measure welfare gains and not the production of knowledge. Almost all existing approaches evaluate how useful a paper or oeuvre is for the creation of subsequent research.[1] A welfare-based analysis in contrast tries to identify a paper's effect on living conditions. If we want to allocate research funds between different disciplines, we need to compare

[1] This includes the empirical results presented below. Further examples are the number of citations, the H-index, or the number of papers published in A+ journals.

the performance of the disciplines. A comparison on the basis of knowledge creation is meaningless, because knowledge-based measures are discipline specific. Output measures based on value added, however, are directly comparable.[2] If we attempt to determine an efficient size of the research sector, the trade-off is between research funds and debt or taxes. Therefore choosing the size of the research sector also requires a research assessment based on welfare.

In order to measure research in terms of welfare, we have to address three questions: who accounts for the creation of research? How are research results transferred to the "applied" sector? And how much value is added by the application of research? The transfer of research is addressed in Nederhof and Meijer [6]. They conduct a survey among practitioners to create a ranking of trade journals based on research transfer. A further achievement of Nederhof and Meijer [6] is that they point out that research evaluations should be based on welfare. Estimates of research transfer can be combined with estimates of value creation to measure research output at journal level. Thus we are left with distributing value added within the research sector.

This paper focuses on distributing value added within the research sector and provides a method in Section 2 and a first implementation in Section 3. Section 3 also includes a journal rankings.

[2] the usefulness of any such comparison and the resulting allocation of research funds depends of course crucially on the reliability of the underlying quality indicators.

2 Research accounting

I adopt an accountant's perspective on the production of research. My aim is to measure the value added of an article. Thus the relevant production entity is the individual article.

An article provides two kind of products. The first product is transfer of knowledge to the applied sector. Transfer of knowledge into the applied sector constitutes the final product of academic research, which is why I call it output. The second product of an article is intellectual input into further research, which is an intermediate good in the production of output. Thus the value, or revenue, of an article is determined by its output and by the extent to which further research relies on an article. The revenue part of an article is sketched on the right-hand side of figure 1.

As an article provides intellectual input for further research, the article also relies on the intellectual contribution of earlier work. Consequently an article has to reward previous research and share its revenue with previous work. The fraction δ of an article's value it can claim for itself is the article's value added. The remaining value is passed on to the research which the article builds upon. The expenditure part of an article is sketched on the left-hand side of figure 1.

The idea of this method is to assign the returns from output to those articles which are responsible for the creation of output. In order to allocate returns, value is transferred from one generation of research to the previous

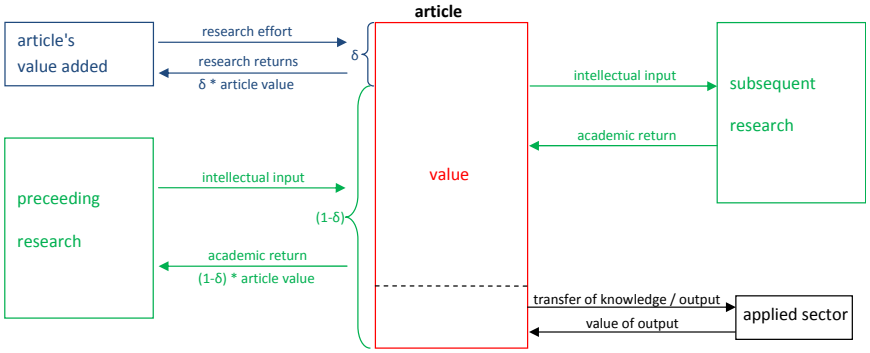

Figure 1: Value creation at article level

one. If applied consequently, we would be able to identify the sources of our welfare back to Adam Smith and further.

Figure 2 illustrates the interaction of value creation and distribution at article level. One article is represented by three rectangles which indicate output (black), value (red), and value added (blue). Articles are horizontally positioned according to their publication date. Green lines indicate intellectual input of articles from left to right and the respective returns in the opposite direction. Numbers give the value associated with the respective element.

I refer to articles by article value. Articles five, six and ten are the most recent articles and have not led to further research yet. Thus their value equals their output. All other articles displayed in Figure 2 receive a transfer of value in return for their intellectual contribution to subsequent research. Value is assigned to previous research according to the relevance of an input. Transfers from one article can therefore differ (see e.g. transfer from Article 10). The same is true for the share of value an article receives as value

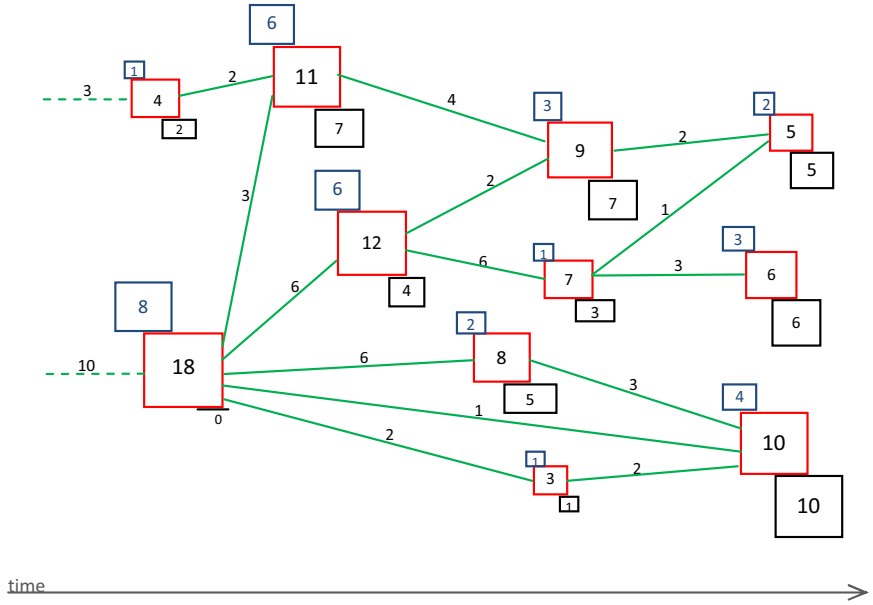

Figure 2: Creation and transfer of welfare

added, which ranges from about fourteen percent (Article 7) to about 55 percent (Article 11).

Note, that Article 18 has a direct and an indirect impact on Article 10. Indirect impact implies that Articles 8 and 3 refine aspects of Article 18 and that those refinements contributed to Article 10. Direct impact implies that Article 10 uses a result from Article 18, which was not refined in Articles eight or three.

