The relation between the quality of research, researchers' experience, and their academic environment

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Abstract

This article investigates to what extent researchers' experience and the solidity of their academic environment influence the quality of their research. The hypotheses are derived from the assumptions that experience matters for quality research and that there are great intellectual synergies to be obtained from interacting with many colleagues who are active researchers. All articles published between 2000 and 2006 in five leading transportation journals are included in the analysis, and their research quality is measured by the number of times each article is cited by August 2016. Controlling for other factors influencing citations, such as article age and the number of references, the most important finding is that both experience and academic environment matter for performing quality research. When the authors' experience, measured by the number of previous publications, increases by 1% from its average level, their published articles are expected to garner 0.31% more citations. Moreover, when the research activity at the unit to which the authors are affiliated, measured by the unit's total number of publications, increases by 1% from its average level, the number of times their articles are cited will increase by 0.19%. This signals that, relatively speaking, the researchers' own experience and merits mean more than the academic environment with regard to producing high-quality research. The above results enable us to discuss how researchers' experience can compensate for working in less active academic communities holding research quality constant.

Introduction

Discoveries made through research have changed the lives of people worldwide and have altered our understanding of the world (Kunnskapsdepartementet 2014). That such implications can arise from high-quality research makes the following question vital for designers of research policy: What is the relationship between quality research and both the experience of researchers and the quality of their academic environment?

A positive relationship between research performance and experience has been confirmed in earlier studies using age (Bonaccorsi and Daraio 2003) or past research merits (T.- E. S. Hanssen and Jørgensen 2015) as indicators of experience. Although this relationship is not very close due to different talents among researchers, there seems to be a consensus that experience is important.

In addition to the researchers' talent and experience, the dominant driver of research quality is the number of researchers with whom an individual is able to communicate (Kenna and Berche 2011). Because learning always occurs in and cannot be separated from a social context (Vygotsky 1962), researchers' performance is influenced by intellectual synergies that occur when researchers interact (Stankiewicz 1979). Since the number of possible interactions between department members increases exponentially with department size (Wallmark et al. 1973), it can be assumed that large research departments will produce higher quality research than smaller ones (Kyvik 1995). However, it should be noted that the information technology currently available has made it easier for researchers to get in contact (Ebadi and Schiffauerova 2015), which likely reduces researchers' dependency of being part of a large research department in order to produce high quality research.

Empirical evidence is somewhat mixed with respect to the relationship between research output and department size (Vabø and Kårstein 2014). This could be due to the results of two forces pulling in opposite directions. First, intellectual synergies can arise as increasing department size expands the number of possible interactions between researchers. On the opposite side is the Ringelmann effect, which suggests that the productivity of individual group members is reduced as the size of their group increases (Ringelmann 1913). The Ringelmann effect has been explained as being due to a loss of coordination, or motivation, or a combination of the two (Steiner 1972).

It is reasonable to assume that greater intellectual synergies arise from communicating with active, as opposed to inactive, researchers. This suggests that the potential for intellectual synergies at a department is more dependent on the extent to which the researchers publish regularly than on its number of employees. In this study, we therefore assume that the total number of publications at a research unit is a better indicator or measure of the intellectual synergies than its pure number of researchers.

This article investigates to what extent research performed by experienced researchers working in departments with high research activity is of higher quality than research from less productive departments by inexperienced researchers. In line with the arguments of Diamond (1986), we will use the number of times an article is cited as a measure of its scientific quality or influence. Citing another article strongly indicates that the articles was useful for the research (Woelert 2013), and Bertocchi et al. (2015) supports the use of bibliometric data to evaluate articles' quality. Using Italian data, Bertocchi et al. (2015) concluded that there is no evidence of systematic differences between bibliometric ranking of articles and their peer review evaluations by experts. Similarly, Patterson and Harris (2009) find that a paper of the highest quality, as measured by independent experts as part of a normal peer review process, is about 10 times more likely to be found in the most cited quintile than in the least cited quintile.

It should however be noted that the use of citations as a proxy for research quality is open for debate. Research is cited for a variety of reasons (Garfield 1998), several of which are not positively related to the quality of the work cited. Such reasons include: to provide leads to poorly disseminated, poorly indexed, or uncited work; to disclaim the work of other scientists; or to dispute claims made by other scientists (see Garfield 1962).[1] Some researchers therefore consider that citation counts more as a measure of impact (Martin and Irvine 1983) or visibility (Horta et al. 2016), and not so much a measure of research quality.

Although there is no perfect association between the quality of research and how frequently it is cited, we will, as did the Norwegian Productivity Commission (NOU: 2016: 3 2016), use citation counts as a measure of quality in research. Since researchers have incentives to cite their own research to improve its visibility, and not so much because of its quality, all self-

[1] A thorough review on citing motives is provided by Bornmann and Daniel (2008).

citations are excluded from our analyses. This further strengthens the argument for using citation counts as a proxy for research quality.

A department's research activity within the field of transport is operationalised by the total number of previous publications in five central peer-reviewed transportation journals by the members of the research department in question; that is the department where each author is employed. Finally, authors' research experience is measured by the total number of scientific articles they have published previously. Because, we can expect that, all else equal, the authors of multi-authored articles will have a higher number of previous publications than authors of articles without co-authors our definition of research experience also captures the effect of scientific collaboration. This is particularly important as recent studies, based on data from various research fields and timeframes, tend to find that collaborative research is more cited than non-collaborative research (Lariviere et al. 2015; Ronda-Pupo and Katz 2016; Gazni and Didegah 2011).

Consequently, we can examine the relative importance for quality research of experience compared to operating within robust and active academic communities. In doing so, we also control for various author, article and journal characteristics, which earlier studies have shown to affect the number of citations (for a review see: Bornmann and Daniel 2008). The analysis is based on data from 433 transport research departments worldwide. All articles published between 2000 and 2006 in five leading transportation journals are included in the analysis, and their citation counts are checked by the start of August 2016.

The remainder of this article is organised as follows. Section 2 presents the literature and hypotheses on how different factors influence how often an article is cited, with a special emphasis on the importance of the research activity at the authors' workplace and their own research experience. Moreover, a description of how all of the variables used are operationalised and defined is presented. The data used and the model's specification and interpretation are presented in Section 3, followed by the estimation results in Section 4. Finally, in Section 5, the findings are discussed and summarised.

