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Adoption of Electronic and Personal Health Records: An Economic Analysis

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ABSTRACT

We investigate strategic issues surrounding the adoption of electronic health records (EHR) and personal health records (PHR) using an economic framework. Through our analysis, we find evidence that health care providers do not have an incentive to implement interoperable EHR systems even though the implementation of EHR systems (interoperable or otherwise) will increase consumer surplus. In this context, we conjecture that PHR platforms can fundamentally alter the incentives of health care providers, potentially leading to increased EHR adoption under some conditions. In a pluralistic health care system like that which exists in the United States, where health care providers have varying incentives to implement interoperable electronic health records, an online PHR platform can provide an alternative means for consumers to freely exchange their health records among different providers.

Keywords

Electronic health records, personal health records, switching cost, two-sided market, national health information network, adoption

INTRODUCTION

The development of an IT infrastructure has an enormous potential to improve the safety, quality, and efficiency of health care in the U.S., where almost \$300 billion is spent on unnecessary or ineffective treatments each year (Landro 2005). An estimated 44,000 to 98,000 people die due to medical errors each year according to a much-cited Institute of Medicine report (Institute of Medicine 2000). One major reason for medical errors is that different physicians treating the same patient do not all have access to all the medical records. The availability of such information, which could be provided by a national health network, would give patients and their doctors a complete up-to-date view of a patient's medical history, medications and the like, and would allow patients to track and note any mistakes in their doctors' records. This would also facilitate better decision making (e.g., ordering appropriate tests), identification of patients for drug recalls and outbreaks of emerging diseases, faster and more efficient clinical trials, and monitoring of bioterrorism.

In fact, as far back as 1991, the Institute of Medicine called for a widespread implementation of a computer-based system to remedy the inherent flaws in paper records, improvement in patient safety, and a reduction in medical errors (Institute of Medicine 1991). Despite the support for and reported benefits of EHR, the level of adoption has been far from impressive in the United States. In fact, the \$2.1 trillion U.S. health care system trails several of its counterparts in OECD countries in the use of EHR.

On the benefit side, a RAND Corporation study suggested that the effective implementation of a national health-information network could save the nation about \$81 billion annually through improvements in health care efficiency and safety, in addition to another savings of a similar amount through better prevention and management of chronic diseases (Hillestad, et al. 2005). On the cost side, a team of well-known experts have estimated that the national health-information network would cost \$156 billion in capital investment over five years and \$48 billion in annual operating costs (Kaushal, et al. 2005). Clearly, there is a strong case for the widespread and accelerated adoption of EHR.

A 2001 Harris Interactive study contends that the difference in EHR adoption rates between Europe and the U.S. is due to the prevailing market structures and the misaligned incentives. In Europe's single payer systems, the payer can (and often does) dictate what physicians must do. In contrast, each provider in the U.S. pluralistic system must make its own decision of

whether to digitize its medical records, which can cost a small group practice upwards of \$200,000 (Smith 2003) or a major hospital \$20 million or even more (Wysocki 2004). Because consumers and institutions that ultimately pay for health care (including federal and state governments as well as businesses) reap much of the vast savings associated with the adoption of EHR, recouping the capital investments in EHR by a provider is difficult for a health care provider (Bender, et al. 2006).

Sensing an opportunity, technology giants Google and Microsoft have recently entered this domain with their personal health record (PHR) solutions (Lohr 2008). PHR is an electronic health record on an individual that can be drawn from multiple sources, while being managed, shared, and controlled by the individual. Google has partnered with the Cleveland Clinic to pilot its PHR dubbed Google Health, while Microsoft is piloting its own system, called Health Vault, with the Mayo Clinic. PHRs come with application interfaces that facilitate integration with providers' clinical electronic records, so that patients can send personal information, at the individual's discretion, into the EHR or pull information from the EHR into the PHR. One of the main criticisms of the EHRs implemented to date is that these systems do not communicate with each other and are islands of information themselves. Experts in the field have long noted that, in the absence of a national health information exchange and a willingness by medical providers to share their closely guarded patient information, the true potential of EHR could never be realized. However, recent introduction of PHR tools with standard interfaces and data structures stand to change the status quo as they empower the patients in building a digital history of their health and easily sharing those records with the related parties as they see fit.