In reality this approach has three main problems. First, we do not know the output of an article. Second, we do not know which articles contributed to an article's output. I regard this as a minor problem, because scientists use to cite results which they used. The use of citation data for research evaluation is not unproblematic, but widely accepted due to the

lack of better alternatives. A comprehensive, but by nature incomplete list of shortcomings can for example be found in Ritzberger [9].

The third problem with regard to an implementation of the above described approach is that we don't know how much the individual articles contributed to output. Citations only indicate the use of an article not the relevance. Even worse, Serrano [10] points out that citations can also indicate bad contributions to a topic. Finally, the articles' share in value creation δ is likely to differ from article to article.

3 A first implementation

This section presents a first implementation of the above described approach using citation data from 1985 to 2003. The aim is to estimate articles' impact on research between 2001 and 2003. If an article gets cited, output is transferred from the citing article to the cited one. All cited articles are assumed to have been equally relevant for the creation of an article. Using this method an article distributes its output over all articles which are directly or indirectly cited by this article. The resulting measures of article quality can be interpreted as the articles' imprint on economic research in 2001 to 2003.[3]

[3] Atallah and Rodriguez [1] use patent to patent citations to estimate the importance of patents, which is similar to the method used in this paper.

3.1 Formal description

Let $c_{i\to j}$ represent a citation from article i to article j, then $c_i = (c_{i\to j_1} \;\; c_{i\to j_2} \;\; \dots \;\; c_{i\to j_n})'$ is the corresponding citation vector and $C = c_1' c_2' \dots c_n'$ the corresponding citation matrix.

In order to split output to be transferred between the cited papers, I normalize each article's citations to sum up to one. Normalized expressions (denoted by d) are obtained by dividing each element by the number of cited items, i.e. $d_{i\to j} = c_{i\to j}/c_{i\to *}$, $d_i = (d_{i\to j_1} \;\; d_{i\to j_2} \;\; \dots \;\; d_{i\to j_n})'$, and $D = d_1' d_2' \dots d_n'$.

Given a complete set of literature which covers all citable sources, any reference can be matched with an article. The dataset I use, however, is incomplete with respect to research not published in journals, with respect to uncovered journals and it is limited in time. The limitation in time causes older articles to receive a disproportionately high share of output: the output of an article published in 2000 can be distributed among articles published between 2000 and 1985, whereas all output of articles from 1985 goes to articles in 1985 ,if a transfer takes place at all. Thus, if we use the number citations in the dataset to normalize citations, old articles receive disproportionate high weight. Normalizing by the number of references instead of the number of citations found in the dataset, has two unpleasant effects. First, only a fraction of output is transferred from one generation of articles to the previous one. Second, the fraction of output an article can

pass to its citations depends on the share of references which are found as citations. I evade this problem by introducing a year dependent correction factor which fixes the citation to reference ratio to the ratio in 2003.[4] I normalize citations in the just described way and refer to them as direct citations in the following.

An indirect citation of order q from article i to article j is a chain $c_{i\to k_1}\ c_{k_1\to k_2}\ \ldots\ c_{k_q\to j}$. Put differently, an indirect citation of order q is a link passing q generations of articles. The normalized indirect citations of order $q \geq 1$ from article i to article j are given by

$$\begin{aligned} ic_{i\to j,q} &= ic_{i\to 1,q-1}d_{1\to j} + ic_{i\to 2,q-1}d_{2\to j} + \ldots + ic_{i\to n,q-1}d_{n\to j} \\ &= \sum_{k=1}^{n} ic_{i\to k,q-1}d_{k\to j}. \end{aligned}$$

Note that $ic_{i\to j,q}$ can capture many different chains or paths from article i to article j. Direct citations are indirect citations of order zero, i.e. $ic_{i\to j,0} \equiv d_{i\to j}$. The indirect citation matrix of order q takes the simple formula $IC_q = IC_{q-1}D = D^{q+1}$.

The most important aspect of this method is to distribute output among all directly and indirectly cited articles. Therefore a fraction δ of an article's output remains with the article while the rest is passed on to its references.

[4] In 2003 27% of the references are found as citations. In 1994 this share has fallen to 18%. Thus I assume that another 9% of 1994's references could be identified if the dataset was 10 years longer. The number of citations would be 1.5 times the number reported. The correction factor for 1994 is therefore 1.5. If a 1994 article has one citation, the cited article receives only two thirds of the output.

δ should reflect the value added of an article or, at aggregate level, the improvement of research by one generation of articles.

The mapping of output from articles to articles can be summarized in a transmission matrix

$$\begin{aligned}\mathtt{T} &= \delta(1-\delta)D + \delta(1-\delta)^2 IC_1 + \delta(1-\delta)^3 IC_2 + \ldots = \textstyle\sum_{q=0}^{\infty} \delta(1-\delta)^{q+1} IC_q \\ &= \textstyle\sum_{q=0}^{\infty} \delta(1-\delta)^{q+1} D^{q+1}. \end{aligned} \tag{1}$$

Estimates of articles' value added result from combining the transmission matrix with an output vector:

$$\mathtt{I} = \delta\mathtt{w} + \mathtt{T}'\mathtt{w}, \tag{2}$$

where $\mathtt{w}$ is an estimate of the welfare gain stemming from each article's knowledge transfer.

3.2 The data

I use citation data from the Social Science Citation Index (SSCI) compact disc edition for the years 1986 to 2003. The 1986 edition also covers some articles published in 1985. I only consider articles published in journals that were listed in the economics list of the SSCI in early 2010 and were already included in the 2003 CD edition. The resulting set of articles is limited to articles classified as article, discussion, letter, note, reprint or review which

yields a subset of around 113,000 articles. Within this set of articles about 510,000 citations are found. For the most recent years this implies that approximately one quarter of the references are found as citations.

3.3 Ranking journals

Ranking journals on the basis of citations became popular with the introduction of the impact factor (Garfield [2]). A number of improvements have been proposed subsequently. While the impact factor considers only the number of citations, Liebowitz and Palmer [5] propose to take the citing journal's quality into account. Palacios-Huerta and Volij [8] suggest to use the invariant method, which corrects for citation quality and for reference intensity. Correcting for reference intensity implies that fields of research with long reference lists (and therefore more citations) do not receive higher quality indices, ceteris paribus.

