Requirement:题目

Energy and the Cell Phone This question involves the “energy” consequences of the cell phone revolution. Cell phone usage is mushrooming, and many people are using cell phones and giving up their landline telephones. What is the consequence of this in terms of electricity use? Every cell phone comes with a battery and a recharger.

B 题:能源和手机 这个问题涉及到手机革命的能源问题。 手机使用率迅速增加，许多人使用手机并放弃了固定电话。 这方面的电能使用会带来什么后果? 每个手机都配备了电池和充电器。

Requirement 1 Consider the current US, a country of about 300 million people. Estimate from available data the number H of households, with m members each, that in the past were serviced by landlines. Now, suppose that all the landlines are replaced by cell phones; that is, each of the m members of the household has a cell phone. Model the consequences of this change for electricity utilization in the current US, both during the transition and during the steady state. The analysis should take into account the need for charging the batteries of the cell phones, as well as the fact that cell phones do not last as long as landline phones (for example, the cell phones get lost and break).

要求 1 考虑现在的美国， 人口约为 3 亿， 从现有数据估计美国有 H 个家庭， 每个家庭有 M 个成员， 以前是使用固定电话的。 现在， 假设所有的座机被手机取代，也就是说每个家庭成员都有一部手机。 建立当前美国在手机使用的过渡和稳定两个阶段用电状况变化的模型， 分析应该考虑到对移动电话充电的需要， 同时移动电话不能像固定电话那样长期使用也是一个现实问题（比如说移动电话可能会丢失或者损坏）

Requirement 2 Consider a second “Pseudo US”—a country of about 300 million people with about the same economic status as the current US. However, this emerging country has neither landlines nor cell phones. What is the optimal way of providing phone service to this country from an energy perspective? Of course, cell phones have many social consequences and uses that landline phones do not allow. A discussion of the broad and hidden consequences of having only landlines, only cell phones, or a mixture of the two is welcomed.

要求1考虑 “ 伪美国 ”--一个约 3 亿人口， 跟当前美国具有相同的经济状况的国家。 然而， 这个新兴国家既没有固定电话也没有移动电话， 从能源角度看， 为这个国家提供电话服务的最佳方式是什么? 当然， 手机有很多固定电话所不具有的用途和社会影响。 这个讨论要涉及单独使用固定电话或者单独使用移动电话， 或者混合使用二者所带来的广泛和潜在的影响。

Requirement 3 Cell phones periodically need to be recharged. However, many people always keep their recharger plugged in. Additionally, many people charge their phones every night, whether they need to be recharged or not. Model the energy costs of this wasteful practice for a Pseudo US based upon your answer to

Requirement 2. Assume that the Pseudo US supplies electricity from oil. Interpret your results in terms of barrels of oil.

要求 3 手机需要定期充电。 但是许多人在不考虑手机是否要充电的情况下， 总是将充电器一直插在电器插槽上， 有的甚至整晚都在给手机充电。 在你的要求 2 解决方案的基础上， 针对 “ 伪美国 ”， 建立上述浪费方式的能源消耗的数学模型。 另外， 假定 “ 伪美国 ” 以石油作为电力来源，以原油桶为单位计算浪费量。

Requirement 4 Estimates vary on the amount of energy that is used by various recharger types (TV, DVR, computer peripherals, and so forth) when left plugged in but not charging the device. Use accurate data to model the energy wasted by the current US in terms of barrels of oil per day.

要求 4 估计各种需要充电的电器设备（电视、 DVR 、 电脑外围设备等） 所使用能源的数量， 考虑设备没有使用， 但插头仍然插在插座上的情况。 要求用精确的数据建立模型， 估计当前美国每天所浪费的能源数量， 以原油（桶 / 天） 计量。

Requirement 5 Now consider population and economic growth over the next 50 years. How might a typical Pseudo US grow? For each 10 years for the next 50 years, predict the energy needs for providing phone service based upon your analysis in the first three requirements. Again, assume electricity is provided from oil. Interpret your predictions in term of barrels of oil.