These developments lead us to ask the following research questions. Can social surplus increase with EHR, but yet providers not adopt it? Given heterogeneous providers, which type of provider would gain from joint adoption of interoperable versus non-interoperable EHR systems? What role can a Web-based PHR platform (such as those by Microsoft and Google) play in this environment? What would be the incentive of the PHR platform in providing such a service? Our ongoing research intends to develop and analyze a stylized model that provides answers to these questions. In determining optimal EHR/PHR adoption strategies, providers consider improvements in care and value provided to their patients on the one hand and technology implementation costs, subscription fees (if any), and reduced switching costs for current customers on the other. In this regard, a key feature that can limit adoption of PHRs is that adoption can lower the costs of customers switching to alternative providers. We characterize the online platform as serving a two-sided market because platforms such as Google and Microsoft will be able to leverage, through appropriate pricing, either of their clientele (patients and providers) to ensure participation of the other in maximizing their profits. To the best of our knowledge, this is the first study that systematically and analytically investigates how the two most cited barriers to the widespread adoption of EHR (i.e., sizable costs and misaligned incentives) can be overcome in a pluralistic health care system such as the one in the United States.

The next section presents a review of the related literature. In Section 3, we set up an economics model that incorporates switching costs to explain the nature of the competition between health care providers. This is then expanded in Section 4 to include the possibility of adopting EHR systems and the presence of a PHR platform, which generates a two-sided market. The final section concludes with a discussion of the results and their broader implications.

2. LITERATURE REVIEW

Our research mainly draws from two streams of literature – the information systems (IS) research on health care and the economics literature on health care. We briefly touch upon some of the relevant literature.

2.1. Information Systems Research on Health Care

The lack of widespread adoption of EHR systems has naturally prompted research in information systems on health care. These can be classified under two heads: those that analyze the returns on investment in IT in health care and those that deal with the nature of adoption of technology.

One of the seminal research that evaluates the returns on investment in information technology is by (Devaraj and Kohli 2000) which looks at the payoff on IT investments of eight hospitals over a period of three years. The research finds evidence on the time-lagged benefits of IT investment that might not be evident from cross-sectional studies. (Menon, et al. 2000) uses a similar longitudinal approach that shows the productivity effects of IT in health care evidenced in hospital data collected by the Washington State Department of Health across three types of departments from 1976 through 1994.

A stream of IS literature examines the adoption of healthcare information technologies (HIT) by healthcare providers, with the Technology Acceptance Model (TAM) as their backdrop. Various factors have been empirically observed to affect HIT adoption – hospital size, system membership (stand-alone or affiliated), tax status (Hikmet, et al. 2008), infrastructure and technical support (Bhattacharjee and Hikmet 2008), tax payer mix (Menachemi, et al. 2007), and the prevalence of professional certifications (Hikmet and Bhattacharjee 2006). Other literature that examine the adoption of technology in health care includes Hu, et al. (1999) and Koumbati (2006).

2.2. Economics Research on Health Care

Kenneth Arrow's seminal article on health economics (Arrow 1963) articulated for the first time the fundamental differences of medical care markets from other traditional forms of markets (this was later expanded upon by Titmuss (1971)). Arrow explained that many of the important concepts in the medical marketplace are a "social response to the lack of full information in the market" (Newhouse 2002). The health economics literature looks at a wide range of issues – analyzing the effects of the various market institutions on social welfare, demand and supply side pricing, managing moral hazard, and the effects of insurance on medical care (for a very good exposition to the vast literature in this area, see (Newhouse 2002)). A significant amount of the literature in the area of health care economics abstracts away the role of insurers or other payers in modeling provider competition in prices (see, for example, the classical papers by Pauly (1968) and Crew (1969), and in a slightly different context Grossman (1972)).

As the online PHR platforms represent entities that position themselves between the providers and the consumers, they serve both of these segments (and price those offerings accordingly). For a provider, the choice of joining the PHR platform (and the implied lower switching costs faced by the patients) depends on whether the competing provider has adopted EHR and joined the platform, and this introduces network externalities into the analysis. Such externalities are key to a "two-sided" market setting, which we capture in our model. Our model draws on the burgeoning literature in the area of two-sided markets (two very good reviews come from Roson (2005) and Rochet and Tirole (2006)). Armstrong (2006) and Armstrong and Wright (2007) analyze the competition between various economic agents in a stylized two-sided market framework.