The main drawback of the invariant method is its bad performance if the citation matrix is close to be reducible. Kóczy and Strobel [4] criticize that the invariant method can be manipulated which is also true for the Liebowitz-Palmer [5] method. There are at least two other problems with regard to the invariant method. The invariant method cannot be combined with an output vector in a meaningful and straightforward way. Furthermore, the invariant method is biased in favor of upstream disciplines if it is applied to cross-discipline data. From an economist's point of view this

might be pleasing if economics is compared to business administration, but undesirable if economics is compared to mathematics. Given the lack of output estimates and the data I use, my points of criticism do not apply.

Several journal rankings are presented below. The first ranking is a ranking according to the invariant method. Reference intensity is corrected at the article level. Then articles from 2001 to 2003 are aggregated into journals. I limit the cited period to articles published between 2001 and 2003, i.e. only citations to articles within this period are counted. The resulting ranking *Inv 3y* is reported in the second column of Table 1.

Journal rankings usually restrict the cited period to a few years. This is understandable for rankings conducted by researchers (Palacios-Huerta and Volij [8] 1993-99, Kalaitzidakis, Mamuneas and Stengos [3] 1994-98, or Ritzberger [9] 2003-05), because data has to be collected or bought. Limiting the cited period has, however, unpleasant consequences. Researchers and editors are induced to publish papers on hot topics which are likely to attract citations quickly and thus improve their rankings. Promising but unfashionable research is more likely to be rejected, because a paper's success is less likely to fall into the relevant period. Choosing a rather long cited period has the additional benefit that strategic manipulations are undermined, because any manipulation will have a smaller impact on the resulting ranking.

If we consider a long cited period, additional problems arise. Rankings of

journal quality usually judge per article quality. What is the correct number of articles, if journal size (in terms of articles) varies over time? And how do we treat journals with incomplete citation record, be it due to missing data coverage or because a journal was newly founded?

A ranking is up to date, if it reflects the latest citation patterns. The influence of past years should be proportional to the years' respective share of citations. The influence or weight a year receives can vary from journal to journal if journal coverage differs.[5] Articles are weighted by the journal's yearly weight divided by the number of articles the journal has published in this year, i.e. $w_i = \frac{w_{y_i,j_i}}{na_{y_i,j_i}}$.

Column three in Table 1 reports the ranking of journals according to (direct) citations to the years 1985 to 2002. The method used to compile the ranking in column three is slightly different than the invariant method, because articles are weighted on a yearly basis to determine a journal's weight. If the journal size was constant over time and all journals had full coverage, the results should be identical. The ranking is therefore labeled *Inv* 18y*.

Limiting the cited period has quite substantial effects on some journals' ranking as can be seen by comparing *Inv 3y* and *Inv* 18y*. Games and Economic Behavior moves from rank 30 to rank 9, the Journal of Math-

[5] Assume a dataset covers ten years of citation data and we want to construct a ranking based on the latest two years. Further suppose that each of the ten years covered receive 10% of citations from the latest two years. Then every year is weighted equally if a journal has full coverage. If a journal is covered only four years, then each year is weighted by one quarter.

ematical Economics from rank 52 to rank 15, and the Journal of Health Economics from rank 74 to rank 29. The list of major rank changes could be easily expanded. Among those journals that gain are many journals that publish economic theory (Journal of Mathematical Economics, Games and Economic Behavior, International Journal of Game Theory, Journal of Risk and Uncertainty, and Theory and Decision). Research on economic theory seems to take rather long to be used by more applied researchers. The ranking of journals publishing theoretical econometrics, in contrast, remains more or less unchanged.

Table 1: Comparison of journal rankings

Journal	Inv 3y	Inv* 18y	Imp w	Imp u
ECONOMETRICA	71,57 (2)	100 (1)	100 (1)	67,84 (3)
QUARTERLY JOURNAL OF ECONOMICS	100 (1)	78,69 (2)	94,12 (2)	82,32 (2)
JOURNAL OF ECONOMIC LITERATURE	51,98 (4)	63,7 (3)	76,18 (3)	100 (1)
JOURNAL OF POLITICAL ECONOMY	42,55 (6)	63,67 (4)	72,05 (4)	65,73 (4)
REVIEW OF ECONOMIC STUDIES	31,31 (8)	50,78 (5)	52,15 (6)	40,45 (7)
JOURNAL OF FINANCIAL ECONOMICS	51,59 (5)	46,48 (6)	52,25 (5)	35,36 (9)
BROOKINGS PAPERS ON ECONOMIC ACTIVITY	17,99 (21)	34,69 (7)	50,15 (7)	58,88 (5)
JOURNAL OF ECONOMIC THEORY	31,07 (9)	31,7 (8)	32,14 (11)	22,46 (21)
GAMES AND ECONOMIC BEHAVIOR	13,14 (30)	30,18 (9)	34,3 (10)	21,08 (24)
AMERICAN ECONOMIC REVIEW[a]	37,49 (7)	29,89 (10)	36,17 (9)	38,83 (8)
ECONOMIC POLICY	29,23 (10)	28,44 (11)	36,59 (8)	51,22 (6)
RAND JOURNAL OF ECONOMICS	20,64 (14)	26,65 (12)	27,8 (13)	29,36 (12)
JOURNAL OF MONETARY ECONOMICS	20,23 (15)	24,41 (13)	29,69 (12)	33,11 (11)
JOURNAL OF ECONOMETRICS	24,24 (12)	23,12 (14)	23,7 (16)	27,39 (13)
JOURNAL OF MATHEMATICAL ECONOMICS	6,95 (52)	20,89 (15)	18,81 (19)	14,11 (56)
JOURNAL OF ECONOMIC PERSPECTIVES	29,13 (11)	20,24 (16)	25,82 (14)	34,76 (10)

[a] This version of the paper does not distinguish between the AER and the AER Papers and Proceedings issue. Seperating the Papers and Proceedings issue from the remaining journal is likely to increase the ranking of the AER.