要求 5 考虑人口及经济增长在未来的 50 年内的情况。 如何使 “ 伪美国 ” 发展壮大？ 对于今后 50 年内的每一个 10 年进行电话服务的能源需求预测， 前提是在你前三个要求的分析基础上进行。 另外， 假定以石油作为电力来源， 以原油桶为单位计算。

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Modeling Telephony Energy Consumption

建立关于移动电话对于能源消费的数学模型

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Summary
摘要

The energy consequences of rapidly changing telecommunications technology are a significant concern. While interpersonal communication is ever more important in the modern world, the need to conserve energy has also entered the social consciousness as prices and threats of global climate change continue to rise. Only 20 years after being introduced, cellphones have become a ubiquitous part of the modern world. Simultaneously, the infrastructure for traditional telephones is well in place and the energy costs of such phones may very well be less. As a superior technology, cellphones have gradually begun to replace the landline but consumer habits and perceptions have slowed this decline from being an outright abandonment.

To evaluate the energy consequences of continued growth in cellphone use and a decline in landline use, we present a model that describes three processes—landline consumption, cellphone consumption, and landline abandonment—as economic diffusion processes. In addition, our model describes the changing energy demands of the two technologies and considers the use of companion electronics and consumer habits. Finally, we use these models to determine the energy consequences of the future uses of the two technologies, an optimal mode of delivering phone service, and the costs of wasteful consumer habits.

高速发展的远程通讯对能源的影响是显而易见的。在人际交流变得越来越重要的现代社会，随着全球气候变化的代价和威胁越来越大，节约能源问题已经变为一种社会共识。尽管被引进只有20年，移动电话却已经成为现代社会无处不在的一个部分。与此同时，传统电话的基础结构已经十分完善，这些电话的能源代价也变得越来越小。作为一个愈加先进的科技，移动电话已经开始逐渐取代传统座机，但是消费习惯和用户理解却未能使这一趋势进一步加速，因为消费者并没有果断放弃传统座机。

为了评估移动电话持续上升的使用量和座机的使用减少给能源带来的影响，我们建立了一个描述三种过程的的模型，作为有效的发展过程，这三种过程是：座机消费，移动电话消费和座机遗弃情况。除此之外，我们的模型描述了两种科技之间变化的能源需求，考虑了相关的电子设备的使用和消费习惯。最后，我们用这些模型来预测未来这两种科技对能源消费的影响，同时预测了接送电话服务的理想模式和浪费型消费习惯的代价。

Introduction

引入:

The telephone has become a fundamental part of our social fabric. In the past couple of decades, we have seen a shift from fixed landline telephones, generally one per household, to individual ownership of cellphones. We attempt to determine the impact of this change on American energy consumption.

移动电话已经成为我们的社交生活中的基础部分.在过去的几十年里,我们见证了从几乎每家一部的固定电话到几乎每人都拥有一部手机的快速转变.我们试图估计这种转变对于美国能源消费的影响.

The factors that go into accurately modeling telephony energy consumption are complex. We need to take into account also the energy consumption of peripheral devices, such as answering machines for landline phones and chargers for cellphones. Moreover, landline phones are not a uniform product. Cordless phones consume considerably more energy than their corded counterparts. Likewise, the total energy cost of cellphone usage is complicated by such factors as recharging, replacement, and battery recycling. Our model takes all of these factors into account, and additionally attempts to use the limited real-world data available to chart the changes in each of these factors over time.

想要详尽而准确地描述电话能源消费的每一个因素是很复杂的.我们需要考虑周边设备的能源消费,比如电话答录机和手机充电器.更重要的是,固定电话设备没有统一的设备标准.无线电话比座机消耗了大得多的能量.同样的, 如果考虑充电,替换手机,电池循环利用等因素的变化 ,移动电话对于总能源的消费就会显得比较复杂.我们的模型考虑了所有这些因素,还尽量的利用现实生活中可用的有限数据来模拟出每个因素随时间的变化规律.

Perhaps the most complex factor to model is adoption of technological innovations in a population. This is relevant not only to landline adoption and cellphone adoption, but additionally de-adoption of landline phones in the face of cellphone usage can be considered an independent innovation and modeled accordingly. Research into the phenomenon indicates that it can be modeled globally by the differential equation

可能最复杂的因素是模拟科技进步在人群中的采纳程度.这不仅与座机和移动电话采纳程度有关,而且与移动电话作为一个独立的创新被引进后座机的采纳减少有关. 关于这个现象的研究可以通过几个等式在全球范围内的模拟而实现..

$$\frac{dP}{dT} = rP\left(1 - \frac{P}{K}\right),$$

where P is the proportion of the population that has adopted the innovation at time t,r is the adoption rate, and K is the saturation point for the innovation.