3. Provider Competition under Switching Costs

In this section, we present a stylized game theoretic model of a market with heterogeneous health provider services. Our setting involves a variant of Hotelling's linear city market that allows us to examine the optimal EHR and PHR adoption strategies in the competitive equilibrium.

There are three types of players in the market: providers, consumers, and a monopolist PHR platform. One profit-maximizing provider is located at each end of the linear city and are denoted with P_0 (located at zero) and P_1 (located at one). The providers are differentiated with respect to their effectiveness in delivering care. Factors such as past experience, size, available technology, and experience of staff may allow a provider to outperform others. Consequently, consumers derive different gross utilities when they receive care from the providers. We denote the gross utility of receiving care from P_0 and P_1 by r_0 and r_1 , respectively, where $r_0 > r_1$ without loss of generality. A unit mass of consumers are uniformly distributed on the linear city $[0,1]$ in terms of their personal taste, which can vary by factors such as geographical proximity and practice philosophy of the providers. The proportion α previously purchased from P_0 and the proportion $1-\alpha$ of experienced customers previously purchased from P_1 . When a consumer receives care from a provider, she incurs a utility loss equivalent to the distance on the linear city between her location and that of the provider. Our benchmark case is one characterized by no EHR or PHR for either provider as well as identical switching costs $s > 0$. Switching costs are small compared to the value of care offered by the providers.

We assume providers in the health care market compete in terms of both prices and amenities such as valued services. To simplify the discussion, we characterize such competition in terms of a single variable for each provider, price net of amenities. That is, if the only effect on a provider's cost of an increase in amenities is on its marginal cost, and the effect is linear such that $c(a_k) = \theta + a_k$, then competition among providers can be expressed in terms of the choices of prices net of amenities, with the net price for provider k defined by $p_k^n = p_k - a_k$. A lower net price can be interpreted as a seller either lowering price or increasing amenities to attract additional consumers, with either action reducing the net revenues per unit sold for the provider.

Providers choose prices net of amenities, p_0^n and p_1^n , to maximize current profits with each provider taking the net price of the other provider as given. For the case where consumers' future values of the providers are identical across providers the resulting Nash equilibrium set of net prices is given by:

$$p_0^n = 1 + \theta + (1/3)(r_0 - r_1 + s(1-\eta)(2\alpha-1))$$

and

$$p_1^n = 1 + \theta + (1/3)(r_1 - r_0 + s(1-\eta)(1-2\alpha))$$

where η is the fraction of new consumers in the market.

Profits for the two providers are given by:

$$\pi_0 = \frac{(3+r_0-r_1+s(1-\eta)(2\alpha-1))^2}{18} - k_0$$

and

$$\pi_1 = \frac{(3-r_0+r_1-s(1-\eta)(2\alpha-1))^2}{18} - k_1$$

The above results illustrate several key features of the analysis. First, note that if two providers obtain the same proportion of experienced consumers ($\alpha = 1/2$), then neither switching costs (s) nor the proportion of experienced consumers ($1-\eta$) in the market affects net prices or profits. However, if there is asymmetry in the extent providers claim experienced consumers, this is not the case. In particular, let $\alpha > 1/2$ such that provider P_0 reaps a larger proportion of experienced consumers, an outcome suggested by the previously assumed preference bias for that provider ($r_0 > r_1$). Then, the introduction of switching costs results in an increase in both net prices and profits for provider P_0 , while provider P_1 experiences a fall in both net prices and profits. These results are more pronounced the greater the proportion of experienced consumers ($1-\eta$).¹ A related point is that the likelihood a patient switches to P_0 or to P_1 (y and $1-x$, respectively) decreases with an increase in the cost of switching. Finally, note that total consumer surplus, given by

$$CS = \alpha \left[\int_0^y (r_0 - p_0'' - z) dz + \int_y^1 (r_1 - p_1'' - (1-z) - s) dz \right] + (1-\alpha) \left[\int_0^x (r_0 - p_0'' - z - s) dz + \int_x^1 (r_1 - p_1'' - (1-z)) dz \right]$$

increases with a decrease in switching costs, as the lower switching costs for those switching, along with the lower prices and profits for customers of the larger provider, more than offset the higher prices and profits for the smaller provider that accompanies the lower switching costs.