Factors associated with citation counts

We will henceforth divide the explanatory factors that we assume influence how often an article is cited (its quality) into the following four groups: (1) the academic environment of the department in which the researchers operate, (2) the researchers' academic experience, (3) characteristics of the article and (4) journal characteristics.

The quality of the academic environment

Experienced researchers with long publication lists have higher levels of human capital and produce research of higher quality than less experienced researchers (T.- E. S. Hanssen and Jørgensen 2015). Hence, it is reasonable to assume that the collective human capital is higher in research departments whose members have published extensively than in units whose members have published few scientific articles. Human capital spillover makes it likely that a researcher will become more productive, that is, produce higher quality research, the more research-active his colleagues are. However, the marginal effect on research quality of a better research environment is likely to diminish rapidly.

In this study, the quality of the research environment in which the researchers operate, that is, the collective human capital of their colleagues, is measured by the weighted sum of scientific publications produced by the staff in the five leading transportation journals at their unit (PI) in the 5 years preceding the given article publication date. In our data, if, for example, the authors published an article in 2003, we count the total number of publications by the staff during the period from 1997 to 2002. As it normally takes 1 to 2 years from the beginning of writing an article until it is published, this means that the authors are working on it during the same period as PI is measured.

Note that this definition of quality implies that measures of research such as patents, extramural funding, national science awards, technology transfer to industry and the creation of spin-off companies are not included in PI. To gather data on these measures would require an overwhelming effort. We consider, thus, peer-reviewed scientific articles as the main research output from research departments, which is reasonable, at least regarding those who work in social sciences and humanities departments.

The five journals analysed are Transportation (*TR*), Transportation Research Part A (*PA*), Transportation Research Part B (*PB*), Transportation Science (*TS*) and Journal of Transport Economics and Policy (*JT*). PI is defined as

$$(1)\ PI = N_{JT} + v_{PA}N_{PA} + v_{TR}N_{TR} + v_{PB}N_{PB} + v_{TS}N_{TS}$$

in which N_{JT}, N_{PA}, N_{TR}, N_{PB} and N_{TS} denote the number of publications in JT, PA, TR, PB and TS, respectively. The weights (v −values) indicate the different journals' relative three-year impact factors compared to the impact factor of JT. PI is thus research production measured in JT-equivalents.[2]

It is notable that the value of *PI* depends on both the number of researchers at the unit and how productive each is. Hence, a high (low) *PI* at a unit can be the result of many (few) employees affiliated with it and/or many (few) publications per employee. Consequently, the quality of the academic environment will, according to our definition, be the same and will equal the level *PI*=15 if five researchers publish three articles each as when three researchers publish five articles each.

From the discussion above, we assume that the number of citations an article achieves (CI) increases concavely with *PI*, meaning that the effect on *CI* from one unit increase in *PI* is positive but diminishes as *PI* increases.

Authors' characteristics

A recent study has found that research by experienced researchers tends to be more frequently cited than research by inexperienced researchers (T.- E. S. Hanssen and Jørgensen 2015). More precisely, they concluded that the number of times an article is cited (CI) increases concavely with the total number of previous publications by the authors (PP). This result supports Becker's well-known work from 1964, which states that on-the-job training is one of the most important investments that can be made in human capital (Becker 1964). Individuals with more or higher quality human capital achieve higher performance and, therefore, it is reasonable to

[2] From SCImago (2015), we deduced the following values of the weights: $v_{PA} = 1.131, v_{TR} = 1.261, v_{TS} = 1.405$ and $v_{PB} = 1.556$. A similar method has been used in Norway to measure the research activity (publication points) at different universities and colleges; see Aagaard et al. (2014).

assume that experienced researchers will produce higher quality research, which, in turn, will be more frequently cited.

The second author characteristic controlled for is the alphabetical position of the first authors' surname (AN). Articles written by authors whose surname begins with a letter close to the beginning of the alphabet have been found to be more frequently cited than articles written by authors whose surname is at the end of the alphabet (Tregenza 1997; T.- E. S. Hanssen and Jørgensen 2015). It has been suggested that "alphabetical discrimination" occurs because the search results in abstract and citation databases can be sorted according to the alphabetical position of the first author's surname. Moreover, reference lists are often sorted alphabetically, and it could be that researchers who look through the reference lists "have had their fill before they reach the end" (Tregenza 1997). Hence, articles written by authors whose surname begin with a letter close to the beginning of the alphabet have greater visibility, increasing the likelihood that the article is cited. In summary, based on the above findings, we expect that CI decreases as AN increases.[3]

Article characteristics

Evidence suggests a positive (see e.g. Abramo and D'Angelo 2015; Beaver 2004; Aksnes 2003), and increasing (Wuchty et al. 2007), association between an article citability and the number of authors. The relationship could be due to the authors having different scientific influences (Onodera and Yoshikane 2015), that is, the larger scientific network of n+1 authors, than that of n authors only (T-E S Hanssen and Jørgensen 2014). In addition, multi-author articles might benefit from a division of labour (T.- E. S. Hanssen and Jørgensen 2015). Although there are examples of studies where the relationship between the number of authors and citations is weak or insignificant (T.- E. S. Hanssen and Jørgensen 2015; Walters 2006), we expect to find a positive relationship between the CI and NA .

Several works conclude that, all other things being equal, articles with long reference lists are cited more frequently than articles with short reference lists (e.g. Lokker et al. 2008; T-E S Hanssen and Jørgensen 2014). The positive association between the number of times an article can be expected to be cited (CI) and its number of references (RF) has been interpreted as an

[3] It is obvious that the value of AN has nothing to do with an article's quality. This reveals one weakness of using citation counts as a quality indicator.

indication that references make articles more visible in electronic databases (Didegah and Thelwall 2013). Moreover, it has been suggested that authors tend to cite the works of their ex-citers (Webster et al. 2009; Stremersch et al. 2007).

An article's title has been labelled the most important element of scientific articles (Jamali and Nikzad 2011). The title is an important marketing tool of which the primary function is to draw the reader's attention and provide a foretaste of the article's content. Consequently, the title can influence the initial selection or rejection of an article (Yitzhaki 2002). With regard to how the number of words in an article's title influences citation counts, two arguments in opposite directions can be made. First, articles with shorter titles could be more frequently cited because long or confusing titles can act as deterrents to further reading (Vintzileos and Ananth 2010). However, longer titles are more likely to contain any given search term in electronic databases (Subotic and Mukherjee 2014). Both arguments gain support from empirical studies (see Paiva et al. 2012; Jamali and Nikzad 2011; Habibzadeh and Yadollahie 2010), and this makes it difficult to form a clear presumption regarding how the length of an article title (WT) influences its citation counts.

