

Zweifel, Peter; Janus, Katharina

**Conference Paper**

## Physician ethics: undermined or enhanced by modes of payment?

Beiträge zur Jahrestagung des Vereins für Socialpolitik 2016: Demographischer Wandel - Session: Health I, No. B09-V1

**Provided in Cooperation with:**

Verein für Socialpolitik / German Economic Association

*Suggested Citation:* Zweifel, Peter; Janus, Katharina (2016) : Physician ethics: undermined or enhanced by modes of payment?, Beiträge zur Jahrestagung des Vereins für Socialpolitik 2016: Demographischer Wandel - Session: Health I, No. B09-V1, ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften, Leibniz-Informationszentrum Wirtschaft, Kiel und Hamburg

This Version is available at:

<https://hdl.handle.net/10419/145708>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# Medical Ethics: Enhanced or Undermined by Modes of Payment?

Peter Zweifel, PhD, Emeritus and Katharina Janus, PhD

This version: 28 Oct. 2014

## ABSTRACT

**Background:** In the medical literature ((Begley (1987), Gervais et al. (1999), American Academy of Dermatology (2000))), the view prevails that any change away from fee-for-service (FFS) jeopardizes medical ethics, defined as motivational preference in this article. The objective of this contribution is to test this hypothesis by first developing two theoretical models of behavior, building on the pioneering works of Ellis and McGuire (1986) and Pauly and Redisch (1973). Medical ethics is reflected by a parameter  $\alpha$  which indicates how much importance the physician attributes to patient well-being relative to his or her own income. Accordingly, a weakening of ethical orientation amounts to a fall in the value of  $\alpha$ . While economic theory traditionally takes preferences as predetermined, such a change is possible in the light of Evolutionary Economics (Bolle, 2000).

**Methods:** The model based on Ellis and McGuire (1986) depicts the behavior of a physician in private practice, while the one based on Pauly and Redisch (1973) applies to providers who share resources such as in hospital or group practice. Two changes in the mode of payment are analyzed, one from FFS to prospective payment (PP), the other, to pay-for-performance (P4P). One set of predictions relates physician effort to a change in the mode of payment; another, physician effort to a change in  $\alpha$ , the parameter reflecting ethics. Using these two relationships, a change in ethics can observationally be related to a change in the mode of payment. The predictions derived from the models are pitted against several case studies from diverse countries.

**Results:** A shift from FFS to PP is predicted to give rise to a negative observed relationship between medical ethics of physicians in private practice under a wide variety of circumstances, more so than a shift to P4P, which can even be seen as enhancing medical ethics provided physician effort has a sufficiently high marginal effectiveness in terms of patient well-being. This prediction is confirmed to a considerable degree by circumstantial evidence coming from the case studies. As to physicians working in hospital or group practice, the prediction is again that an observer will infer that a transition in hospital payment from FFS to PP weakens their ethical orientation. However, this prediction is not fully borne out; a likely reason is that hospitals also differ strongly in terms of their organizational culture, a factor that is not held constant in the case studies. A transition to P4P may lead observers to conclude that it actually enhances medical ethics of healthcare providers working in hospital or group practice. This prediction receives a degree of empirical support from the case studies.

**Conclusion:** The claim that moving away from FFS undermines medical ethics is far too sweeping. It can only in part be justified by observed relationships, which even may suggest that a transition to P4P strengthens medical ethics.

**Key Words:** Medical ethics, Physician behavior, Mode of payment, Fee-for-service, Prospective payment, Pay-for-performance, Evolutionary economics

**Acknowledgment:** The authors benefitted greatly from a thorough checking of their math by Simon Spika, PhD (University hospital, Zurich) and the contribution of a case study by Adi Stepan, PhD (Emeritus, Technical University of Vienna). They gratefully acknowledge partial support by the Brocher Foundation (Hermance near Geneva, Switzerland).

## INTRODUCTION

In the medical literature, the view prevails that any change away from fee-for-service (FFS) jeopardizes medical ethics (Begley (1987), Gervais et al. (1999), American Academy of Dermatology (2000)). Redwin (2011, 53-74) even interprets the French codes of conduct as saying that e.g. sharing fees within a group practice is to be considered unethical. The objective of this contribution is to test the hypothesis that departing from FFS needs to be seen as a threat to medical ethics. It first develops two theoretical models of physician behavior building on pioneering work by Ellis and McGuire (1986) as well as Pauly and Redisch (1973). Ellis and McGuire depict the behavior of a physician in independent practice, while Pauly and Redisch analyze a provider who shares resources such as in a hospital or a group practice. In keeping with Ellis and McGuire, ethical orientation is reflected by a parameter  $\alpha$ , which indicates the contribution of patient well-being to physician utility relative to his or her self-interest.

While in conventional economic theory, this parameter characterizes a type, making it predetermined, Evolutionary Economics admits the possibility of changes in preferences induced by changes in the economic environment (Bolle, 2000, extending Bester and Güth, 1998). Two sets of predictions are derived. One relates physician effort on behalf of patients to a change in the mode of payment, the other, physician effort to an (exogenous) change in the parameter  $\alpha$  depicting medical ethics. Based on these two relationships, it becomes possible to link physician ethics to changes in the mode of payment. In Evolutionary Economics this change would be interpreted as causal. However, adopting this view would create the challenge of elaborating on the exact impact of mode of payment on medical ethics. In order

to avoid this challenge, the link between the two is interpreted non-causally in the guise of a correlation in this paper. Estimating such a correlation requires the use of multiple indicators of professional ethics each of which contains measurement error. For instance, in their study of intrinsic motivation of French general practitioners, Sicsic et al. (2012) find that Multiple Correspondence Analysis, Confirmatory Factor Analysis, and a two-parameter Logistic Model produce very similar results. ‘Satisfaction with professional activity’ proved to be the most informative of eleven indicators, closely followed by ‘The job is considered personally rewarding’.

Thus, using a host of indicators critics like the American Academy of Dermatology (2000) might observe a negative correlation between a latent construct ‘physician ethics’ and mode of payment, leading them to infer that a weakening of professional ethics is induced by transitions from FFS to prospective payment (PP) and to pay-for-performance (P4P), respectively. It will be shown that this inference depends on several well-defined parameters, notably the marginal cost of effort borne by the physician. In the ensuing section, parameters of this type serve to predict whether such an outside observer would conclude that a departure from FFS undermines medical ethics. Several case studies from diverse countries suggest that predictions of this type are confirmed. Thus, observers such as the American Academy of Dermatology (2000) are likely to conclude that departing from FFS does create a risk of weakening medical ethics; however, this risk is more pronounced in the case of PP than in the case of P4P. The Conclusion section contains a summary and an outlook.