4. COMPETITION WITH ELECTRONIC HEALTH RECORDS AND THE PHR PLATFORM

Electronic Health Records

In the base model discussed above, providers have paper-based records. We now consider the implications of the option of implementing an EHR at a cost F . Consistent with the literature (see, for example, (Bender, et al. 2006)), the main benefit of EHR accrues to the patients of the adopting provider. The gross utility of receiving care at the adopting provider rises by a positive amount (denoted by δ) after implementation and thus can potentially affect the adopting provider's market share.² According to the 2007 Harris Interactive survey mentioned earlier, 54 percent of the respondents said that if they were to choose between two doctors, of whom only one used electronic health records, their choice would be influenced by the availability of this technology at least to some extent. In another phone survey of 2,000 adults in eastern Massachusetts, 19 percent said they would switch their medical affiliation if they found a provider that offered electronic health records (Goth 2008).

At an additional cost F_i , a provider can choose to implement an "interoperable" system (Hillestad, et al. 2005), one that is built according to established data standards. Several standards currently exist for the interoperability of EHR systems, although in reality their implementation remains extremely limited. These include standards like the ATSM Continuity of Care Record for transfer of patient health records summary (based on XML), the ANSI X12 standard for transmitting billing information (this has become popular in the United States because of the regulatory requirements under the Health Insurance Portability and Accountability Act (HIPAA) for transmitting billing data to Medicare), the DICOM standard for representing and transferring radiology images, the HL7 set of standards for transmitting messages or documents like physician notes, etc. An interoperable EHR system can integrate with the other provider's system in order to seamlessly exchange patient records, if that system is also interoperable.

The PHR Platform

¹ This is because $\frac{\partial \pi_0}{\partial s} > 0$ and $\frac{\partial \pi_1}{\partial s} < 0$ for $\alpha > \frac{1}{2}$, and vice versa, assuming positive market share for both providers in equilibrium.

² While adoption of EHR increases the gross utility of receiving care at the adopting provider, the increase is not large enough to switch the size and preference advantage P_0 enjoys over P_1 ($r_0 > r_1 + \delta$).

Similar to the services of Google Health and Microsoft's HealthVault, a platform offers an online PHR service to patients and providers. The main benefit of this service is that it provides patients with up-to-date online access to their medical history. For Google and Microsoft, such a gain can attract specific types of individuals to their sites, and the potential to target market such individuals can generate increased revenues for Google and Microsoft. From the consumer's viewpoint, such potential can exacerbate consumers' privacy concerns, and we denote the associated cost with f . For example, privacy advocates have raised the concern that Google Health is not covered by HIPAA, and therefore patients can make it unwittingly easier for entities like the government, a legal adversary or a marketing company to obtain private information when their records are stored online. Microsoft and Google have promised not to share any information stored on their systems with any other entity, internal or external. Although the online PHR platforms have a strong incentive to enforce strict privacy rules in order to be successful, consumers would nevertheless continue to have concerns about online infomediaries, and f denotes the associated cost.

The PHR platform charges p_p to providers and p_c to patients. Note that, while we focus on the explicit fees paid by consumers, one could consider p_c more broadly to include revenues generated for the PHR platform from increased traffic in general and target marketing in specific. For a patient to be able to use the PHR service, her provider (who initially maintains the medical history) should first sign up with the platform by paying the fee p_p and upload the patient's records on to the platform's servers. Once records are uploaded, interested consumers can establish an account with the platform and access their records for a fee (p_c). By strategically positioning itself between patients and providers, the PHR platform can charge appropriate prices to leverage participation on either side of the market in a way that maximizes its total profit. The choice of joining the PHR platform depends on whether the other provider has adopted EHR and joined the platform, and this introduces network externalities into the analysis.

The PHR platform takes on the responsibility of developing the middleware and routines that will enable the automatic transfer of patients' health records from providers' EHR systems to its servers. Having a PHR account eliminates the cost a patient incurs when transferring health records to a new provider. All the patient needs to do in this case is to either grant appropriate access rights to the new provider (if it has joined the platform) or download the records and email or take them to the provider (if it has not joined the platform).