Finally, because citations accumulate over time, older articles are more frequently cited than newer articles (T.- E. S. Hanssen and Jørgensen 2015; Bergh et al. 2006; Judge et al. 2007). Consequently, the number of times an article is cited (CI) increases with the number of years since its publication (YP).

Journal characteristics

The academic threshold level for an article to be accepted varies greatly between journals. As a result, the average citation rate of the journal in which an article is published has been found to be the single most important factor driving citations (Judge et al. 2007; Vanclay 2013). To control for the prestige and average citation rate of the journals from which the articles analysed in this study were derived, four dummy variables, representing the journals, were included in our model.

From the discussion about the v-values, in Section 2, we would expect the following citation ranking of published articles: Transportation Research Part B > Transportation Science > Transportation > Transportation Research Part A > Journal of Transport Economics and Policy.

Data and model specification

The data

The data used in this study are drawn from the five above-mentioned journals, which are the most highly recognised peer-reviewed transportation journals internationally. The data were collected from Scopus, the world's largest abstract and citation database of peer-reviewed literature (www.scopus.com). Data on articles published in the five journals mentioned from January 1st, 2000, to December 31st, 2006, were analysed by the start of August 2016. The 7-year period from 2000 to 2006 was chosen because it allows sufficient time for the articles to prove their true merit by the middle of 2016.

A summary of the variables is presented in Table 1. The dependent variable (CI) is the number of times each article in our dataset had been cited in Scopus by the start of August 2016, that is, between 10 and 16 years after the articles were first published.

Table 1 shows that articles published in these five journals between 2000 and 2006, on average, were cited 45 times by the start of August 2016 and had 26 references and 11 words in the title.[4] The authors of a representative article had previously, in total, published 52 refereed articles (not only in transportation journals), and their colleagues had, in total, published 13 *JT*-equivalents in the selected transport journals in the 5 years prior to the article being published. Moreover, the proportion of articles from each of the journals ranges from 11% in JT to 28% in both PB and in PA.

Although Scopus is the world's largest abstract and citation database of peer-reviewed literature, there is a disadvantage regarding older articles. It has been reported that the database is not complete for the years prior to 1995 (Neuhaus and Daniel 2008). As a result, for some of the most experienced researchers, that is, those who published articles prior to 1995, our dataset might underestimate their PP values. Moreover, the articles studied in this manuscript might have received citations in publications that are not covered by Scopus. Despite these caveats, we believe we have collected a good and unique dataset for the purposes of our study.

[4] The five journals from which the articles analysed in this study were drawn are all in the top quartile of 119 transportation journals as ranked by SCImago (2015). This confirms that our selected journals are of good quality.

Table 1 Summary statistics of the dataset. Number of observations = 1121.

Variable code	*Definition*	*Mean*	*S.D.*	*Min*	*Max*
CI	Number of citations per article by August 2016	45.31	53.55	1	518
PI^a	Weighted sum of previous publications by the staff in the five transport journals, measured in JT-equivalents	12.50	14.48	0	85.54
PP	Experience, measured by the total number of prior publications by the authors in all refereed journals	52.14	61.23	0	594
AN^b	Place in alphabet of first author's surname	10.83	7.24	1	26
RF	The number of references	26.49	16.48	0	167
NA	The number of authors	2.24	0.95	1	8
WT	Words in title	10.58	3.53	1	27
YP	Years since publication	12.80	2.00	10	16
TR	Transportation, TR = 1 if published here, TR = 0 otherwise	0.14	0.35	0	1
PA	Transportation Research Part A, PA = 1 if published here, PA = 0 otherwise	0.28	0.45	0	1
PB	Transportation Research Part B, PB = 1 if published here, PB = 0 otherwise	0.28	0.45	0	1
TS	Transportation Science, TS = 1 if published here, TS = 0 otherwise	0.19	0.40	0	1
JT	Journal of Transport Economics and Policy, JT = 1 if published here, JT = 0 otherwise	0.11	0.31	0	1

[a] Number of JT-equivalents in the 5 years preceding the given article's publication date.
[b] Articles written by authors whose surname begin with the letter A are given the value 1, an author whose surname begins with the letter B is given the value 2, etc.

Model specification and interpretation

As a starting point, we regress *CI* on the explanatory variables. The diagnostic plots of this regression show that the distribution of the residuals is highly skewed to the right, and that the variance of the residuals clearly depends on the fitted values. Thus, we have log-transformed *CI* to make the distribution of the residuals more symmetric and to stabilise the error variance (see e.g. Fox 2016). A power transformation of CI ($CI^{1/8}$) makes an even more symmetric distribution of the residuals, but because it produces very similar results in the regression, we prefer the more easily interpreted log transformation. This means that we have to leave out the 12 articles with *CI*=0 from our data set of 1133 articles, when running the analysis. Naturally, these 12 zero observations may be included in the data set if the power transformation is chosen. However, in that case, these 12 observations appear as outliers which deviate markedly from the other observations. The main effect of including these points in the regression of $CI^{1/8}$ is that the result of the regression is somewhat disturbed. We may account for an abundance of zeros in the response variable by using a hurdle model or a ZIP model (Smithson and Merkle 2013). However, only 12 zero observations of a total of 1133 observations is hardly an abundance of zeros, and 12 zero observations are too few to get good estimates of the coefficients of the zero part of the model. Consequently, we stick to the model with the log transformation of CI.