Journal	Inv 3y	Inv* 18y	Imp w	Imp u
JOURNAL OF HUMAN RESOURCES	16,58 (22)	19,68 (17)	24,37 (15)	26,33 (14)
JOURNAL OF ACCOUNTING & ECONOMICS	57,13 (3)	17,91 (18)	23,21 (17)	16,73 (37)
JOURNAL OF LABOR ECONOMICS	19,63 (17)	17,18 (19)	21,17 (18)	24,71 (16)
INTERNATIONAL JOURNAL OF GAME THEORY	5,69 (59)	16,63 (20)	16,97 (23)	13,83 (58)
JOURNAL OF INTERNATIONAL ECONOMICS	20,02 (16)	15,97 (21)	18,26 (21)	25,11 (15)
JOURNAL OF LAW ECONOMICS & ORGANIZATION	8,31 (42)	15,49 (22)	15,91 (24)	17,12 (35)
INTERNATIONAL ECONOMIC REVIEW	19,53 (18)	15,21 (23)	15,68 (27)	16,81 (36)
ECONOMIC THEORY	10,93 (32)	14,76 (24)	15,24 (29)	12,45 (73)
SOCIAL CHOICE AND WELFARE	7,39 (48)	14,36 (25)	14,41 (31)	13,76 (59)
JOURNAL OF ECONOMIC GROWTH	16,17 (23)	14,3 (26)	15,88 (25)	21,78 (23)
ECONOMETRIC THEORY	10,11 (36)	14,08 (27)	13,39 (33)	12,39 (74)
JOURNAL OF BUSINESS & ECONOMIC STATISTICS	12,35 (31)	14,05 (28)	15,42 (28)	19,17 (28)
JOURNAL OF HEALTH ECONOMICS	4,25 (74)	13,85 (29)	18,27 (20)	23 (19)
REVIEW OF ECONOMICS AND STATISTICS	18,31 (20)	13,83 (30)	15,87 (26)	21,94 (22)
JOURNAL OF LAW & ECONOMICS	10,53 (34)	13,38 (31)	15,21 (30)	19,4 (27)
JOURNAL OF RISK AND UNCERTAINTY	4,47 (73)	12,49 (32)	13,1 (34)	16,17 (44)
JOURNAL OF PUBLIC ECONOMICS	14,94 (25)	12,44 (33)	14,2 (32)	20,33 (25)
JOURNAL OF FINANCIAL AND QUANTITATIVE ANALYSIS	18,41 (19)	11,32 (34)	12,99 (35)	14,51 (54)
JOURNAL OF INDUSTRIAL ECONOMICS	23,96 (13)	10,6 (35)	11,25 (38)	17,27 (33)
ECONOMIC JOURNAL	14,48 (27)	10,3 (36)	12,61 (36)	23,13 (18)
JOURNAL OF APPLIED ECONOMETRICS	8,93 (41)	10,04 (37)	10,75 (40)	17,94 (30)
JOURNAL OF ECONOMIC DYNAMICS & CONTROL	7,74 (45)	10 (38)	9,8 (43)	13,85 (57)
JOURNAL OF ECONOMICS & MANAGEMENT STRATEGY	8,22 (43)	9,79 (39)	10,68 (41)	13,7 (60)
JOURNAL OF MONEY CREDIT AND BANKING	10,2 (35)	9,4 (40)	11,88 (37)	16,16 (45)
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	5,66 (60)	9,13 (41)	10,35 (42)	24,34 (17)
EUROPEAN ECONOMIC REVIEW	13,89 (28)	9,1 (42)	11,08 (39)	17,73 (32)
INSURANCE MATHEMATICS & ECONOMICS	7,19 (50)	7,31 (43)	18,2 (22)	17,13 (34)
MACROECONOMIC DYNAMICS	13,83 (29)	7,11 (44)	7,37 (50)	11,45 (85)
WORLD BANK ECONOMIC REVIEW	14,86 (26)	6,85 (45)	8,95 (44)	22,84 (20)
INFORMATION ECONOMICS AND POLICY	9,38 (38)	6,73 (46)	7,89 (48)	19,72 (26)
NATIONAL TAX JOURNAL	9,86 (37)	6,36 (47)	8,22 (47)	12,77 (67)
JOURNAL OF URBAN ECONOMICS	4,69 (71)	6,29 (48)	7,56 (49)	15,7 (47)
WORLD BANK RESEARCH OBSERVER	3,17 (84)	6,24 (49)	7,29 (52)	18,78 (29)

Journal	Inv 3y	Inv* 18y	Imp w	Imp u
JOURNAL OF REGULATORY ECONOMICS	5,79 (58)	6,22 (50)	7,35 (51)	13,61 (61)
REVIEW OF INCOME AND WEALTH	4,92 (68)	6,02 (51)	8,34 (46)	14,68 (53)
INTERNATIONAL JOURNAL OF INDUSTRIAL ORGANIZATION	4,81 (70)	5,91 (52)	6,29 (55)	12,67 (69)
ECONOMICS OF EDUCATION REVIEW	4,59 (72)	5,83 (53)	7,03 (53)	12,31 (75)
ECONOMIC INQUIRY	2,66 (93)	5,37 (54)	6,62 (54)	11,87 (80)
JOURNAL OF ECONOMIC HISTORY	6,97 (51)	5,33 (55)	6,07 (58)	11,25 (89)
HEALTH ECONOMICS	1,41 (124)	5,3 (56)	8,55 (45)	15,23 (51)
STUDIES IN NONLINEAR DYNAMICS AND ECONOMETRICS	2,79 (91)	5,15 (57)	4,8 (71)	9,41 (107)
JOURNAL OF DEVELOPMENT ECONOMICS	6,65 (55)	5,11 (58)	6,19 (57)	15,14 (52)
JOURNAL OF ECONOMIC BEHAVIOR & ORGANIZATION	5,87 (57)	4,97 (59)	5,86 (61)	9,92 (104)
JOURNAL OF THE JAPANESE AND INTERNATIONAL ECONOMIES	0,95 (134)	4,97 (60)	5,74 (62)	11,62 (82)
OXFORD ECONOMIC PAPERS-NEW SERIES	3,84 (78)	4,87 (61)	5,53 (63)	12,52 (71)
OXFORD BULLETIN OF ECONOMICS AND STATISTICS	2,72 (92)	4,84 (62)	5,52 (64)	15,72 (46)
IMF STAFF PAPERS	4,98 (66)	4,79 (63)	6,23 (56)	16,26 (43)
INTERNATIONAL TAX AND PUBLIC FINANCE	3,95 (76)	4,66 (64)	6,02 (59)	11,91 (79)
SCANDINAVIAN JOURNAL OF ECONOMICS	3,6 (83)	4,62 (65)	4,99 (69)	11,32 (88)
JOURNAL OF BANKING & FINANCE	6,76 (53)	4,6 (66)	5,24 (66)	11,5 (83)
REGIONAL SCIENCE AND URBAN ECONOMICS	4,98 (65)	4,55 (67)	5,17 (68)	12,08 (78)
ENERGY JOURNAL	7,73 (46)	4,45 (68)	5,96 (60)	16,27 (42)
ECONOMICA	2,52 (98)	4,24 (69)	5,18 (67)	10,9 (91)
JOURNAL OF ECONOMIC SURVEYS	5,09 (63)	4,04 (70)	4,59 (73)	17,9 (31)
JOURNAL OF PRODUCTIVITY ANALYSIS	1,75 (115)	4,01 (71)	4,76 (72)	16,38 (39)
THEORY AND DECISION	1,02 (132)	3,98 (72)	4,08 (79)	6,74 (137)
JOURNAL OF RISK AND INSURANCE	9,37 (39)	3,92 (73)	4,81 (70)	9,32 (108)
JOURNAL OF POLICY ANALYSIS AND MANAGEMENT	5,32 (61)	3,92 (74)	5,43 (65)	10,43 (96)
EXPLORATIONS IN ECONOMIC HISTORY	5,13 (62)	3,88 (75)	4,54 (74)	10,68 (93)
CANADIAN JOURNAL OF ECONOMICS	7,23 (49)	3,75 (76)	3,94 (81)	8,64 (117)
JOURNAL OF REAL ESTATE FINANCE AND ECONOMICS	1,61 (120)	3,57 (77)	3,96 (80)	12,58 (70)
ECONOMICS OF TRANSITION	2,3 (105)	3,41 (78)	4,4 (75)	15,58 (48)
LAND ECONOMICS	2,3 (104)	3,39 (79)	4,22 (77)	15,29 (50)
INTERNATIONAL REVIEW OF LAW AND ECONOMICS	2,28 (106)	3,33 (80)	3,69 (84)	8,33 (124)
LABOUR ECONOMICS	2,62 (94)	3,33 (81)	3,75 (82)	10,13 (97)
JOURNAL OF EVOLUTIONARY ECONOMICS	1,66 (117)	3,29 (82)	3,66 (85)	11,13 (90)
REAL ESTATE ECONOMICS	1,12 (129)	3,21 (83)	3,51 (88)	12,99 (65)