## THE MODELS

To keep the analysis simple, several aspects of medical activity are abstracted from. First, risk aversion is neglected although it is an important parameter in a situation where financiers use PP and P4P to shift financial risk onto service providers, who become responsible for cost overruns. The reason for this neglect is that it greatly simplifies the analysis while not necessarily affecting the results reported below. Clearly, risk aversion gives rise to a strong preference of the status quo due to a lowered utility associated with the alternative (for some experimental evidence, see Zweifel (2011)); however, the issue here is service providers’ behavioral response to a change in the mode of payment rather than measuring their loss of utility that may go along with it. Second, peer pressure and reputation effects are not modelled explicitly but alluded to when discussing particular functional relationship. Third, there has been some evidence suggesting that medical ethics comprises not only a concern for patient health but also for the financial consequences of treatment and even for the consequences for health insurance and

society at large (see e.g. Trottman et al, 2012). This ethical motive is neglected as well in the interest of simplicity.

**Physician in private practice subject to a shift from FFS to PP:** With the simplifications introduced above, the physician utility function posited by Ellis and McGuire (1986) boils down to

$$U = \pi \cdot v[P] + (1 - \pi) \cdot v[F] \\ = \pi \cdot v[p - c(e) + \alpha \cdot w(e)] + (1 - \pi) \cdot v[r(e) - c(e) + \alpha \cdot w(e)] \quad (1)$$

Here, per-patient utility  $U$  has two components, with weights  $\pi$  (reflecting prospective payment;  $P$ ) and  $(1 - \pi)$ , reflecting fee-for-service;  $F$ ), respectively. Accordingly,  $p$  denotes the fixed payment under PP, which does not depend on physician effort  $e$ . From this payment, cost  $c(e)$  must be deducted, which is assumed to be increasing in effort ( $c'(e) > 0$ ). Note that this cost comprises the opportunity cost of physician time. However, by assumption the physician not only cares about his or her own net income but about patient well-being  $w(e)$  as well, which is increasing in effort, too ( $w'(e) > 0$ ). Therefore, effort serves to increase quality of treatment in this model. In principle, this effect could create a feedback loop linking patient well-being to income because a high contribution to patient well-being serves to enhance a service provider's reputation and hence demand for his or her services. However, such feedback would make focusing on 'pure' professional ethics impossible. Learning effects are disregarded as well; they would have to be modelled by complementing the  $c(\cdot)$  and  $w(\cdot)$  functions with the cumulative of past effort as an additional argument, considerably complicating the analysis.

The parameter  $\alpha > 0$  reflects professional medical ethics, indicating the relative importance of patient well-being (which is a broader concept than health outcome, including also the financial consequences of medical care for patients). The second component of utility derives from FFS. It depends on the fee received  $r(e)$ , which is increasing in effort ( $r'(e) > 0$ ), again net of cost  $c(e)$ . Since neither physician nor patient types are distinguished in this simple model, issues of selection and matching cannot be addressed. For instance, the cost function  $c(e)$  might well differ between physician types and between PP and FFS settings (e.g. because FFS patients expect more amenities). Also, patient well-being  $w(e)$  may differ between patient types and settings, e.g. because FFS patients are sicker than PP ones.

The first question to be asked is, How does physician effort respond to a shift in favor of PP, i.e. an increase in  $\pi$ ? Begley (1987), Gervais et al. (1999) and the American Academy of Dermatology (2000) all agree that such a shift has taken place in the United States starting with the passage of the HMO Act in 1973. The introduction of DRG hospital payment by Medicare in 1986 and the rise of capitated

physician payment in Managed Care during the 1990s raised additional concerns regarding professional ethics (Janus, 2003). Other countries such as Germany and Switzerland have also introduced legislation paving the way for Managed Care (Henke, 2004; Zweifel and Schoder, 2008). In mathematical terms, the relationship between physician effort and a shift in favor of PP is given by  $de/d\pi$  (see eq. (A.5) of the Appendix, with  $\approx$  denoting proportionality and where arguments of functions are only repeated if necessary to avoid ambiguity),

$$de/d\pi \approx 1/(1-\pi) \cdot v'[P](-c' + \alpha \cdot w') \quad (2)$$

The sign of this expression (and hence of  $de/d\pi$ ) is indeterminate; it depends on marginal cost of effort  $c'$  compared to its effect on patient well-being  $w'$  weighted by the ethics parameter  $\alpha$ .

The second question is perfectly in line with conventional economic theory, revolving around  $de/d\alpha$ , which indicates how physician effort  $e$  reacts to an exogenous change in the ethics parameter  $\alpha$ . The corresponding expression is derived as eq. (A.6) of the Appendix,

$$de/d\alpha \approx \partial^2 U / \partial e \partial \alpha = \pi \cdot v'[P] \cdot w' + (1-\pi) \cdot v'[F] \cdot w' \quad (3)$$

However, given these two expressions, one can combine the two relationships to obtain  $\frac{de/d\pi}{de/d\alpha} = \frac{d\alpha}{d\pi}$ .

The expression  $d\alpha/d\pi$  indicates how the ethics parameter responds to an increase in the share of activity paid using PP. This makes medical ethics endogenous, contrary to the view of conventional economics stating that preferences are predetermined. In Evolutionary Economics, however, this view is not upheld anymore. In particular, Bolle (2000) as well as Bester and Güth (1998) state conditions for (altruistic) preferences to be sustainable. The problem is that their findings are derived from game theory, which is not the approach adopted in this paper. Therefore, it is preferable to interpret  $d\alpha/d\pi$  as a correlation (although strictly speaking, the model is couched in non-stochastic terms, precluding correlations between random variables). If  $d\alpha/d\pi$  is negative, a negative correlation is observed, leading an observer to infer that a transition from FFS to PP undermines medical ethics; if  $d\alpha/d\pi$  is positive, the conclusion is that it actually enhances medical ethics. Dividing eq. (2) by eq. (3), one obtains

$$\frac{d\alpha}{d\pi} = \frac{de/d\pi}{de/d\alpha} = \frac{1/(1-\pi) \cdot v'[P](-c' + \alpha w')}{w' \{ \pi \cdot v'[P] + (1-\pi) \cdot v'[F] \}} \quad (4)$$