Furthermore, the component-plus-residual plots of the regression of ln*(CI)* on the explanatory variables also show that the distributions of *PI, PP* and *RF* are heavily skewed to the right, and that the partial relationships between ln(*CI*) and each of these variables seem to be nonlinear. Therefore, we linearise these relationships by moving *PI, PP* and *RF* down the ladders of powers intruding the transformed variables $PI^{\tau_{PI}}$, $PP^{\tau_{PP}}$ and, $RF^{\tau_{RF}}$ where $(0 < \tau_{PI}, \tau_{PP}, \tau_{RF} < 1)$, in the model (see Fox 2016). For neither specification of the model did the number of authors (*NA*) contribute significantly. This results probably from the fact that the effect of *NA* on *CI* is captured in the *PP* variable; the correlation between *PP* and *NA* is 0.44 and highly significant. Thus, in order to analyse the impact of the different explanatory variables on an article's citation count, the following modified power model is employed:

$$(2) \quad \ln(CI) = \beta_0 + \beta_{PI}PI^{\tau_{PI}} + \beta_{PP}PP^{\tau_{PP}} + \beta_{RF}RF^{\tau_{RF}} + \beta_{AN}AN + \beta_{WT}WT + \beta_{YP}YP + \beta_{TR}TR + \beta_{PA}PA + \beta_{PB}PB + \beta_{TS}TS + \varepsilon$$

When choosing power transformations of *PI, PP* and *RF* such that the distributions of these variables are symmetric, (i.e. $\tau_{PI} = 0.38$, $\tau_{PP} = 0.31, \tau_{RF} = 0.37$) the component-plus-residual plots of this new regression do not show any nonlinear partial relationships between ln*(CI)* and the regressors.

It follows from the hypotheses presented earlier and the mathematical properties of the model (see appendix) that $\beta_{AN} < 0$; that is *CI* decreases when *AN* increases. Moreover, the earlier discussion suggests that the sign of β_{WT} is uncertain. The remaining independent variables are assumed to have a positive impact on the number of citations. Therefore, we expect to find that $\beta_{PI}, \beta_{PP}, \beta_{RF}, \beta_{YP}, \beta_{TR}, \beta_{PA}, \beta_{PB}, \beta_{TS} > 0$. Our earlier assumptions also suggest that $\frac{\partial^2 CI}{\partial PI^2}, \frac{\partial^2 CI}{\partial PP^2} < 0$. These conditions are fulfilled when τ_{PI} and τ_{PP} are set to the stated values above. Our stated assumptions concerning the magnitudes of the five journals' impact factors also suggest that $\beta_{PB} > \beta_{TS} > \beta_{TR} > \beta_{PA}$. It is notable that the assumed signs of β_{YP} and β_{AN}

imply that CI increases convexly with YP and decreases convexly with AN. Whether CI increases convexly or concavely with RF is, however, uncertain with the restrictions placed on the parameters.

Our model formulation in (2) suggests that the values of the β parameters can, for example, be interpreted in the following way:

- An increase in PI and PP by one percent will always increase CI approximately by $(\beta_{PI} \cdot PI^{\tau_{PI})}$ and $(\beta_{PP} \cdot PP^{\tau_{PP}})$ per cent, respectively. Because $0 < \tau_{PI}, \tau_{PP}$ the elasticities above will increase when PP and PI increase.

- An increase in RF by one unit, will always increase the value of CI by approximately $(100 \cdot \beta_{RF} \cdot RF^{\tau_{RF}-1})$ percent.

- An increase in j, $j = \{AN, YP, WT\}$ by one unit will always increase CI by approximately $(100 \cdot \beta_j)$ percent.

Let us examine more closely the substitution possibilities between PI and PP as far as the quality of published research is concerned. They are complementary factors because more of one increases the marginal effect of the other. Equation (2) implicitly defines PP as a function of PI for given values of $CI\,(CI^*)$ and of the other explanatory variables $(AN^*, RF^*, WT^*, YP^*, TR^*, TA^*, TB^*, TS^*)$; that is,

(3) $PP = F(PI)$

The $F(PI)$ function is convexly decreasing in PI and shows combinations of PP and PI that yield the same number of article citations (CI). From Equation (2), we can deduce the marginal rate of substitution (MRT) between PP and PI (see appendix):

$$(4) \qquad MRT = \frac{\partial PP}{\partial PI} = -\frac{\beta_{PI}}{\beta_{PP}} \cdot \frac{\tau_{PI}}{\tau_{PP}} \cdot \frac{PP^{1-\tau_{PP}}}{PI^{1-\tau_{PI}}}$$

MRT shows the rate at which the academic environment or research activity at the department where the researcher works (PI) can be substituted for his experience (PP) while holding the quality of his research (CI) constant. If PI increases by one unit, PP can decrease by $\frac{\partial PP}{\partial PI}$ units provided that the quality of the published articles is constant.[5]

Estimation results and interpretation

Model diagnostic and parameter values

Table 2 presents the multiple regression estimates for Equation (2) using 1121 articles published between 2000 and 2006 in the five transportation journals. The F-value of 26.29 shows that the model is significant at the 1% level. The explanatory power of the chosen variables (R^2) is 0.19, meaning that the model explains 19% of the variance in citation counts for the 1121 articles.

Model diagnostics do not indicate serious problems with our model. The variance inflation factor (VIF) ranges from 1.02 to 2.79; this is well below 10, at which level one would begin to worry about multicollinearity (Hair 1998). The Breusch-Pagan test for heteroscedasticity suggests that the data does not violate the constant variance assumption. However, the Shapiro–Wilk test for normality shows that we can reject the assumption of normally distributed residuals. This is not a major concern due to our high number of observations (Fox 2016), and it is confirmed by robust regression of our data. The average residual value is approximately zero, and the residuals are not correlated with any of the explanatory variables. We have estimated cluster-robust standard errors by using each article´s author with the largest PP as cluster variable. The most notable change when using these cluster-robust standard errors instead of the standard errors from the regression above is that the *p*-value of the PP-term is changed from 0.0026 to 0.016, such that the coefficient of this term is no longer significant at the 1% level. In conclusion, the properties of the model appear to be statistically valid, thus indicating that the estimation results can be trusted.

[5] The MRT defined here is equivalent with the concept “marginal rate of technical substitution.” It is an important concept when it comes to describing the characteristics of different production functions. See, for example, Nicholson (1998).

The rather low R^2-value may partly come from imprecise data and partly from omitted explanatory variables. As far as the collected data is concerned, we have previously emphasised that Scopus may give uncertain values of the number of times an article is cited (*CI*). The operationalisations of the academic environment (*PP*) and authors' experience *(PI)* are debatable and may, thus, cause disturbance in the model's results. The other explanatory variables are, however, more precise and should not be major sources of uncertain model results. More important is the omission of relevant explanatory factors like the authors' inclination to present the results of their upcoming articles among peers at conferences and their subsequent ability to market the results of the published articles in the media. Moreover, the topic that each article deals with matters. The five transportation journals analysed here cover a wide range of transport subfields that attract various degrees of attention from researchers as well as funding bodies. Articles dealing with popular issues that are easy to get funding for during the period in question (e.g., environmental issues and congestion problems) will attract many readers and consequently achieve many citations.[6] Whether this argument weakens *CI* as a measure of an article's quality is, however, not obvious. One could argue that papers discussing issues that society determines relevant and interesting, in isolation, signal good quality.