以上式子中,p代表在t时刻人群中采纳科技进步成果的比例.r代表采纳率,K代表该科技进步被采纳的饱和度.

Using the descriptions of such a model, we arrive at an accurate fit to available data and can predict future demand for cellphones and landlines. Determining the cost for these respective technologies we arrive at the total energy burden. Briefly, we explore how this question relates to the energy consumption of other household electronics, and how much waste is generated therein. Additionally, we explore the caveat that technological development has been and continues to be wildly unpredictable, and the consequences of this reality.

用这样一个模型的描述，我们达到了准确拟合已有数据的程度,同时能估计未来关于移动电话使用和座机的使用需求.决定这些值得尊敬的科技进步的代价使我们得到了最大的能源负担.简单的说,我们探索了这个问题如何关联到其他家庭的电子产品的能源消费,和这种情况下有多少浪费产生.同时,为了防止误解,我们必须声明,科技进步一直是,同时也将持续是不可预料的,这是一个现实的结果.

A separate question is how best to distribute landline and cellphones throughout a population committed to neither, so as to minimize energy consumption while not violating social preference. This problem is explored through an optimization with respect to energy usage, in which we discover that a country, here a “Pseudo-U.S.,” which supports a cellphone- only communicative infrastructure minimizes its total energy consumption, and also does not violate social demand for novel technologies. Finally, we estimate the total energy consumption by such a nation over the next 50 years.

一个独立的问题是如何最好的在不使用两者的人群中分配座机和移动电话的比例,以达到最小化其能源消费的同时又不影响社会偏好的效果.这个问题将通过考虑能源使用的最优化来探索,在这里,我们引入一个国家,即”伪美国”,其支持移动电话作为唯一基础交流设施使得该国能源损耗达到最小化,与此同时,又不影响对于新科技的社会需求.最后,我们估计了下一个50年对能源总消费趋势.

Model Overview

模型纵览

We examine two approaches to modeling technology diffusion through a population. The first attempts to gauge technology adoption at the house-hold level and aggregate these results to model global trends. However, this approach is unsuccessful, and we explain why. The second approach models technology adoption at the global level; it

我们检验了两种方法来模拟科技在人群中的扩散.第一种试图在家庭的层次估计科技采纳程度,同时综合这些信息来模拟全球的趋势.但是,这种方法不太成功,我们在文中解释了原因.第二种方法模拟了全球层面的科技采纳程度,其包括以下性质:

- accurately models past and present telephony energy consumption,
- makes future predictions of cellphone saturation and landline de-adoption
- consistent with previous technological replacement paradigms, and encompasses a broad range of pertinent factors in telephony energy consumption.

- 准确模拟了过去和现在的电话能源消费情况.
- 做出对未来的电话饱和度和座机采纳率的预测.这种预测与之前的科技替换规律相符.
- 同时包括了电话能源消费中更为广阔的持续性因素.

Model Derivation

模型推导

Adoption of Innovations

科技创新采纳率

Our model describes U.S. usage rates for landlines and cellphones as three diffusive innovation curves. Consider the adoption of an innovation Y. At small times after the development of this innovation, adoption of Y throughout a population is minimal. As the innovation spreads, demand increases until a saturation point is reached. Thus, the spread of Y throughout a population is proportional to its synchronous prevalence, but is checked from exponential growth by an upper bound to its saturation in a population. At its simplest, we can model this as

我们的模型通过画出三个科技创新的扩散曲线来描述美国座机和移动电话的使用情况.把Y看成科技创新的采纳率.在该科技创新发展的极短时间内,人口中的采纳率Y是最小的.随着该科技创新的不断扩散,需求提升以至于达到饱和度.因此,Y在人口中的扩散是与它在群众中的受欢迎程度成正比的,但是这种指数增长只能增长到达人群中使用的饱和度.用最简单的方式表示,我们可以把其归纳为:

$$\frac{dY}{dt} = Y(1-Y).$$

Of course, adoption is not uniform between different technologies, and saturation rates likewise vary. By introducing constants r for adoption rate and S for saturation rates, we can refine our model to

当然,这种采纳率和饱和度在不同科技之间是不同的.通过引入r作为采纳率常量,S作为饱和率,我们可以改善我们的模型到:

$$\frac{dY}{dt} = rY\left(1-\frac{Y}{K}\right),$$

which has a solution in form of the logistic equation. Therefore, for each of the processes we assume a model of the form

该方程的解可以用logistic等式来表示.因此,对于每个过程,我们采取一个以下形式的模型:

$$Y(t) = \frac{A}{1+Be^{-Ct}}.$$

The sigmoidal form of adoption processes is well-known and has been observed in the specific case of cellphone adoption and wireless-only life- style adoption.