Journal	Inv 3y	Inv* 18y	Imp w	Imp u
ENVIRONMENTAL & RESOURCE ECONOMICS	1,84 (114)	3,21 (84)	4,26 (76)	16,64 (38)
OXFORD REVIEW OF ECONOMIC POLICY	3,14 (86)	3,11 (85)	4,22 (78)	13,25 (62)
RESOURCE AND ENERGY ECONOMICS	2,21 (108)	2,95 (86)	3,61 (87)	9,99 (101)
JOURNAL OF POPULATION ECONOMICS	2,97 (88)	2,91 (87)	3,49 (89)	9,99 (102)
ECONOMICS LETTERS	3,12 (87)	2,87 (88)	3,03 (94)	7,41 (132)
GENEVA RISK AND INSURANCE REVIEW	1,5 (123)	2,61 (89)	3,37 (90)	7,33 (133)
PUBLIC CHOICE	2,04 (112)	2,57 (90)	3,08 (92)	8,52 (121)
REVIEW OF INDUSTRIAL ORGANIZATION	8,97 (40)	2,5 (91)	2,89 (96)	8,44 (122)
SOUTHERN ECONOMIC JOURNAL	2,24 (107)	2,4 (92)	2,71 (98)	7,61 (130)
ECONOMIC DEVELOPMENT AND CULTURAL CHANGE	3,62 (82)	2,38 (93)	3,17 (91)	12,83 (66)
NEW ENGLAND ECONOMIC REVIEW	6,67 (54)	2,3 (94)	3,74 (83)	10,51 (95)
JOURNAL OF HOUSING ECONOMICS	0,14 (157)	2,16 (95)	2,09 (103)	9,19 (110)
INTERNATIONAL JOURNAL OF FORECASTING	10,84 (33)	2,05 (96)	2,15 (102)	9,92 (103)
JOURNAL OF COMPARATIVE ECONOMICS	3,63 (81)	2,03 (97)	2,91 (95)	12,31 (76)
ECOLOGICAL ECONOMICS	3,64 (80)	1,88 (98)	3,62 (86)	16,28 (41)
AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS	2,56 (96)	1,84 (99)	2,22 (101)	12,72 (68)
JOURNAL OF ECONOMIC EDUCATION	15,09 (24)	1,82 (100)	3,03 (93)	8,87 (113)
JAPANESE ECONOMIC REVIEW	1,72 (116)	1,74 (101)	1,65 (114)	5,8 (147)
REVIEW OF WORLD ECONOMICS	4,18 (75)	1,68 (102)	2,05 (104)	8,79 (115)
KYKLOS	2,96 (89)	1,65 (103)	2,24 (100)	8,84 (114)
JOURNAL OF TRANSPORT ECONOMICS AND POLICY	1,63 (119)	1,52 (104)	1,59 (115)	8,25 (126)
JOURNAL OF INSTITUTIONAL AND THEORETICAL ECONOMICS	5 (64)	1,51 (105)	1,9 (107)	6,37 (141)
WORLD DEVELOPMENT	2,85 (90)	1,51 (106)	1,95 (105)	12,51 (72)
JOURNAL OF REGIONAL SCIENCE	2,11 (110)	1,51 (107)	1,75 (112)	8,64 (116)
JOURNAL OF ECONOMICS	1,3 (125)	1,48 (108)	1,44 (119)	4,73 (155)
JAPAN AND THE WORLD ECONOMY	0,75 (139)	1,46 (109)	1,52 (116)	5,63 (148)
FEMINIST ECONOMICS	0,22 (154)	1,4 (110)	2,72 (97)	13,1 (63)
JOURNAL OF ECONOMIC PSYCHOLOGY	3,91 (77)	1,4 (111)	1,9 (109)	8,62 (118)
CHINA ECONOMIC REVIEW	4,9 (69)	1,39 (112)	1,78 (111)	10,87 (92)
CONTEMPORARY ECONOMIC POLICY	0,97 (133)	1,33 (113)	1,82 (110)	6,76 (136)
WORLD ECONOMY	1,53 (121)	1,29 (114)	1,94 (106)	10,05 (100)
JOURNAL OF DEVELOPMENT STUDIES	1,53 (122)	1,27 (115)	1,66 (113)	11,45 (86)
JOURNAL OF AFRICAN ECONOMIES	0,23 (153)	1,16 (116)	1,41 (121)	7,92 (127)
ENERGY ECONOMICS	1,22 (127)	1,16 (117)	1,46 (117)	7,64 (129)