Table 2 Model estimation results. The dependent variable is the number of citations per article (*CI*). (N=1121, R^2=0.19, F=26.29***)[ab]

	Coefficient		
$PI^{0.38}$	0.073	***	(2.75)
$PP^{0.31}$	0.091	***	(3.02)
AN	-0.013	***	(-2.97)
$RF^{0.37}$	0.446	***	(10.64)
WT	-0.007		(-0.83)
YP	0.068	***	(4.43)
TR	0.457	***	(3.68)
PA	0.788	***	(7.12)
PB	0.949	***	(8.38)
TS	0.843	***	(7.09)
Constant	0.029		(0.10)

[a] Level of significance: *** indicates $p < 0.01$, ** indicates $p < 0.05$, * indicates $p < 0.10$ (two-tailed).
[b] Values in parentheses are *t*-statistics.

[6] Problems of ranking researchers' merits across different fields are discussed in Perry and Reny (2016).

Finally, it is worth mentioning that articles that aim to review the state of the art of an issue and are written by well-known researchers normally receive many citations. One example in this respect is the article in our dataset with the largest citation count (518) entitled "The mixed logit model: the state of practice," written by Hensher and Greene (2003).

Further discussion of estimation results

All estimated coefficients have signs in the hypothesised direction, and all of them except β_{WT} and the constant term are statistically significant at the 1% level or better. More precisely, the estimations show the following:

- A 1% increase in research activity *(PI)* at the unit to which the authors are affiliated and in previous publication by the author *(PP)* will increase the number of times an article is cited by 0.19 and 0.31%, respectively when *PP* and *PI* have their average values.

- One additional reference (*RF*) will increase the number of times an article is cited *(CI)* by 5.7% taking the average value of *RF* as a starting point.

- The value of $\beta_{AN} \approx -0.01$ suggests, for example, that articles with a first author whose surname begins with the letter B or C, will, all other things being equal, receive 1% and 2% fewer citations, respectively, than articles with a first author whose surname begins with the letter A.

- The value of $\beta_{YP} \approx 0.07$ means that an article published in year *t-1* can be expected to receive 7% more citations than an article published in year *t*.

- Finally, the most cited articles in our sample are, on average, those published in Transportation Research Part B (PB), followed by the articles published in Transportation Science (*TS*), Transportation Research Part A (PA) and Transportation (*TR*). The articles published in PB, TS, PA and TR are, respectively, cited 95%, 84%, 79% and 46% more times than articles published in Journal of Transport Economics and Policy (JT).

- We cannot conclude at a reasonable statistical level that the number of words in the title (*WT*) influences the number of times it is cited (*CI*).

The model results are further illustrated in Figures 1, 2 and 3. Figure 1 shows the relationship between the number of times an article is cited (CI) and the research activity within transport at his or her affiliation (PI) when all other regressors have their average values.

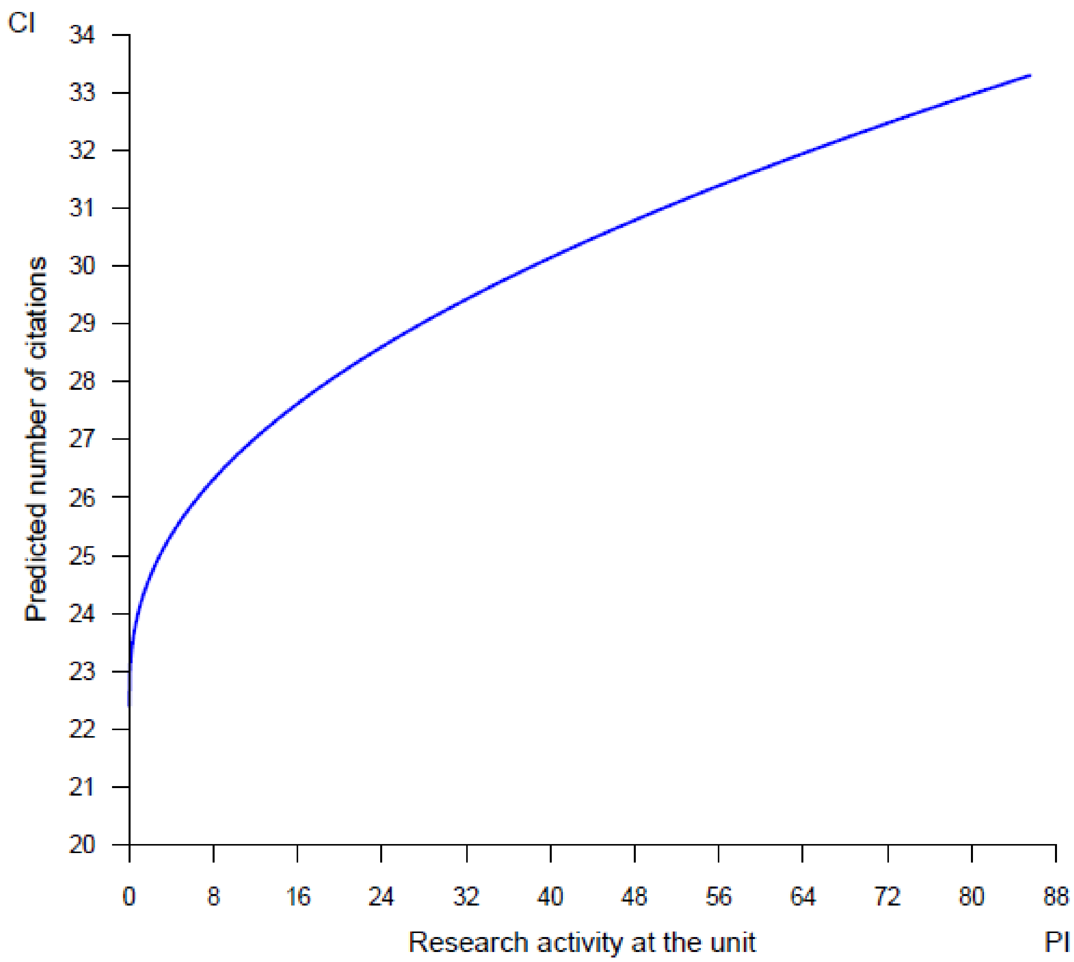

Figure 1: The relationship between the expected number of citations (CI) and research activity at the institution with which the researchers are affiliated (PI) when all regressors except $PI^{0.38}$ have their average values.