The stages of this extended game are as follows. In the first stage, the PHR platform announces the prices (p_c and p_p) for its service. In the second stage, providers simultaneously decide whether to deploy interoperable or non-interoperable EHR systems and whether to join the PHR platform. They then announce their own net prices (p_o^n and p_i^n) for delivering health care. Finally, given the offline switching cost and PHR strategies of the providers, consumers decide which provider to work with and whether to sign up for a PHR account with the platform, if that choice is available.

Analysis of Providers' Adoption of EHR

Each provider has three options (do not adopt EHR, adopt a non-interoperable EHR, and adopt an interoperable EHR), resulting in a total of nine potential outcome combinations. Thus, there are eight *new* scenarios to consider. The solution methodologies for these scenarios are very similar to the one provided in the preceding subsection, hence we only provide the resulting profits in Table 1 (see the Appendix).

Although deploying an interoperable EHR is costlier for providers than deploying a non-interoperable one (by an incremental amount F_i), consumers derive the additional benefit of being able to transfer their records seamlessly from one system to another (and thus avoid the switching cost) when both providers adopt interoperable EHR. However, as can be seen in Table 1, Provider 1 is always worse off when the switching cost drops. Therefore, given this disincentive, there can be no equilibrium in which providers adopt interoperable EHR. We thus have the following lemma.

Lemma 1. *The providers do not have an incentive to invest in interoperable EHR.*

Note that this result is valid regardless of the cost that patients incur when switching providers, a cost that would be eliminated if the providers were to deploy interoperable EHR. Consequently, if the incremental cost of interoperability (F_i) is sufficiently small, the providers' refusal to adopt integrated EHR systems is sub-optimal from a social welfare perspective. This result is consistent with the findings of (Hillestad, et al. 2005), which concluded that even though interoperable EHR systems could result in a large social surplus (estimated to be in the range of \$142-\$371 billion), they are unlikely to be realized in the current health care system. Table 1 summarizes the potential optimality of various outcomes for the health care providers.

		P_1		
		Do not adopt EHR	Adopt non-interoperable EHR	Adopt interoperable EHR
P_0	Do not adopt EHR	Possible equilibrium	Possible equilibrium	Not optimal for P_1
	Adopt non-interoperable EHR	Possible equilibrium	Possible equilibrium	Not optimal for P_1
	Adopt interoperable EHR	Not optimal for P_0	Not optimal for P_0	Not optimal for either provider

Table 1. Optimalities of outcomes for the providers

We now investigate the providers' incentives to invest in non-interoperable systems, which, as we will see, may indeed occur in equilibrium. We introduce our first proposition which suggests that a provider's decision to adopt EHR may be negatively affected by its competitor's adoption. In other words, if a provider has the incentive to adopt EHR when its competitor also adopts, the provider will continue to have the incentive when its competitor does not adopt.

Proposition 1. *The incentive to adopt non-interoperable EHR is smaller when the competing provider also adopts the system than when it does not.*

Lemma 2 outlines which of the two providers should be more interested in adopting EHR. Recall that the providers are differentiated due to their effectiveness in administering care ($r_0 > r_1$) as well as the difference in size (a , where $\alpha > 1/2$). The larger the market share, the easier it is for a provider to recoup the cost of EHR implementation. Because P_0 has a larger market share in the benchmark case, it also has more incentive to adopt EHR than its competitor.

Lemma 2. *The better and larger provider (P_0) has more incentive to deploy non-interoperable EHR.*

Our next proposition outlines the potential equilibrium outcomes. Let Δ denote $r_0 - r_1 + s(1-\eta)(2\alpha-1)$ which is always positive.

Proposition 2. *If $\Delta + \delta/2 < \frac{9F}{\delta} - 3$, then neither provider deploys EHR. If $\Delta + \delta/2 > \left|3 - \frac{9F}{\delta}\right|$, then only P_0 deploys non-interoperable EHR. If $3 - \frac{9F}{\delta} > \Delta + \delta/2$, then both providers deploy non-interoperable EHR.*

As expected, the adoption of EHR is more likely the smaller the implementation cost and the larger the incremental surplus is for consumers due to adoption. Only the more effective provider implements non-interoperable EHR when the switching cost as well as the level of differentiation between the providers (in terms of size and effectiveness of care) are high. On the other hand, both providers adopt the system when the level of differentiation is not significant and the implementation cost is low.