Journal	Inv 3y	Inv* 18y	Imp w	Imp u
ECONOMIC HISTORY REVIEW	8,12 (44)	1,11 (118)	1,43 (120)	8,53 (120)
MANCHESTER SCHOOL	2,1 (111)	1,06 (119)	1,44 (118)	6,18 (143)
APPLIED ECONOMICS	0,53 (145)	0,99 (120)	1,04 (124)	6,04 (144)
AGRICULTURAL ECONOMICS	2,44 (99)	0,97 (121)	1,2 (123)	10,07 (98)
JCMS-JOURNAL OF COMMON MARKET STUDIES	4,93 (67)	0,88 (122)	1,9 (108)	15,39 (49)
ECONOMIST-NETHERLANDS	0,7 (140)	0,84 (123)	1,22 (122)	5,45 (149)
ECONOMIC MODELLING	1,28 (126)	0,84 (124)	0,95 (128)	7 (135)
SCOTTISH JOURNAL OF POLITICAL ECONOMY	0,68 (143)	0,81 (125)	0,96 (127)	6,61 (139)
JOURNAL OF POLICY MODELING	1,65 (118)	0,8 (126)	0,92 (131)	6,68 (138)
JOURNAL OF MACROECONOMICS	2,15 (109)	0,79 (127)	0,79 (136)	4,9 (153)
BULLETIN OF INDONESIAN ECONOMIC STUDIES	6,22 (56)	0,79 (128)	2,5 (99)	16,38 (40)
SMALL BUSINESS ECONOMICS	1,98 (113)	0,78 (129)	0,85 (134)	9,08 (111)
AUSTRALIAN JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	2,41 (100)	0,78 (130)	0,93 (130)	8,91 (112)
JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	0,89 (136)	0,77 (131)	0,94 (129)	8,56 (119)
AMERICAN JOURNAL OF ECONOMICS AND SOCIOLOGY	7,53 (47)	0,72 (132)	0,86 (133)	5,06 (151)
CAMBRIDGE JOURNAL OF ECONOMICS	0,77 (137)	0,7 (133)	1,03 (125)	11,39 (87)
JOURNAL OF AGRICULTURAL ECONOMICS	1,11 (130)	0,67 (134)	0,88 (132)	9,2 (109)
ECONOMIC RECORD	0,41 (148)	0,66 (135)	0,97 (126)	6,39 (140)
EUROPEAN REVIEW OF AGRICULTURAL ECONOMICS	1,21 (128)	0,65 (136)	0,76 (138)	10,07 (99)
ECONOMIC GEOGRAPHY	0,67 (144)	0,62 (137)	0,71 (140)	11,77 (81)
OPEN ECONOMIES REVIEW	2,38 (102)	0,59 (138)	0,77 (137)	5,9 (145)
HISTORY OF POLITICAL ECONOMY	2,39 (101)	0,56 (139)	0,84 (135)	8,31 (125)
REVIEW OF INTERNATIONAL POLITICAL ECONOMY	0,68 (142)	0,51 (140)	0,63 (142)	12,14 (77)
JOURNAL OF WORLD TRADE	3,76 (79)	0,51 (141)	0,73 (139)	9,58 (106)
JOURNAL OF POST KEYNESIAN ECONOMICS	2,6 (95)	0,45 (142)	0,49 (145)	8,37 (123)
ECONOMIC DEVELOPMENT QUARTERLY	0,44 (147)	0,38 (143)	0,67 (141)	14,3 (55)
CANADIAN JOURNAL OF AGRICULTURAL ECONOMICS	0,07 (158)	0,37 (144)	0,41 (148)	4,96 (152)
JOURNAL OF ECONOMIC ISSUES	2,54 (97)	0,35 (145)	0,39 (149)	7,89 (128)
DEVELOPING ECONOMIES	0,16 (156)	0,31 (146)	0,43 (147)	4,51 (156)
EUROPE-ASIA STUDIES	0,77 (138)	0,3 (147)	0,62 (143)	11,46 (84)
FOOD POLICY	0,91 (135)	0,26 (148)	0,43 (146)	7,02 (134)
APPLIED ECONOMICS LETTERS	0,31 (151)	0,24 (149)	0,26 (152)	4,43 (158)
ECONOMY AND SOCIETY	1,04 (131)	0,23 (150)	0,34 (151)	10,53 (94)

Journal	Inv 3y	Inv* 18y	Imp w	Imp u
POST-COMMUNIST ECONOMIES	0,19 (155)	0,21 (151)	0,51 (144)	9,68 (105)
WORK EMPLOYMENT AND SOCIETY	2,34 (103)	0,19 (152)	0,37 (150)	13,04 (64)
SOUTH AFRICAN JOURNAL OF ECONOMICS	0,06 (159)	0,16 (153)	0,17 (153)	4,82 (154)
JAHRBUCHER FUR NATIONALOKONOMIE UND STATISTIK	0 (163)	0,16 (154)	0,17 (154)	4,13 (159)
TRIMESTRE ECONOMICO	0,34 (149)	0,15 (155)	0,14 (156)	3,63 (163)
TIJDSCHRIFT VOOR ECONOMISCHE EN SOCIALE GEOGRAFIE	0,45 (146)	0,11 (156)	0,13 (157)	5,84 (146)
EASTERN EUROPEAN ECONOMICS	0,7 (141)	0,09 (157)	0,13 (158)	4,47 (157)
FUTURES	3,16 (85)	0,09 (158)	0,14 (155)	7,45 (131)
EMERGING MARKETS FINANCE AND TRADE	0,25 (152)	0,04 (159)	0,05 (159)	3,68 (162)
POLITICKA EKONOMIE	0,33 (150)	0,02 (160)	0,02 (162)	6,31 (142)
EKONOMISKA SAMFUNDETS TIDSKRIFT	0 (164)	0 (161)	0 (163)	2,64 (164)
REVUE D ETUDES COMPARATIVES EST-OUEST	0 (162)	0 (162)	0,03 (160)	3,74 (161)
EKONOMICKY CASOPIS	0,02 (160)	0 (163)	0 (164)	3,93 (160)
DESARROLLO ECONOMICO-REVISTA DE CIENCIAS SOCIALES	0 (161)	0 (164)	0,03 (161)	5,44 (150)