This response is indeterminate in principle because the sign of  $(-c' + \alpha \cdot w')$  can be positive or negative (all the other terms are positive). Nevertheless,  $d\alpha/d\pi$  can be signed in a number of situations. First,  $d\alpha/d\pi > 0$  if  $(-c' + \alpha \cdot w') > 0$ , i.e. the perceived correlation between medical ethics and a transition from FFS to PP is positive if it is caused by three conditions, two of which must be simultaneously satisfied: (i) the physician is highly ethical before the change ( $\alpha$  high) and (ii) his or her effort still has a substantial impact on patient well-being at the margin ( $w'$  high), or (iii) his or her marginal cost of effort  $c'$  is small compared to effects (i) and (ii). This set of conditions might be satisfied in the (rare) cases of surgeons in private practice whose effort is crucial for the survival of their patients. But then, surgeons' additional effort usually has a high marginal cost in terms of concentration, leisure forgone, and use of costly equipment. This is a likely reason for their annual hours of work being the same 2,080 as those of general practitioners although their hourly wage is some USD 164 rather than USD 83 as of 2013 (see [healthcaresalaryonline.com/family-practice-doctors-salary.htm](http://healthcaresalaryonline.com/family-practice-doctors-salary.htm) and [healthcareworkerssalary.com/physicians/general-surgeons-salary](http://healthcareworkerssalary.com/physicians/general-surgeons-salary)). Moreover, if  $d\alpha/d\pi > 0$ , its value would be high only if  $(1 - \pi)$  in the numerator is small and  $v'[P]$  is large. This means that most of the activity is paid PP initially and yet the physician continues to derive much extra utility when working even more under PP. As to  $w'$  in the denominator, this term cannot be small because this would render a positive effect impossible, as argued above. Since this is a rather unlikely combination, any ethics-enhancing effect of stronger PP orientation is probably limited.

Second, however,  $d\alpha/d\pi < 0$  is a distinct possibility according to this model, implying that a transition towards (more) PP indeed would be seen as weakening medical ethics. It is easy to perceive the correlation as negative; all it takes is for the marginal cost of effort  $c'$  to be high initially while either the ethical orientation is slight ( $\alpha$  low) and/or the marginal effect of effort on patient health limited ( $w'$  low). This could be descriptive of overworked general practitioners who have come to realize that they cannot really do much for their patients – with the exception of those few doctors out in the countryside with an extremely strong professional ethic. Again,  $d\alpha/d\pi < 0$  is marked precisely when the PP share  $\pi$  is low initially while the physician's effect on patient health is limited ( $w'$  low in the denominator of eq. (4)).

**Conclusion 1:** Medical ethics are unlikely to be perceived as being positively correlated with a transition from FFS to PP; rather, the perceived correlation tends to be negative, leading observers to conclude that PP jeopardizes medical ethics. The main condition for this to occur is that the marginal effect of physician effort on patient health is limited. Given a negative perceived correlation, it is seen as substantial if PP has a small share initially.

**Physician in private practice subject to a shift from FFS to P4P:** Currently, pay-for-performance (P4P, symbolized by  $O$  in equations) is little used in ambulatory care where solo private practice continues to be the norm. However, it may become more widespread in future, motivating analysis of an increase in the P4P share ( $d\omega > 0$  in eq. (5) below). Usually, P4P is tied to clinical benchmarks; however, its ultimate end is a better alignment of service providers' incentives with patient health (Roland, 2004). Therefore, one can replace  $r(e)$  by  $p(w(e))$  in the utility function reflecting P4P payment, with  $p'(w) > 0$  signifying its (possibly rather tenuous) positive relationship with patient well-being  $w$  (which in turn increases with effort  $e$ , as before). The utility function then becomes

$$U = \omega \cdot v[O] + (1 - \omega) \cdot v[F] \\ = \omega \cdot v[p(w(e)) - c(e) + \alpha \cdot w(e)] + (1 - \omega) \cdot v[p - c(e) + \alpha \cdot w(e)] + (1 - \omega) \quad (5)$$

From eq. (A.8), one obtains

$$de/d\omega \approx 1/(1 - \omega) \cdot v'[O] \{ -c' + (p' + \alpha)w' \} \quad (6)$$

Also, eq. (A.9) states

$$de/d\alpha \approx \partial^2 U / \partial e \partial \alpha = \omega \cdot v'[O] \cdot w' + (1 - \omega) \cdot v'[F] \cdot w' \quad (7)$$

Note that this expression is analogous to eq. (3), with  $\pi$  and  $P$  replaced by  $\omega$  and  $O$ , respectively.

Division of eq. (6) by eq. (7) yields

$$\frac{d\alpha}{d\omega} = \frac{de/d\omega}{de/d\alpha} = \frac{1/(1 - \omega) \cdot v'[O] \{ -c' + (\alpha + p')w' \}}{w' \{ \omega \cdot v'[O] + (1 - \omega) \cdot v'[F] \}} \quad (8)$$

The major difference from PP (see eq. (4) again) is that the effect of improved patient health  $w'$  is strengthened since its multiplier is now  $\alpha + p' > \alpha$ . This hinges on the plausible assumption that ethically motivated service providers do not systematically negotiate for P4P contracts that in fact disregard patient welfare ( $p'(w) = 0$ ).

In eq. (8),  $d\alpha/d\omega > 0$  if  $\{ -c' + (\alpha + p')w' \} > 0$ , i.e. the observed correlation between ethics and a transition from FFS to P4P is positive already if payment increases strongly enough with patient well-being ( $p'$  high) to balance marginal cost of effort  $c'$ ; an initial ethical orientation is not necessary this time,  $\alpha = 0$  being admissible. Therefore, a movement away from FFS is not seen as undermining medical ethics provided P4P reflects improvements in patient well-being to a sufficient degree (see also Roland, 2007). Conversely,  $d\alpha/d\omega < 0$  is still possible if marginal cost of effort  $c$  is very high initially while



either ethical orientation is weak ( $\alpha$  low) and/or the marginal effect of effort on patient well-being is limited ( $w'$  low). Yet the set of parameter configurations resulting in a perceived weakening of medical ethics is smaller under P4P than under PP.