Note also that the providers are worse off when they both adopt non-interoperable systems compared to the benchmark case because, while adoption of EHR does not alter their optimal net prices and market shares, it lowers providers' profits due to the implementation cost. Using economic terminology, this represents a *Prisoner's dilemma* for the providers – either would be better off if they could agree upon not implementing an EHR solution, but competitive pressures force them to nevertheless adopt it. Given the the third condition presented in Proposition 2, ending up in a Prisoner's dilemma is more likely when the two providers are comparable in terms of their efficiencies and market shares while the implementation cost (and hence the severity of the dilemma) is low. The benefits of the EHR adoption are completely absorbed by the consumers, a conclusion which mirrors the empirical findings in reports by Harris Interactive and McKinsey Consulting that we referred to earlier.

Proposition 3. *When implementation cost F is high and the benefit to the patients of implementing an EHR (δ) and the switching cost are low, social welfare may drop with the adoption of non-interoperable EHR. Consumer surplus, on the other hand, always increases with the adoption of non-interoperable EHR.*

A high cost of implementation (which negatively affects the providers' surplus), coupled with the relatively smaller benefits of implementation accruing to the patients, would lead to a cumulatively lower social surplus.

Analysis with the PHR Platform

In this section, we lay out our approach for analyzing the effect of PHR platforms, which is part of our current ongoing research. We first check whether there is any difference in the providers' incentives to adopt PHR. As discussed earlier, a provider first needs to adopt EHR in order to be able to partner with the PHR platform and communicate with it electronically. Once the provider joins the platform, consumers that authorize the uploading of their medical records onto the platform's servers then have quick and easy online access to their records, reducing the cost of obtaining care from a different provider. Correspondingly, if a provider has adopted EHR, it will also adopt PHR through the platform as long as its profit with PHR adoption is at least as much as that without it.

There are three possibilities regarding who joins the platform: (i) only P_0 , (ii) only P_1 , and (iii) both P_0 and P_1 . Suppose initially that only P_0 joins the platform at the price p_p . The utilities of consumers who receive care from their established providers remain the same as before. The difference in this case is that established patients of P_0 that wish to receive care from P_1 now have two options in transferring their medical records to the new provider. They can either do it physically as before (at a cost s), or they can open a PHR account that would allow them to submit a copy of the records to the new provider. In the latter case consumers pay the fee p_c and incur the privacy cost f in the process. We assume that p_c is sufficiently low such that these consumers choose the latter option ($p_c \leq s - f$), because otherwise the platform's service is never used. We initially suppose that P_1 has not adopted EHR in this proposed equilibrium. We expect that the outcomes will be somewhat similar to those in the benchmark case, except that, instead of incurring the offline switching cost, consumers who switch providers now pay a fee to the PHR platform and experience a disutility due to the corresponding privacy loss. Depending on parameter values, we conjecture that there will be scenarios where the platform will subsidize both platforms in order to be able to charge the patients of the providers for the service. We also intend to explore the effect of the PHR platform on the consumer surplus. The results of these analyses will be ready for presentation by AMCIS 2009.

5. CONCLUSION

Studies have consistently reported the little progress that is being made in the U.S. toward a national health network, despite its distinct potential benefits. The problem, as we show in Lemma 1, lies in the fact that the adoption of interoperable systems will not take place unless all key decision makers in a pluralistic system are better off with easy sharing of health records. Online service providers such as Google and Microsoft have sensed the profit potential in this status quo, and have therefore decided to develop online PHR services that can extract some of the available surplus as rent. So, rather than an integrated, globally distributed health network, we are probably moving towards a system where health records are transported to and aggregated in "the cloud". Our analysis will indicate whether platforms such as those of Microsoft and Google will have the incentive to not only provide the "middleware" for an interoperable system, but also in some cases subsidize the health care providers in building their own EHR systems (or equivalently provide it as a cloud computing service).

There are certain limitations to this kind of work. Most importantly, government regulation, technology, and external pressures exert significant impact on health information systems adoption decisions, and mathematical models like ours, no matter how complicated, cannot fully explain the complex dynamics of IT adoption. Therefore, our results should be interpreted with the understanding that not all key factors are captured by our model.

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