Proceeding globally, we initially model the consumption of telephones from their inception by the equation:

该"S型"科技创新采纳过程曲线是很著名的,并且已经在移动电话和无线通讯的具体情况中观察到.

继续下一步,以全球角度来看,我们最初通过以下式子模拟移动电话的消费的初始情况:

$$p_l(t) = A\left(\frac{1}{1+Be^{-C(t-D)}} + \frac{1}{1+Ee^{-F(t-G)}} - 1\right), \qquad \textbf{(1)}$$

where the D and G parameters are chosen so that time is shifted relative to the onset of cellphone adoption. This expression is essentially the addition of two sigmoid curves. The first models the adoption of the landline phone as a new innovation; and the second models the de-adoption of landlines as an independent innovation of a “wireless-only” lifestyle, which has a subtractive effect total landline usage.Likewise, the consumption by cellphones is given by

这个式子中,选择D和G参数是因为这两者能够代表时间的推移与刚开始时移动电话采纳情况的对应关系.这样的表述是两条"S"型曲线所必要的辅助.第一条曲线模拟了座机作为新的科技创新的采纳情况.第二条曲线模拟了在"只有无线通讯"的生活习惯下,座机作为一个独立创新的未被采纳的程度,这样的情况对于总的座机使用有一个负影响.同时,移动电话消费通过下列式子给出

$$p_c(t) = \frac{J}{1 + e^{-K(t-L)}}, \qquad (2)$$

where again L is a time shift chosen to make the model coincide with cellphone adoption.

这里的L是为了使得模型与移动电话采纳情况联系起来的参数,L代表了时间的推移.

We tried to model this at the microscopic level, but that proved to be an intractable approach. From census data, the number of households with m members over the course of history is readily available [U.S. Census Bu- reau 2007]. Equally accessible are the rates of penetration and average costs of cellular and landline communications penetration [U.S. Census Bureau 2001; Eisner 2008]. With this abundance of data, one may be tempted to propose an econometric forecast of telephony usage that is driven by the marginal cost-benefit analysis that a household performs. However, de- termining the functional form that defines the behaviors that are muddled by habits and irrationality are troubling. When reduced to a first-order approximation, such a model still requires the calibration of numerous pa- rameters [Koyck 1954]. After attempting such an approach several times, we abandoned it. We believe the above model captures the data equally well without making undue assumptions.

我们试图在微观层面上建立一个模型,但是这被证明是一个难以掌控的方法.从统计数据来看,一个有m个成员的家庭的数据,随着时间的变化是可以得到的.同样可以得到的有渗透率(这里"渗透"应该理解为"采纳")和每单位的移动电话和座机渗透所需要的平均成本.有了这么丰富的数据,我们就可以提出一个关于电话使用的经济角度预测,这样的预测是通过每个家庭所呈现出来的边际成本-效益分析来得出的.但是,决定由于习惯和非理性导致混乱行为的功能结构将是令人烦恼的.当降低到一阶近似的时候,这样一个模型仍然需要通过很多的参数进行校准[Koyck 1954].在试图尝试这种方法多次后,我们放弃了.我们相信我们上述模型对数据拟合的一样好,就算没有做出一些假设.

Energy Cost of Landlines
座机的能源消耗

Together these two functions model three processes: landline adoption, wireless adoption, and wireless only adoption. Additionally, they describe the long-term behavior of these processes as they reach a steady state. To approach the question of annual energy consumption by telephony prod- ucts, we combine these functions with models for energy expenditure by landline phones and their peripherals, as well as cellphones and their pe- ripherals. The formula for energy consumption by landline phones andVariable

综合这两个功能模型和三个过程:座机采纳情况,无线设备采纳情况,和只有无线设备被采纳的情况.另外,它们描述了这些过程到达稳定状态前的长期行为.为了解决电话类产品每年消费量的问题,我们在模型的功能中结合了座机及其周边电话设备的能源损耗,同样也结合了移动电话和其周边设备的能源损耗.下面的是座机和其周边设备能源消耗的式子:

$$E_l(t) = Pp_lh(\pi_a e_a + \pi_b e_b + \pi_c e_c + \pi_d e_d).$$

表格1描述了符号系统及其相应的解释.时间变量为t,t=0表示在作为初始值的1960年的相应数据情况.