**Conclusion 2:** A transition from FFS to P4P may induce a positive correlation between the ethics of physicians in private practice and P4P on the condition that P4P reflects improvement in patient health to a high degree. However, there is still potential for a negative correlation (albeit smaller than under PP) leading to the view that medical ethics is undermined by P4P. This is the case if the marginal effect of physician effort on patient health is very limited, especially when FFS is dominant initially.

**Hospital and group practice physician subject to a shift from FFS to PP:** The crucial difference from the physician in private practice is that resources are now shared. Inspired by the pioneering contribution by Pauly and Redisch (1973), building on earlier work by Ward (1958) on workers' co-operatives, utility  $U$  is now defined,

$$U = \pi \cdot v[P] + (1 - \pi) \cdot v[F] \\ = \pi \cdot v[(B - C(e)) / n + \alpha \cdot w(e)] + (1 - \pi) \cdot v[R(e) / M - c(e) + \alpha \cdot w(e)] \quad (9)$$

The first component (with weight  $\pi$ ) is related to activity under PP. Hospital and group practice physicians often are salaried; at the very least, they increasingly are not permitted to bill patients directly in the United States (and many industrial countries as well). Yet their career prospects and hence future income may depend on whether their activity results in a positive financial margin for the hospital. This margin is given by  $(B - C(e)) / n$ , with  $B$  symbolizing the hospital's or group's (fixed) budget. As to total treatment cost  $C(e)$ , it comprises the salary of the physician considered, which in turn can be assumed to cover his or her opportunity cost of effort. Total cost increases (somewhat) with the effort of the physician considered, while  $n$  denotes the number of patients treated by the hospital department or physician group, respectively. The FFS component of eq. (9) reflects the institution's revenue which (weakly) depends on the effort of the physician considered. Division by the number of staff physicians  $M$  transforms this into a pro-rata share. As before, the ethical component is given by  $\alpha \cdot w(e)$ .

With  $d\pi > 0$  symbolizing an increase in the importance of prospective payment, one has this time (see eq. (A.12)),

$$de / d\pi \approx 1 / (1 - \pi) \cdot v'[P](-C' / n + \alpha \cdot w') \quad (10)$$

Moreover, one has from eq. (A.13),

$$de/d\alpha \approx \partial^2 U / \partial e \partial \alpha = \omega \cdot v'[O] \cdot w' + (1-\omega) \cdot v'[F] \cdot w' > 0 \quad (11)$$

Division of eq. (10) by eq. (11) yields

$$\frac{d\alpha}{d\pi} = \frac{de/d\pi}{de/d\alpha} = \frac{1/(1-\pi) \cdot v'[P](-C'/n + \alpha \cdot w')}{w' \{ \pi \cdot v'[P] + (1-\pi) \cdot v'[F] \}} \quad (12)$$

Whereas the sign of  $d\alpha/d\pi$  is again indeterminate in general, some predictions are nevertheless possible. A shift from fee-for-service (FFS) to prospective payment (PP) causes hospital and group practice physicians to act less ethically ( $d\alpha/d\pi > 0$ ) if  $(-C'/n + \alpha \cdot w') < 0$ . This is the case if the hospital's or group's marginal cost per case  $C'/n$  is high or its the impact of extra effort on patient well-being is limited ( $w'$  small) or ethics is weak initially ( $\alpha$  low). Conversely, two conditions need to be satisfied for ethics to be enhanced, viz. (i) marginal cost per case  $C'/n$  is low and (ii) extra effort has a strong effect on patient well-being or medical ethics is strong initially. The correlation (positive or negative) between ethics and the transition from FFS to PP is marked if the share  $\pi$  of PP is small initially and further reinforced if the marginal utility  $v'[F]$  associated with FFS is relatively high (which is likely because physicians' status quo bias is important especially in the early phase of transition when they lack experience with PP (see Zweifel (2011)).

**Conclusion 3:** Among hospital and group practice physicians, the correlation between ethics and a transition from FFS to PP is positive under rather restrictive conditions only, which might be satisfied staff physicians in a large, well-managed hospital or group practice. Conversely, there are many settings where this correlation is negative, especially when marginal cost per patient treated is high.

**Hospital and group physician subject to a shift from FFS to P4P:** The physician's utility function is modified using elements of eqs. (5) and (9) to read

$$\begin{aligned} U &= \omega \cdot v[O] + (1-\omega) \cdot v[F] \\ &= \omega \cdot v[R(w(e))/M - c(e) + \alpha \cdot w(e)] + (1-\omega) \cdot v[R(e)/M - c(e) + \alpha \cdot w(e)]. \end{aligned} \quad (13)$$

The first component with weight  $\omega$  relates to activity under P4, its term  $R(w(e))$  reflecting that fact that revenue of the hospital or group practice now depends on patient well-being  $w(e)$ . Here again, much depends on the degree to which P4P actually reflects patient well-being, i.e.  $R'(w)$ . From eq. (A.15), one has

$$de/d\omega \approx 1/(1-\omega) \cdot v'[O] \{R'(w)/M \cdot (w'-1) - c' + \alpha \cdot w'\} \quad (14)$$

In analogy to eq. (11) above, one has

$$de/d\alpha = w' \cdot \{\omega \cdot v'[O] + (1-\omega) \cdot v'[F]\} \quad (15)$$

Division of eq. (14) by eq. (15) yields

$$\frac{d\alpha}{d\omega} = \frac{de/d\omega}{de/d\alpha} = \frac{1/(1-\omega) \cdot v'[O] \{R'/M \cdot (w'-1) - c' + \alpha \cdot w'\}}{w' \cdot \{\omega \cdot v'[O] + (1-\omega) \cdot v'[F]\}} \quad (16)$$

Therefore, a positive correlation obtains between medical ethics and a transition from FFS to P4P in hospital and group practice if two conditions are satisfied, (i) marginal effectiveness of physician effort in terms of patient well-being must exceed a lower bound ( $w' > 1$ ), and (ii) the marginal cost of physician effort  $c'$  is low compared to its marginal effectiveness in terms of patient well-being  $w'$ . Note that a positive correlation can obtain even if  $\alpha = 0$ , i.e. if there is no ethical orientation initially. A positive correlation is magnified if (a) marginal revenue of the hospital or group practice depends strongly on the effort of the physician considered ( $R'$  high), (b) marginal revenue is shared between few physicians ( $M$  low), or (c) the initial share of P4P payment  $\omega$  is small.