The figure illustrates that CI increases concavely with PI. An average article published in these five journals will, approximately 13 years after publication, have been cited on average 24.1

times if the authors work at a department with very little research activity in transportation (PI=1). In comparison, an article written by authors affiliated with units that have a total PI-value of 25 (double the average) will be cited, on average, 28.7 times during the same 13-year period, that is, 19% more citations than an article by authors from institutions with very low research activity (PI=1). Figure 1 neatly illustrates, however, how the marginal effect of PI on CI diminishes rather quickly.

Figure 2 shows how the number of times an article is cited (CI) is influenced by the authors' experience, measured by their total number of previous publications (PP). Similar to Figure 1, we assume that all other regressors have their average values. Thirteen years after being published, articles written by authors with, for example, one and 104 previous publications (double the average), will be cited, on average, 22.8 times and 30.6 times, respectively. Hence, an article written by a researcher with double the average number of published articles can be expected to receive approximately 34% more citations than an article written by inexperienced ones. Similar to PI, the marginal effect on CI of increasing PP diminishes rapidly. These results are broadly in line with Hanssen and Jørgensen (2015).

Using formula (3), the substitution possibilities between research activity where the researcher is affiliated (PI) and his own research experience (PP) is deduced when $AN, RF, WT, YP, TR, PA, PB$ and TS have their average values and for the following three levels of article quality (CI): 26 citations, 28 citations (median value) and 31 citations. Along each of the three curves, the quality of the article, measured by its number of citations, is constant. The figure shows, for example, that rather inexperienced researchers $(PP \approx 5)$ working in active academic environments $(PI \approx 59)$ can produce the same median research quality $(CI = 28)$ as very experienced researchers $(PP \approx 77)$ affiliated with poor academic units $(PI \approx 6)$.

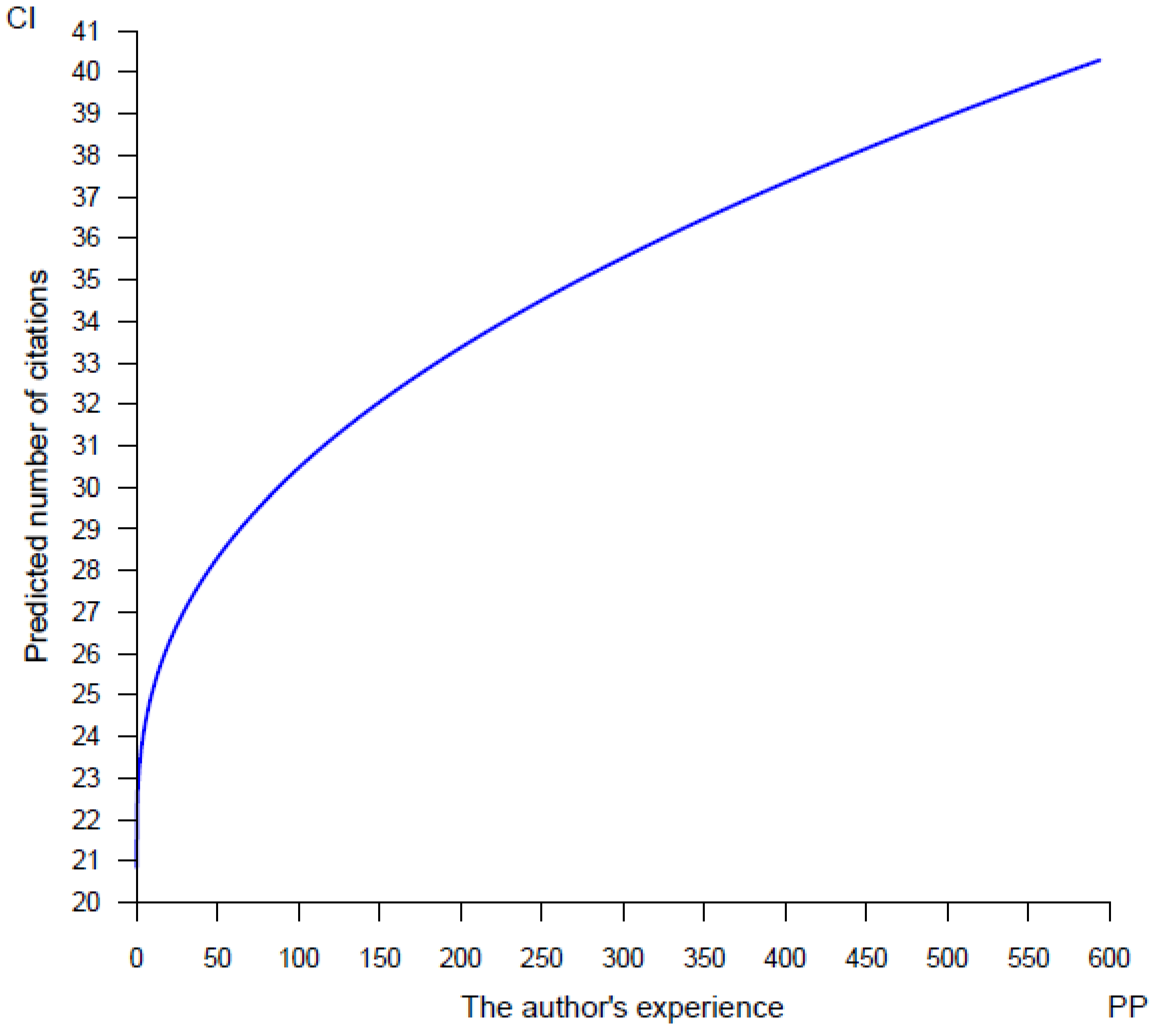

Figure 2: The relationship between the expected number of citations (CI) and the number of previous publications by the authors (PP) when all regressors except $PP^{0.31}$ have their average values.

The slope of these curves shows the rate at which PI can be substituted for PP (MRT). It follows from equation (4) that in the two above-mentioned points on the curve for the median research quality *(CI=28)*, *MRT* is equal to -0.24 and -6.49 when *PI* is equal to 6 and 59, respectively. This means that researcher's experience, measured by the total number of articles they have previously published (*PP*), can be reduced by 6.49 when the research activity at their workplace (*PI*) increases from 6 to 7, when holding the quality of their published articles constant at the median level. However, when *PI* increases from 59 to 60, then *PP* can only be reduced by 0.24, still holding the quality of their published articles constant at the median level.