Variables and their meanings.

Variable	Description
$P(t)$	Population of U.S. in year t
$p_l(t)$	Landlines per person in U.S.
$h(t)$	Handsets per landline
$\pi_a(t)$	Percentage of landline owners with corded phones
$e_a(t)$	Yearly Energy Consumption (YEC) (kWh) by corded phones
$\pi_b(t)$	Percentage of landline owners with cordless phones
$e_b(t)$	YEC by cordless phones
$\pi_c(t)$	Percentage of landline owners with combination cordless phone/answering machines
$e_c(t)$	YEC by combination cordless phone/answering machines
$\pi_d(t)$	Percentage of landline owners with separate answering machines
$e_d(t)$	YEC by separate answering machines

(以上变量的解释依次为:1.在第t年美国的人口.2.美国每人的座机拥有率.3.每台座机对应的手机数目.4.座机用户拥有有线电话在总人口中所占的比重.5座机用户拥有的有线电话的能源年消耗量.6.座机用户拥有的无线电话在总人口中所占的比重.7.座机用户拥有的无线电话的能源年消耗量.8.座机用户同时拥有无线电话或者答录机在总人口中所占的比重.9.座机拥有者同时占有的无线电话或者答录机的能源年消耗量.10.座机用户拥有分开的答录机在总人口中所占的比重.11.座机用户拥有的分开的答录机的能源年消耗量.)

Due to a lack of relevant data, we make several assumptions:
因为数据的缺乏,我们做出了如下的假设:

- All yearly energy consumption functions are constant over time. Because corded phones draw their energy solely from phone lines, there is little room for variation in their power draws, so this at least seems reasonable. However, answering machines, cordless phones, and combinations of the two do not have this restriction, and it seems likely that they are becoming more energy efficient with time. However, no data were available to support this hypothesis, so we fixed YEC based on available sources.

- 每年的能源年消耗量随着时间是平稳的.因为有线电话只从电话线汲取能源,所以该能源的变化量很小，至少这看上去是合理的.然而,电话答录机,无线电话,和两者的综合使用没有如上的限制,而且,它们很可能随着时间的推移变得更加节能.但是,没有可用的数据可以支撑如上的结论,所以我们在可用的资源之上建立YEC.

- The adoption of cordless vs. corded phones and answering machines no doubt follows its own sigmoidal curve, but again no data are avail- able. So the variables h, πa, πb, πc, πd are all modeled as first-order linear approximations.

- 无线电话,对比有线电话和电话答录机的采纳情况,无疑遵循了它本身的"S"型曲线,但是又一次,没有可用的数据来支撑.所以构造变量h, πa, πb, πc, π用于一阶线性近似.

Regardless, results produced by the model agree well with available data for energy consumption.

无论如何,模型的最终结果与能源消耗的可用数据相当吻合.

Energy Cost of Cellphones
移动电话的能源成本

The energy cost for cellphones can be modeled as
移动电话的能源成本可以建立如下的模型:

$$E_C(t) = Pp_c(E_{c1} + E_{c2}),$$

where

$$E_{c1}(t) = f_C(C_{\text{charge}}t_{\text{charge}} + C_{\text{standby}}t_{\text{standby}})$$

$$E_{c2}(t) = R_{\text{cell}}R(t).$$

Table 2 describes each relevant variable.
表格2描述了相关的变量

Table 2.
Variables and their meanings.

Variable	Description
$P(t)$	Population of U.S. in year t
$p_c(t)$	Number of cellphones per person
E_{c1}	YEC by cellphones and chargers
E_{c2}	YEC by cellphone recyclers
f_C	Frequency of cellphone charging
C_{charge}	Charger wattage during charging
t_{charge}	Daily charger time spent charging
C_{standby}	Charger wattage during standby
t_{standby}	Daily charger time spent in standby
R_{cell}	Energy needed to recycle one cellphone battery
$R(t)$	Percentage of cellphones recycled in year t