Conversely, the correlation between ethics and P4P is negative if (i')  $w' < 1$  and (ii') marginal cost of effort  $c'$  exceeds its marginal effectiveness and (iii') ethical orientation is weak initially ( $\alpha < 1$ ). Since these three conditions have to be simultaneously satisfied, the set of parameter combinations resulting in  $d\alpha/d\pi < 0$  is smaller than in the case of PP applied to hospitals and group practices (see the discussion leading up to Conclusion 3).

**Conclusion 4:** Among hospital and group practice physicians, the correlation between medical ethics and a transition from FFS to P4P is positive if two conditions are cumulatively satisfied; an initial ethical orientation is not necessarily among them. It is negative only if three conditions are cumulatively satisfied, among them a weak ethical orientation initially.

## EVIDENCE FROM CASE STUDIES

### Case study No. 1: ‘Blue Award\$\$’ (USA ca. 2007), Physicians in private practice subject to a transition from FFS to P4P

Blue Cross-Blue Shield of Michigan asked primary care physicians to consider switching patients from brand-name to generic cholesterol-lowering statin prescriptions against a \$100 payment per patient enrolled in its plan. To facilitate switches, the HMO mailed physicians a list of Blue Care Network patients who were taking two or more brand-name statins. This initiative resulted in \$2 million (mn.) in expenses for payments to doctors, \$5 mn. in drug cost savings for the Blue Care Network, and \$1 mn in copayment savings for members.

This evidence belongs to the category, ‘Physician in private practice subject to a shift from FFS to P4P’. The question is whether it points to a positive correlation with medical ethics ( $d\alpha/d\omega > 0$  in eq. (8)) or a negative one ( $d\alpha/d\omega < 0$ ). The discussion will proceed element by element, starting with the eq. (6) than analyzing eq. (8) directly. Some medical experts might argue that switching patients away from a brand-name drug amounts to less effort on the part of the treating physician ( $de < 0$ ). However, since bioequivalence of the generic was assured in this case, communicating this equivalence to patients likely meant increased physician effort ( $de > 0$ ). In view of eq. (6),  $de/d\omega > 0$  is the outcome if treating physicians could be convinced that switching enhanced their patients’ well-being, causing  $w'$  to be positive. With USD 1 mn. less copayment by patients, switching arguably did contribute to patient well-being (if defined broadly to also include net income rather than just health). Also, eq. (A14) states that even without any initial ethical orientation ( $\alpha = 0$ ), the P4P parameter  $p' > 0$ , corresponding to the 100 USD payment, may balance the marginal cost of effort  $c' > 0$  borne by the physician.

Next, with  $w'$  positive,  $d\alpha/d\omega > 0$  is ascertained (see eq. (7)). Eq. (8) then indicates that ‘Blue Award\$\$’ induced a positive correlation between medical ethics and P4P, suggesting an enhancement rather than weakening of medical ethics.

### Case study No. 2: ‘Excellus Blue Cross Blue Shield’(USA 2007), Physicians in private practice subject to a transition from FFS to P4P

This case study again belongs to the category, ‘Physician in private practice subject to a shift from FFS to P4P’. Blue Cross/Blue Shield of Upstate New York offered a 3 to 5 percent increase in reimbursement of office visits if a contracting physician group managed to increase the ratio, ‘Generic drugs prescriptions / brand-name prescriptions’ by five percentage points. For example, members of a physician group characterized by an initial ratio 1:1 (or 50%, respectively) were entitled to up to 5

percent higher payment provided this ratio increased to 55% (or 1:0.82, respectively). While all groups achieved this target, one of them even exhibited an eight percentage point increase in this ratio. So, were the physicians of that group more or less ethically oriented than the others? For answering this question, one has to know that patients benefitted from a reduction of 10 to 12 percent in terms of copayment, pointing to  $w' > 0$  in eq. (4) of the text.

Quite likely, this initiative gave rise to a positive correlation between ethics and P4P. Its effect on physician effort is positive according to eq. (6) provided  $c'$ , the marginal cost to prescribing physicians associated with increasing the generics/brand-name ratio is more than balanced by  $(\alpha + p')w'$ , the combined effects of ethics, extra reimbursement, and marginal effort on patient well-being. Therefore, the members of the physician group reaching an increase by eight percent might well have been characterized by a particularly high value of  $\alpha$ , the parameter indicating ethical orientation. Yet, as shown in eq. (8), these physicians might also have been characterized by a particularly low initial P4P share  $\omega$ . As in case study No. 1, 'patient well-being' needs to be defined broadly here to include the financial situation of patients because outcomes in terms of health are not affected by the switch to generics by assuming bioequivalence.

### **Case study No. 3: GAIA and AOK Hessen (Germany 2007), Physicians in private practice subject to a transition from FFS to P4P**

In 2007, GAIA (a company specializing in social change) and AOK Hessen (one of the largest social health insurers of Germany) teamed up in an attempt not to expand the use of generics but the use of low-cost generics in prescriptions. AOK Hessen offered physicians Euro 20 for switching a patient from generic A to lower-cost generic B. Four months into the project, 46 percent of the 15,000 patients involved had been switched; however, in a mere 4.2 percent of treatment cases, physicians had claimed the extra payment. Later on, both shares reached higher final values which however are not known. Again, this initiative belongs to the category, 'Physician in private practice subject to a shift from FFS to P4P' because a P4P element was added to otherwise unchanged FFS payment. The observed facts can be interpreted in terms of eq. (6) as follows. First, AOK Hessen realized that claiming the extra reimbursement also entails marginal cost in terms of time. It kept the total value of  $c'$  low by inserting a button in its member records that was to be activated by a nurse to document the Euro 20 claim. The fact that the great majority of service providers nevertheless abstained from exercising this option might indicate particularly strong medical ethics.

In eq. (8), the crucial question is whether  $w'$ , the marginal effect of physician effort on patient well-being is positive. At first blush, this does not seem to be the case because patients were not relieved of copayment when accepting the switch to the lower-cost medication B. Yet when interviewed, many

physicians stated that ‘one cannot take any money for a task that is essentially part of one’s job *and in the patients’ interest*’ (emphasis added). This can be interpreted as indicating that respondents considered switching to a lower-cost generic as enhancing patient well-being, possibly because they realized that a reduction in pharmaceutical expenditure covered by AOK Hessen would transpire into a lowered contribution rate for the insured, *ceteris paribus*.