Columns four and five show journal rankings according to the imprint method. Using article imprint causes a further complication. Given the data and the assumptions I use, older articles have on average higher imprint scores and would therefore have a greater impact on a journal's ranking. I do not think that this greater impact actually reflects a larger impact, but that it simply results from assuming that all citations of an article are equally important. To arrive at a ranking that represents the citation patterns of the citing period (here 2001-03), I normalize the sum of each year's article scores to some constant.[6]

For the calculation of article imprint I set δ equal to 0.16, which I regard as a reasonable proxy.[7] For the calculation of the ranking labeled as *Imp w*,

[6]Because there are very few citations to articles published in 2003, this normalization does not make sense for 2003. Thus I do do not consider articles published in 2003 in the transmission matrix (1) when article imprint is calculated. The share of output articles from 2003 receive for transferring output to the applied sector is off course counted. Also output is passed on, if an 2003 article is cited.

[7]I guess that a cited item is on average around 12 years old. The average annual productivity growth in OECD countries has been about 1.2% between 1985 and 2003. If

I assume that an article's output equals the quality weight of the journal in which the article was published. Article imprint is calculated according to equation 2.

The resulting ranking is very close to the ranking which uses direct citations to the whole period. The correlation between the two rankings is 0.992 (based on journal score, not on journal ranks). Insurance Mathematics & Economics is the big outlier as it moves from rank 43 to 22. Health economics also benefits from the change in methodology as the Journal of Health Economics rises from rank 29 to rank 20 and Health Economics rises from rank 56 to rank 45.

Differences between the two methods used to compile *Inv* 18* and *Imp w* seem to disappear at the aggregation level of journals. This is not true for the ranking reported in the last column of table 1.

The ranking labeled as *Imp u* assumes that output, i.e. value created through knowledge transfer, is the same for every paper published between 2001 and 2003. This assumption could be justified by arguing that journals which rank lower in the previous rankings are more applied journals. I do not regard this as a reasonable assumption. Yet, I present this ranking as reference case.

Table 2 gives the correlation between the different rankings (based on

research drives productivity the two growth rates should be the same in the long run. For an illustrative exercise as this one the exact value might be not so important, as the estimates at journal level are quite robust to changes in δ. The correlation between the resulting ranking with $\delta = 0.16$ and $\delta = 0.1$ is 0.99995, the correlation between $\delta = 0.16$ and $\delta = 1/3$ is 0.9996, and the correlation between $\delta = 0.16$ and $\delta = 0.5$ is still 0.9986.

Table 2: correlation of journal rankings

	Inv 3y	Inv* 18y	Imp w	Imp u
Inv 3y	1	0.8963	0.9057	0.8314
Inv* 18		1	0.9924	0.,9001
Imp w			1	0.9302
Imp u				1

journal score). All four rankings are highly correlated, which is quite normal for journal rankings. *Inv* 18* and *Imp w* have the highest correlation. Furthermore, the correlation between the other rankings is considerably lower.

Due to the many assumptions made and due to data limitations the question which ranking reflects welfare gains best is an open one. Controlling for citation quality at article level, however, is a logical evolution in journal rankings. Palacios-Huerta and Volij [8] already mention the desire to control for citation quality at article level. To apply the invariant method to citation data, articles have to be aggregated into some aggregate, for example into journals. Using a long citation period allows articles to build up article specific quality indices before the aggregation takes place.

3.4 Ranking articles

When articles of different age are compared, article scores have to be discounted. Research today creates welfare in the future. Thus we have a standard investment situation. Research which takes longer to affect welfare yields ceteris paribus a smaller return. I consider long-term interest

rates to be the appropriate discount factor. For the following calculations, I assume a real interest rate of 4.2%.

Table 3 compares the rank of articles according to unweighted citations, citations weighted by imprint journal weights (*Imp w*) and article imprint. Citations are restricted to citations from articles published between 2001 and 2003.

Table 3 should be read with cautiousness. The results can be misleading due to the assumptions made, erroneous data, and missing data. I want to illustrate the methodological influence on a paper's rank. It is not my intention to judge the listed papers or any omitted ones. The table reports the ranks of those papers which make it into the top 30 according to at least one method.

Table 3: Rank comparison at article level

article	unweighted citations	weighted citations	imprint
Engle RF; Granger CWJ (ECONOMETRICA, 1987)	106,05 (1)	41,39 (20)	61,93 (8)
Johansen S (J Ec Dyn Contr, 1988)	89,08 (2)	28,39 (49)	33,41 (33)
Lucas RE (JME, 1988)	61,94 (3)	49,66 (9)	89,38 (1)
Newey WK; West KD (ECONOMETRICA, 1987)	55,31 (4)	61,2 (2)	80,34 (3)
Bollerslev T (J Econometrics, 1986)	52,77 (5)	37 (25)	43,48 (20)
Summers R; Heston A (QJE, 1991)	51,67 (6)	44,76 (13)	65,16 (7)
Romer PM (JPE, 1990)	51,65 (7)	34,7 (29)	48,27 (15)
Mankiw NG; Romer D; Weil DN (QJE, 1992)	48,69 (8)	29,52 (43)	33,05 (34)
Johansen S; Juselius K (Oxf. B Ec Stat, 1990)	47,93 (9)	9,1 (759)	14,87 (225)
Romer PM (JPE, 1986)	47,07 (10)	31,53 (37)	79,9 (4)
Johansen S (ECONOMETRICA, 1991)	44,68 (11)	23,09 (82)	21,64 (99)
Perron P (ECONOMETRICA, 1989)	44,32 (12)	16,7 (188)	19,82 (126)