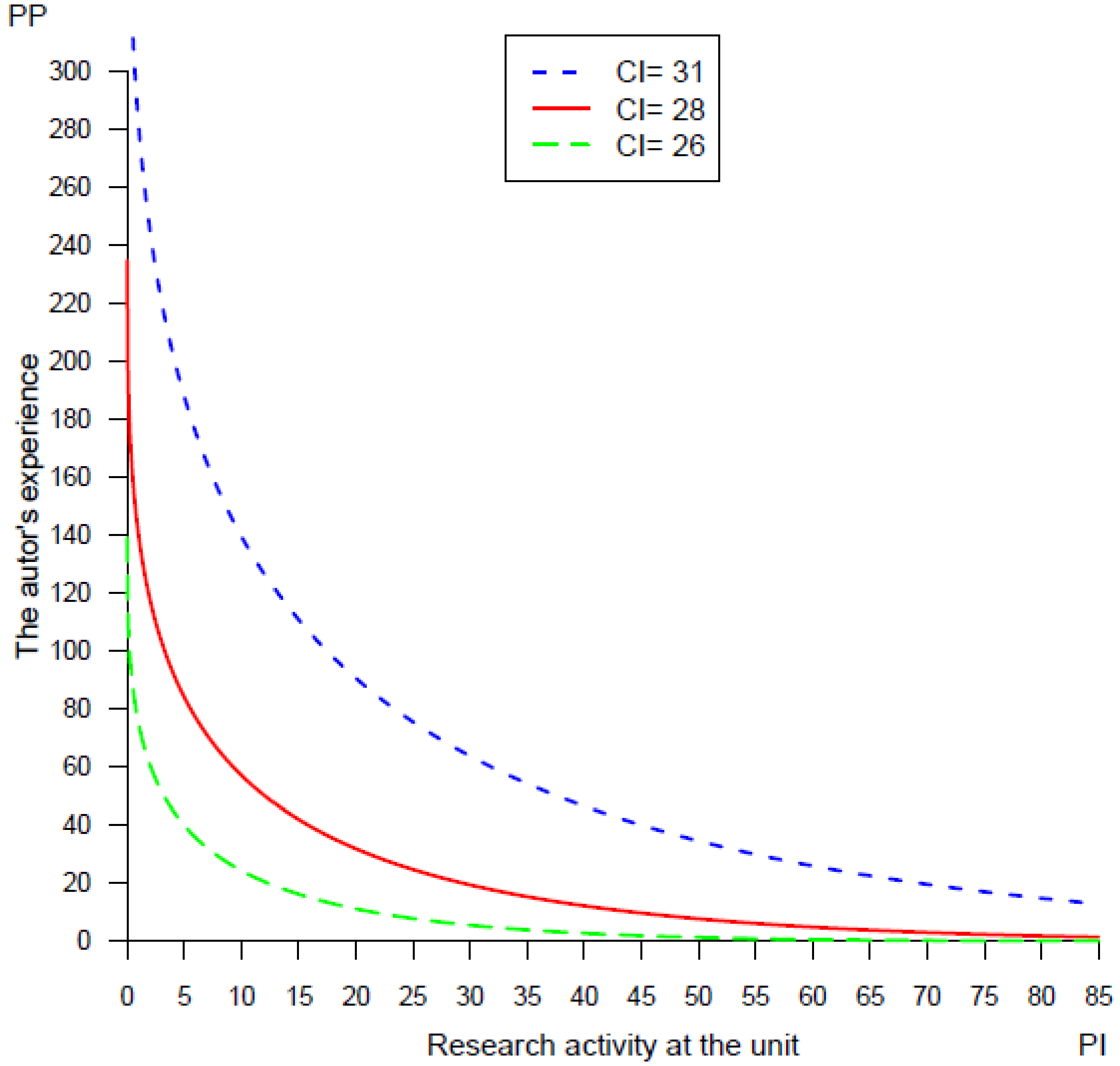

Figure 3: Estimated substitution possibilities between the author's experience (PP) and research activity at the author's workplace (PI) for three different article quality levels.

Limitations of the study

We find it important to emphasise that our work has, like all empirical studies, several weaknesses due to erroneous data reports, the validities of the variables and model misspecification. As far as the operationalisation and validity of the most important variables are concerned, first, we have used the number of times articles are cited (CI) 10 to 16 years after they have been published as an indicator of their quality. Although citation counts are a common measure of article quality (Diamond 1986) and seem to coincide with peer review evaluation by experts (Bertocchi et al. 2015) it has some weaknesses. A highly cited paper may also, as mentioned earlier, arise from it being massively promoted by the authors towards peers and because it deals with popular issues. To what extent the last argument weakens CI as a quality measure is, as mentioned earlier, open to debate. Moreover, in line with earlier studies (Tregenza 1997; T.- E. S. Hanssen and Jørgensen 2015), this study also shows that the place in the alphabet of the first author surname (AN) influences an article's citation counts. The value of AN has apparently nothing to do with the quality of an article. It should also be noted that some articles may be "discovered" when they are older than 16 years.

Second, the researchers' experience (PP) and the quality of the academic environment in which they work (PI) are described by the previous number of total publications by themselves and by their peers in five leading transportation journals, respectively. For disciplines such as sciences and engineering, the values of PP and PI may be more reliant on time spent in laboratories and the laboratories' standard. The total number of previous publications by the authors (PP) may also be an imprecise indicator of experience because their involvement in each article, as well as the article's total workload varies greatly.

Third, it should be noted that our analysis is based on publications in only the field of transport economics such that it may be questioned whether our results are valid for research generally. Our results might be most relevant for the social sciences and humanities, in which the number of published articles is the most visible signal of research production. In this respect, we find it also worth noting that transport economics is an old and important subfield within economics; quite a few prominent academic economists like Daniel McFadden[7] and Kenneth Small have written break through articles within economics, taking issues from transport as starting points.

However, we think neither of the abovementioned weaknesses of our work is very serious. A good indicator in this respect is that the estimation results are, broadly speaking, in line with accepted theories and common sense. They also coincide with earlier empirical studies regarding the influence of some article and journal characteristics on an article's citation counts. Finally, the statistical properties of the model do not indicate serious model misspecification.