With  $w' > 0$  likely,  $\{-c' + (\alpha + p')\}$  determines the sign of the numerator. For the great majority of physicians who did not present the Euro 20 claim,  $p'(w) = 0$ , causing their multiplier to boil down to  $\{-c' + \alpha\}$ . About one-half of them did not switch to the lower-cost generic, presumably because their marginal cost of effort  $c'$  was relatively high. Unfortunately, the initiative involved only general practitioners, so one cannot filter surgeons and other physician specialties characterized by particularly high opportunity cost of time. The fact that a physician did not switch therefore does not permit to infer anything about his or her initial ethical orientation  $\alpha$ . Moreover, the sign of  $d\alpha/d\omega$  remains open, indicating that the correlation between medical ethics and P4P remains ambiguous.

The small subset of physicians performing the switch while claiming the Euro 20 payment is more informative. Recall that AOK Hessen had made special effort to keep marginal cost  $c'$  of presenting the Euro 20 as low as possible. In the decisive multiplier  $\{-c' + (\alpha + p')\}$ , this keeps  $c'$  small compared to  $p'$ . Therefore, providers without an ethical orientation initially ( $\alpha = 0$ ) may even have been led to develop one since  $d\alpha/d\omega > 0$  for them. Those with an ethical orientation initially ( $\alpha > 0$ ) give rise to a positive observed correlation between ethics and P4P as well.

The sizable subset of providers switching but not claiming the Euro 20 payment is the most telling. For them, the multiplier becomes  $\{-c' + \alpha\}$ . Therefore, physicians with a low initial value of  $\alpha$  would cause a negative correlation between medical ethics and P4P as a consequence of the switching initiative since  $d\alpha/d\omega < 0$ . By way of contrast, the initiative is found to induce a positive correlation among all physicians with a strong initial ethical orientation compared to their marginal cost of effort. Overall, the fact that there were so many non-claimers points to the possibility that the observed correlation between ethics and the shift towards P4P by AOK Hessen may be positive, suggesting a strengthening rather than weakening medical ethics.

#### **Case study No. 4: North Shore-LIJ Health System (United States, 2005), Hospital physicians subject to a transition from FFS to P4P**

The North Shore-LIJ Health System, comprising 14 hospitals, participated in Hospital Quality Incentive Demonstration (HQID) project, initiated by the Centers for Medicare & Medicaid Services (CMS) in 2005. The LIJ System won P4P awards amounting to almost 0.8 mn. US\$ (Page, 2009). North Shore University Hospital excelled in particular although P4P payments were relatively small and went to the hospital, not the physicians. But physicians were given immediate feedback regarding core quality measures, causing them to be convinced that they were acting in the best patient interest. In terms of eq. (16) of the model, the additional revenue accruing to the hospitals was not distributed to the physicians, resulting in  $R'/M = 0$  in the numerator (the denominator is positive). This makes this case interesting because contrary to Conclusion 4 stating that no initial ethical orientation is necessary for a positive correlation between medical ethics and P4P, such an orientation is needed, hinging on the sign of  $-c' + \alpha \cdot w'$ . In contradistinction with case study no. 3, the sponsors of the scheme made no particular effort to keep physicians' marginal cost of effort  $c'$  low. However, management claimed that over four years, the HQID project saved the lives of an estimated 4,700 heart attack patients. Quite likely, this caused physicians to revise their estimate of  $w'$ , the impact of their extra effort on patient welfare. However, without a sufficiently strong initial ethical orientation ( $\alpha > 0$ ), outside observers would hardly conclude that the P4P component introduced by CMS actually enhanced rather than undermined medical ethics, at least among the physicians working for the North Shore-LIJ Health System. Finally, note that North Shore University Hospital may have excelled because for its physicians, the share of activity under P4P  $\omega$  was particularly low (see the discussion below eq. (16) again).

## **CONCLUSIONS**

This contribution uses economic models of physician behavior that depict professional ethics to identify the circumstances in which breaking away from fee-for-service (FFS) payment may weaken professional ethics, a claim often advanced by the medical profession. Ethical orientation is depicted by the

importance a physician assigns to patient well-being relative to his or her own financial interests. The transitions analyzed are from FFS to prospective payment (PP) and pay-for-performance (P4P), respectively. They are combined with two settings, private (solo) practice and hospital or group practice (with a sharing of resources), resulting in four categories. In the solo practice setting, a transition to PP is indeed found to lower the relative importance of patient well-being in a wide variety of circumstances, thus undermining medical ethics (Conclusion 1). However, it may well be enhanced by a transition to P4P provided that P4P payment is tied to improvements in patient health to a sufficiently high degree (Conclusion 2). In the case of physicians in hospital and group practice, changing payment in favor of PP again tends to undermine their ethics as well, notably among highly specialized physicians, who typically have great impact on patient well-being (Conclusion 3). Finally, a transition towards P4P might enhance professional ethics of physicians in hospital and group practice if their impact on patient well-being is not only substantial but also exceeds the marginal cost of their effort; interestingly, their initial ethical orientation does not matter.

Four case studies (three from the United States, one from Germany) provide some preliminary evidence regarding these predictions. Three of them fall into the category ‘Physicians in private practice subject to a transition from FFS to P4P’; in particular, the authors were unable to identify case studies relating to a transition from FFS to PP. Therefore, not all of the four predictions could be pitted against the available evidence. However, the four case studies do support the theoretical prediction that a transition to P4P need not cause physicians to attribute a reduced importance to patient well-being compared to their own financial interests. To the contrary, outside observers would likely have concluded that the medical orientation both of physicians in private and hospital practice was enhanced.

Of course, these findings are subject to several qualifications. First, the four predictions hold only in the context of the models posited, which may neglect important aspects of private, hospital, and group practice. For instance, physicians’ own interests may also include their free time as well as their reputation rather than their income only. Second, equating ethical orientation with the importance of patient well-being relative to the physician’s own financial interests may fail to comprise the full scope of professional ethics. Third, the three modes of payment (FFS, PP, and P4P) might be modelled without sufficient detail. Finally, the four case studies presented fall way short of a comprehensive econometric analysis relating the theoretical parameters ranging from initial ethics to the marginal cost of effort to changes in the mode of payment. However, one finding is likely to be robust. The claim that breaking away from FFS necessarily undermines physicians’ professional ethics is too sweeping; there are various circumstances in which it must be qualified and could even prove wrong.