article	unweighted citations	weighted citations	imprint
Barro RJ (QJE, 1991)	41,41 (13)	24,22 (72)	50,45 (11)
Grossman SJ; Hart OD (JPE, 1986)	40,75 (14)	79,15 (1)	88,12 (2)
Kwiatkowski D; Phillips PCB; Schmidt P; Shin YC (J Econometrics, 1992)	38,51 (15)	16,28 (205)	11,52 (394)
Arellano M; Bond S (RES, 1991)	38,34 (16)	34,59 (30)	27,15 (57)
Hamilton JD (ECONOMETRICA, 1989)	33,5 (17)	27,99 (50)	29,03 (52)
Krugman P (JPE, 1991)	30,45 (18)	19,56 (126)	25,35 (69)
Katz LF; Murphy KM (QJE, 1992)	30,19 (19)	47,13 (10)	74,84 (5)
Clarida R; Gali J; Gertler M (JEL, 1999)	30,03 (20)	50,11 (7)	32,41 (36)
Artzner P; Delbaen F; Eber JM; Heath D (Math Finance, 1999)	29,76 (21)	51,49 (6)	26,95 (60)
Kimball MS (ECONOMETRICA, 1990)	28,44 (22)	28,73 (47)	25,67 (66)
Staiger D; Stock JH (ECONOMETRICA, 1997)	27,95 (23)	46,48 (11)	30,31 (46)
Levine R; Renelt D (AER, 1992)	27,02 (24)	14,44 (270)	21,17 (104)
Hanushek EA (JEL, 1986)	26,86 (25)	21,52 (99)	44,76 (18)
Jensen MC (AER, 1986)	26,35 (26)	39,19 (22)	49,18 (14)
Phillips PCB (ECONOMETRICA, 1987)	24,77 (27)	42,59 (16)	61,65 (9)
Osterwaldlenum M (Oxf. B Ec Stat, 1992)	24,58 (28)	7,79 (1051)	6,36 (1217)
Sachs JD; Warner A (Brookings P, 1995)	24,39 (29)	17,15 (178)	15,44 (212)
Deininger K; Squire L (World Bank Ec R, 1996)	24 (30)	16,49 (192)	10,99 (446)
Laporta R; Lopezdesilanes F; Shleifer A; Vishny RW (JPE, 1998)	23,91 (31)	50,09 (8)	43,32 (21)
Hart O; Moore J (JPE, 1990)	22,94 (33)	36,3 (26)	36,7 (29)
Becker GS; Murphy KM (JPE, 1988)	22,51 (36)	36,09 (27)	37,38 (27)
Gilboa I; Schmeidler D (J Math E, 1989)	22,51 (37)	52,66 (4)	40,36 (24)
Binmore K; Rubinstein A; Wolinsky A (Rand J Ec, 1986)	22,24 (39)	32,8 (33)	36,94 (28)
Cho IK; Kreps DM (QJE, 1987)	20,32 (43)	52,89 (3)	50,26 (12)
Kandori M; Mailath GJ; Rob R (ECONOMETRICA, 1993)	19,56 (49)	40,52 (21)	44,24 (19)
Clarida R; Gali J; Gertler M (QJE, 2000)	18,67 (56)	42,52 (17)	24,11 (74)
Young HP (ECONOMETRICA, 1993)	18,46 (60)	44,57 (14)	46,55 (16)
Fama EF; French KR (JFE, 1993)	18,19 (61)	45,72 (12)	40,87 (23)
Andrews DWK (ECONOMETRICA, 1991)	18,13 (63)	37,4 (24)	41,16 (22)
Laibson D (QJE, 1997)	17,3 (71)	43,34 (15)	29,46 (48)
Holmstrom B; Milgrom P (J Law Ec Org, 1991)	16,42 (77)	37,82 (23)	33,73 (32)

article	unweighted citations	weighted citations	imprint
Mcafee RP; Mcmillan J (JEL, 1987)	15,4 (92)	17,14 (179)	39,14 (25)
Milgrom P; Shannon C (ECONOMETRICA, 1994)	14,53 (102)	41,59 (19)	32,64 (35)
Hansen GD (JME, 1985)	13,18 (132)	17,68 (157)	34,82 (30)
Kohlberg E; Mertens JF (ECONOMETRICA, 1986)	13 (137)	35,54 (28)	67,17 (6)
Pakes A; Pollard D (ECONOMETRICA, 1989)	10,37 (228)	52,55 (5)	50,05 (13)
Fudenberg D; Maskin E (ECONOMETRICA, 1986)	9,71 (270)	24,94 (70)	45,71 (17)
Aumann RJ (ECONOMETRICA, 1987)	6,96 (608)	14,59 (260)	38,31 (26)
Dasgupta P; Maskin E (QJE, 2000)	6,22 (752)	42,11 (18)	23,72 (80)
Summers R; Heston A (R Inc Wealth, 1988)	4,31 (1592)	2,36 (5404)	57,71 (10)

The ranking of the last article is striking. Data problems might play a role here, in particular the limitation of citations to the set of available articles. Other articles (e.g. Johansen and Juselius, Osterwaldlenum, Aumann, or Dasgupta and Maskin), however, show that substantial differences in the rankings are not unusual. Considering that all rankings are based on the same data, the differences are remarkable. Older articles are ranked particularly high under the imprint method. But this should come at no surprise, because older articles had more chances to get cited.

The question which method performs best is probably personal judgment. Taking into account the high variation of article quality within a journal (see for example Oswald [7]), the imprint method should provide a more reliable estimate of article influence compared to weighted citations. The imprint method also makes strategic manipulations less attarctive, as it is less obvious who will benefit from a manipulation in the end.

4 Conclusion

The main message of this paper is clear: if we want to make research more efficient, we have to consider research output as value added to society. If we do not succeed in measuring research output in a reliable way, we will not be able to allocate resources efficiently between disciplines. Nor will we be able to determine the efficient size of the research sector.

This paper presents a method to allocate output within the academic sector. Given this tool, we are able to assess article imprint, the impact of articles on (current) research.

This paper provides two instant benefits. First it shows that considering long citation periods has a major impact on journal rankings. As old articles are still used for current research, there is no reason to disregard those articles in journal rankings. Using longer citation periods also eliminates distortions for researchers and editors to focus on hot topics. Moreover, using long citation periods undermines incentives for manipulation. The second instant achievement of this paper is that it improves the efficiency of the invariant method by controlling for citation quality at article level.

Two main problems remain. Output has to be measured in some reliable way. The paper by Nederhof and Meijer [6] is a start, but more research is needed to assess channels of knowledge transfer and the value of this transfer. Furthermore citation relevance has to be addressed. If all citations count equally, citation analysis will remain of limited value. With regard

to the future, researchers could start to classify their references just like we use to indicate the statistical significance in regression output. Those classifications can then be used in citation analysis.

The availability and comprehensiveness of citation data still constitutes a problem. This should, however, become a problem of the past as standardizations like the Digital Object Identifier (DOI®) System become more widespread.

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