[7] Daniel McFadden and James Heckman were awarded the Nobel Prize in economics in 2000. An extensive review of the developments in the economics of transportation is given in Winston (1985).

Concluding remarks

In this paper, we have developed and estimated a model aiming to explain the factors that influence the quality of published research, measured by the number of citations, when we exclude self-citations. Special emphasis is placed on discussing the influences from the authors' experience and the quality of the research environment in which the authors operate. This enables us to examine to what extent a solid academic environment at the unit to which the researchers are affiliated can compensate for a lack of research experience and vice versa as far as producing quality research is concerned. The above issue has always been important for politicians and bureaucrats addressing research planning. The data used in the study are 1121 articles published in the five most recognised transportation journals during the seven-year period from 2000 to 2006. Their number of citations is then checked by the start of August 2016.

The two most important findings are that experience and academic environment matter for performing quality research. When the authors' experience, measured by their total number of previous publications (PP), increases by 1% from its average level, their published articles are expected to garner 0.31% more citations (CI). Moreover, when the research activity at the unit to which the authors are affiliated, measured by the unit's total number of publications within the transport discipline (PI), increases by 1% from its average level, the number of times their articles are cited will increase by 0.19%. This signals that, relatively speaking, the researchers' own experience means more than the academic environment in regard to producing high-quality research. Our model specification and results imply that CI increases concavely with both PP and PI. Hence, the marginal effects on research quality of more experienced researchers and a better academic environment diminish rapidly.

The model estimations also shed light on substitution possibilities between experience and academic environment while still holding constant the quality of the articles published. For example, the researcher´s experience, measured by the total number of articles they have previously published (PP), can be reduced by 6.49 when the research activity at their workplace (PI) increases from 6 to 7, holding the quality of their published articles constant.

This work is, as far as we know, the first attempt to elaborate empirically on the interrelationships between research quality at a research unit, its level of research activity, and the experience of its staff. These are important and ongoing issues for all research units who want to find the right mix of headcounts and experience.

Appendix: Deducing some mathematical properties of the model used

It follows from Equation (2) that the expressions for the first and second derivatives are $\frac{\partial CI}{\partial i} = \beta_i \cdot CI \cdot i^{\tau_i - 1}$, $\frac{\partial CI}{\partial j} = \beta_j CI$, $\frac{\partial^2 CI}{\partial i^2} = \beta_i \cdot CI \cdot i^{\tau_i - 2}\,[\beta_i \cdot i^{\tau_i} + \tau_i - 1]$ and $\frac{\partial^2 CI}{\partial j^2} = \beta_j^2 CI$, $i = \{PI, PP, RF\}, j = \{AN, YP, WT\}$. When $0 < \tau_i < 1$ it implies that $\frac{\partial CI}{\partial i}, \frac{\partial CI}{\partial j} \geq (<)\ 0$ when $\beta_i, \beta_j \geq (<) 0$, $\frac{\partial^2 CI}{\partial i^2} > 0$ when $\beta_i < 0\ \ or\ \beta_i\ > 0$ and $i > \left[\frac{1-\tau_i}{\beta_i}\right]^{1/\tau_i}$, $\frac{\partial^2 CI}{\partial i^2} < 0$ otherwise. When τ_{PI} and τ_{PP} are set to the stated values in Equation (2) $\frac{\partial^2 CI}{\partial PI^2}, \frac{\partial^2 CI}{\partial PP^2} < 0$ when *PI*<278 and *PP*<690, whilst $\frac{\partial^2 CI}{\partial RF^2} < 0$ when *RF* < 2.54. Moreover, $\frac{\partial^2 CI}{\partial j^2} > 0$ for all values of β_j. The derivatives show that neither are constant but rather vary with the values of i and j. The absolute change in CI when one variable changes by one unit is thus dependent on the values of all explanatory variables in the model.

To obtain a good interpretation of the $\beta -$ values, we can focus on the elasticity values. The above derivatives imply that $EL_i CI = \frac{\partial CI}{\partial i}\frac{i}{CI} = \cdot\ \beta_i \cdot i^{\tau_i}$ and $EL_j CI = \frac{\partial CI}{\partial j}\frac{j}{CI} = \cdot\ \beta_j \cdot j$ where $EL_i CI$ and $EL_j CI$ denote the elasticity of CI with respect to i and j, respectively. Hence, the absolute values of the elasticities of CI with respect to $i, i = \{PI, PP, RF\}$ increase concavely with *i*, whereas the elasticities of CI with respect to $j, j = \{AN, YP, ...\}$ increase proportionally with j.

From the above derivatives it also follows that $\left(\frac{\frac{\partial CI}{\partial i}}{CI}\right) = \beta \cdot i^{\tau_i - 1}$ and $\left(\frac{\frac{\partial CI}{\partial j}}{CI}\right) = \beta_j$. Thus, an increase in *i* by one unit will always increase CI by $(100 \cdot i^{\tau - 1} \cdot \beta_i\ )$ %, while an increase in *j* by one unit will always increase CI by approximately (100 · β_j) %. Our model specification implies that the relative changes in CI when i and *j* change by one unit, are independent of the values of the other explanatory variables. Moreover, the relative changes in j, $j = \{AN, YP, WT\}$ are independent of their own values whereas the relative changes in $i, i = \{PI, PP, RF\}$ decrease with their own values.

Equation (2) implicitly defines PP as a function of PI for given values of CI (CI^*) and of the other explanatory variables ($AN^*, RF^*, WT^*, YP^*, TR^*, TA^*, TB^*, TS^*$); that is

$$PP = F(PI) = \left\lfloor \frac{\ln CI - \beta_{PI} PI^{\tau_{PI}} - q}{\beta_{PP}} \right\rfloor^{1/\tau_{PP}}$$

in which $q =\ \beta_0 + \beta_{RF} RF^{0.37^*} + \beta_{AN} AN^* + \beta_{WT} WT^* + \beta_{YP} YP^* + \beta_{TR} TR^* + \beta_{PA} PA^* + \beta_{PB} PB^* + \beta_{TS} TS^*$

From the *F(PI)* relationship above we can deduce the marginal rate of substitution (MRT) between PP and PI:

$$MRT = \frac{\partial PP}{\partial PI} = -\frac{\beta_{PI}}{\beta_{PP}} \cdot \frac{\tau_{PI}}{\tau_{PP}} \cdot \frac{PP^{1-\tau_{PP}}}{PI^{1-\tau_{PI}}}$$

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