## REFERENCES

- American Academy of Dermatology (2000), Position Statement on Capitation's Impact on Medical Ethics. Washington DC: AAD.
- Begley CE (1987), Prospective payment and medical ethics, *Journal of Medical Philosophy*, 18(2), 107-122.
- Bester H, Güth W (1998), Is altruism evolutionarily stable?, *Journal of Economic Behavior and Organization*, 34, 193-209.
- Bolle, F (2000), Is altruism evolutionarily stable? And envy and malevolence?, *Journal of Economic Behavior and Organization*, 42, 131-133.
- Ellis RP, McGuire TG (1986), Provider behavior under prospective reimbursement: cost sharing and supply, *Journal of Health Economics*, 5(2), 129-151.
- Gervais KG, Priester R, Vawter DE, Otte KK, and Solberg MM (1999), *Ethical Challenges in Managed Care*. Washington, DC : Georgetown University Press.
- Henke KD (2004, ed.), *Integrierte Versorgung und neue Vergütungsformen in Deutschland (Integrated care and new forms of remuneration in Germany): lessons learned from comparison of other health care systems*, Baden-Baden: Nomos.
- Janus, K (2003), *Managing Health Care in Private Organizations: Transaction Costs, Cooperation and Modes of Organization in the Value Chain*. Frankfurt: Peter Lang.
- Page, L (2009), North shore-LIJ health system chief quality officer explains how his organization ached P4P, *Becker's ASC Review*, Sept. 9.
- Pauly MV, Redisch M (1973), The not-for-profit hospital as a physicians' cooperative, *American Economic Review*, 63 (1), 87-99.

Redwin MA (2011), *Conflicts of Interest and the Future of Medicine: The United States, France and Japan*. New York: Oxford University Press.

Roland M (2004), Linking physicians' pay to the quality of care - a major experiment in the United Kingdom, *New England Journal of Medicine*, 351(14), 1148-1154.

Roland M (2007), The Quality and Outcomes Framework: too early for a final verdict, *British Journal of General Practice*, July, 525-526.

Sicsic J, Le Vaillant M, and Franc C (2012), Intrinsic and extrinsic motivations in primary care: An exploratory study among French general practitioners, *Health Policy*, [dx.doi.org/10.1016/j.healthpol.2012.08.020](https://doi.org/10.1016/j.healthpol.2012.08.020).

Trottmann M, Rischatsch M, and Zweifel P (2013), Generic Substitution, financial interests, and imperfect agency, *International Journal of Health Care Finance and Economics*, 13 (2), 115-138.

Ward B (1958), The firm in Illyria: market syndicalism, *American Economic Review*, 48(4), 566-589.

Zweifel P (2011), Swiss experiment shows physicians, consumers want significant compensation to embrace coordinated care, *Health Affairs*, 30(3), 510-518.

Zweifel P and Schoder J (2008), Managed-Care-Konzepte und Lösungsansätze – Ein internationaler Vergleich aus schweizerischer Sicht (Managed-care concepts and solutions – an international comparison from a Swiss point of view) , in: V.E. Amelung et al. (eds), *Vernetzung im Gesundheitswesen – Wettbewerb und Kooperation*, Stuttgart: Kohlhammer, 149-166.



## APPENDIX

This Appendix contains the steps leading to equations (2), (3), (6), (7), (10), (11), (14), and (15) of the text.

**Physician in private practice subject to a shift from FFS to PP:** Differentiation of eq. (1) yields the first-order condition for an (interior) optimum,

$$\frac{dU}{de} = \pi \cdot v'[P](-c' + \alpha \cdot w') + (1 - \pi) \cdot v'[F](r' - c' + \alpha \cdot w') = 0 \quad (\text{A.1})$$

For an interior solution to obtain, marginal cost  $c'$  must evidently exceed marginal patient well-being weighted by ethics,  $\alpha \cdot w'$ . This renders the first term negative (mirroring the disincentive effect of fixed prospective payment), while the second is positive as long as the FFS margin is nonnegative.

Now consider an exogenous change  $d\pi > 0$ , i.e. an increased share of prospective payment. Since the first derivative of the utility function must have the value zero before and after the change, the right-hand side of eq. (A.2) below is zero. Its left-hand side shows the two components of the change in marginal utility induced by  $d\pi$  and the adjustment of effort  $de$ ,

$$\frac{\partial^2 U}{\partial e^2} \cdot de + \frac{\partial^2 U}{\partial e \partial \pi} \cdot d\pi = 0 \quad (\text{A.2})$$

This can be solved to obtain

$$\frac{de}{d\pi} = - \frac{\partial^2 U / \partial e \partial \pi}{\partial^2 U / \partial e^2} \quad (\text{A.3})$$

Therefore, assuming that the second-order condition for a maximum  $\partial^2 U / \partial e^2 < 0$  is satisfied, the sign of  $de / d\pi$  is determined by the sign of  $\partial^2 U / \partial e \partial \pi$  ( $\approx$  symbolizes proportionality),

$$de / d\pi \approx \partial^2 U / \partial e \partial \pi = v'[P](-c' + \alpha \cdot w') - v'[F](r' - c' + \alpha \cdot w') \quad (\text{A.4})$$

Since the first-order condition is always satisfied by assumption, eq. (A.4) can be simplified, using an expression derived from eq. (A.1),  $v'[F](r' - c' + \alpha \cdot w') = -\pi / (1 - \pi) \cdot v'[P](-c' + \alpha \cdot w')$ . Substitution into eq. (A.4) yields eq. (2) of the text,

$$\begin{aligned} de / d\pi &\approx v'[P](-c' + \alpha \cdot w') + \pi / (1 - \pi) \cdot v'[P](-c' + \alpha \cdot w') \\ &\approx 1 / (1 - \pi) \cdot v'[P](-c' + \alpha \cdot w') \end{aligned} \quad (\text{A.5})$$

Now consider another shock,  $d\alpha > 0$ , representing an exogenous change causing medical ethics to be strengthened or more pronounced. For instance, some physician may simply be a more ethical type than another, which raises the question of whether this has an impact on his or her effort. By analogy, the sign of  $de/d\alpha$  is the same as the sign of  $\partial^2 U / \partial e \partial \alpha$ , which is approximated by

$$de/d\alpha \approx \partial^2 U / \partial e \partial \alpha = \pi \cdot v'[P] \cdot w' + (1 - \pi) \cdot v'[F] \cdot w' \quad (\text{A.6})$$

This is eq. (3) of the text; it is an approximation because in principle there is an additional term (see eqs. (1) and (A.1)), amounting to  $+\pi \cdot v''[P](-c' + \alpha \cdot w')^2 + (1 - \pi)v''[F](-r' - c' + \alpha \cdot w') \cdot w' < 0$  given the usual assumption of decreasing marginal utility, i.e.  $v''[\cdot] < 0$ . To reflect risk aversion in the context of a risk prospect  $v''[\cdot] < 0$  would be required; however, given that risk aversion is neglected,  $v''[\cdot] = 0$  is a justifiable simplification since this term is of second order relative to  $v'[\cdot]$ .

**Physician in private practice subject to a shift from FFS to P4P:** The change  $d\pi$  has to be replaced by a change  $d\omega > 0$ , indicating an increase in the share of activity financed by P4P. From eq. (5), one has the modified first-order condition,

$$\frac{dU}{de} = \omega \cdot v'[O](p' \cdot w' - c' + \alpha \cdot w') + (1 - \omega)v'[F](r' - c' + \alpha \cdot w') = 0 \quad (\text{A.7})$$

From this, one obtains

$$\begin{aligned} de/d\omega &\approx \partial^2 U / \partial e \partial \omega = v'[O](p' \cdot w' - c' + \alpha \cdot w') - v'[F](-c' + \alpha \cdot w') \\ &= 1/(1 - \omega) \cdot v'[O]\{(-c' + (p' + \alpha)w')\} \end{aligned} \quad (\text{A.8})$$

after substitution of the expression  $v'[F](r' - c' + \alpha \cdot w') = -\omega/(1 - \omega) \cdot v'[O]\{-c' + (p' + \alpha)w'\}$

derived from the first-order condition (A.7). This is eq. (6) of the text. Next, differentiation of eq. (A.8) w.r.t.  $\alpha$  yields

$$de/d\alpha \approx \partial^2 U / \partial e \partial \alpha = \omega \cdot v'[O] \cdot w' + (1 - \omega) \cdot v'[F] \cdot w' \quad (\text{A.9})$$

In full analogy with eq. (A.6) above. This is eq. (7) of the text.

**Hospital and group practice physician subject to a shift from FFS to PP:** One obtains by differentiating eq. (9) of the text,

$$\frac{dU}{de} = \pi \cdot v'[P](-C'/n + \alpha \cdot w') + (1 - \pi) \cdot v'[F]\{R'(e)/M - c' + \alpha \cdot w'\} = 0 \quad (\text{A.10})$$

For an interior solution to obtain, either the marginal cost per patient  $C'/n$  must exceed marginal patient well-being weighted by ethics  $\alpha \cdot w'$ , or marginal revenue per physician  $R'/M$  must exceed the physician's own marginal cost of effort  $c'$ .

Let the importance of PP increase. Assuming again that the second-order condition,  $\partial^2 U / \partial e^2 < 0$  is satisfied, the sign of  $de/d\pi$  is determined by the sign of  $\partial^2 U / \partial e \partial \pi$ ,

$$de/d\pi \approx \partial^2 U / \partial e \partial \pi = v'[P](-C'/n + \alpha \cdot w') - v'[F](R'/M - c' + \alpha \cdot w') \quad (\text{A.11})$$

By eq. (A.10), one has  $v'[F](R'/M - c' + \alpha \cdot w') = -\pi / (1 - \pi) \cdot v'[P](-C'/n + \alpha \cdot w')$ .

Substituting this into eq. (A.13), one obtains eq. (10) of the text,

$$\begin{aligned} de/d\pi &\approx v'[P](-C'/n + \alpha \cdot w') - \pi / (1 - \pi) \cdot v'[P](-C'/n + \alpha \cdot w') \\ &\approx 1 / (1 - \pi) \cdot v'[P](-C'/n + \alpha \cdot w') \end{aligned} \quad (\text{A.12})$$

As to  $de/d\alpha$ , one approximately obtains from eq. (A.11),

$$de/d\alpha \approx \partial^2 U / \partial e \partial \alpha = w' \{ \pi \cdot v'[P]w' + (1 - \pi)v'[F] \}, \quad (\text{A.13})$$

which is identical to eq. (A.6). This is eq. (12) of the text.

**Hospital and group physician subject to a shift from FFS to P4P:** Finally, consider an increase in the share of P4P-financed activity,  $d\omega > 0$ . Differentiation of eq. (12) yields

$$\frac{dU}{de} = \omega \cdot v'[O](R' \cdot w' / M - c' + \alpha \cdot w') + (1 - \omega)v'[F](R'/M - c' + \alpha \cdot w') = 0 \quad (\text{A.14})$$

which implies  $v'[F](R'/M - c' + \alpha \cdot w') = -\omega / (1 - \omega) \cdot v'[O](R' \cdot w' / M - c' + \alpha \cdot w')$ .

Applying eqs. (A.3) and (A.14) in analogous manner, and substituting, one obtains eq. (14) of the text,

$$\begin{aligned} de/d\omega &\approx \partial^2 U / \partial e \partial \omega = v'[O] \{ (R' \cdot w' / M - c' + \alpha \cdot w') - v'[F](R'/M - c' + \alpha \cdot w') \} \\ &= v'[O] \{ (R' \cdot w' / M - c' + \alpha \cdot w') + 1 / (1 - \omega) \cdot (R'/M - c' + \alpha \cdot w') \} \\ &= 1 / (1 - \omega) \cdot v'[O] \{ R'/M (w' - 1) - c' + \alpha \cdot w' \} \end{aligned} \quad (\text{A.15})$$

As to  $de/d\alpha$ , it is again analogous to eq. (A.6) above,

$$de/d\alpha \approx 1 / (1 - \omega) \cdot v'[O] \{ R'/M \cdot (w' - 1) - c' + \alpha \cdot w' \} \quad (\text{A.16})$$

This is eq. (15) of the text.