(以上变量依次解释为:1.第t年的美国人口.2.每个人所拥有的移动电话数目.3.移动电话和充电器的能源年消耗量.4.回收的移动电话的消耗年消耗量.5.移动电话的充电频率.6.充电器充电时消耗的瓦特数.7.每天所花的充电时间.8.每天充电器待机(即不充电)的时间.9.回收一个手机电池所需要的能量.10.第t年的手机回收的比例)

The immediate contributions to cellphone energy consumption are charging the phone and leaving the charger plugged in with no phone attached. It is difficult to find data on cellphone charging frequency. Rosen et al. [2001] argue that people charge their phone 50 times each year at their residence (noting that many people charge the phone in their car); but this figure seems very low. Newer phones with a multitude of features require more-frequent charging. Since charging the cellphone has developed into a habit for most people, we assume that people charge the phone every night and keep the charger attached to an outlet all the time.

移动电话对能源消耗贡献最多的是充电完后仍然留在插座上的充电器.很难找到有关数计充电频率的数据. Rosen et al. [2001]认为人们每年在家中充电约50次(考虑到许多人在轿车中充电),但是这个数据似乎有点偏低.有更多功能的新式电话需要更加频繁的冲电.考虑到给手机充电已经成为我们大多数人的一个习惯,我们认为每晚都给电话充电,并让充电器始终插在插座上.

Rosen et al. [2001] observe that the average time to charge a cellphone is 2 hrs, which seems low in comparison to other data, which suggest 3– 4 hrs to charge to 80% and an additional 8 hrs to charge to 100%. However, a phone charged every night is unlikely to have a nearly-empty battery. We assume that the overnight charging does not affect the 2-hr charging time. That 50% of cellphone batteries are lithiumion batteries, which do not allow for overcharging, justifies this assumption [Fishbein 2002; Rosen et al. 2001]. Once a lithium-ion battery is charged, the power drawn differs negligibly from that when no phone is connected to the charger [Rosen et al. 2001]. Therefore, we feel justified in adopting Rosen et al.'s statistic.

Rosen et al. [2001]观察到手机的平均充电时间是2小时,相对其他数据来说,这个数据有点偏低.其他数据显示,如果要充电到80%,需要3-4个小时,需要8个小时才能给手机充满电.然而,一个每天晚上都充电的手机很少有可能会有几乎没电的时候.我们认为,通宵的充电并不影响两个小时的充电时间.50%的手机电池都是锂电池,锂电池不允许过度充电,[Fishbein 2002; Rosen et al. 2001]为这个假设提出了证明.一旦锂电池充满电,能量变化就跟没插手机在充电没什么区别了[Rosen et al. 2001].所以说,我们认为,采用Rosen et al的模型是合理的.

To model the energy cost of recycling used cellphone batteries, we consider the batteries to be recycled by the Rechargeable Battery Recycling Corporation, justified by its significant market share and the fact that it recycles batteries in the U.S. [Office Depot 2004].

为了建立回收手机电池的能量消耗模型,我们考虑了电池要被RBRC循环，考虑到它巨大的市场份额和美国手机电池循环的现状

Energy Optimization
能源优化

Given the above functions for energy costs for cellular and landline telephone usage, we can optimize energy consumption. A Pseudo U.S. with the approximate size of the U.S. would likely have a similar distribution of household size.

在得到以上座机和移动电话使用的能源消耗的基础上,我们可以进一步优化能源消费模型.与真实美国规模相近的伪美国,很可能有与之相近的家庭规模分布.

Let Hm be the number of households with m members and Lm the fraction of households with m members that have landline service. If we assume that the communication needs of every family are satisfied by either having a landline or by each member possessing a cellphone, the numbers of required cellphones Tc and landline phones Ti can be calculated as

Hm是一个有m个成员的家庭的数目,lm是有m个成员且拥有有线电话的家庭的比例.如果我们假定每个家庭的沟通需求能够通过拥有一部座机或者每个家庭成员拥有一部移动电话来满足. 移动电话的需求量为Tc和座机需求量为Ti

$$T_l = \sum_{m=1}^{7} l_m H_m, \qquad T_c = \sum_{m=1}^{7} m(1 - l_m) H_m.$$

We believe that in the absence of a landline, members of a household will not share cellphones.

我们相信在没有座机的情况下,家庭成员们是不会共享一部移动电话的.

The total telephony energy demand of the proposed plan for Pseudo U.S. is

对于伪美国,这个设想中的计划对于电话能源总需求为

$$E(t) = E_l(t) + E_c(t).$$

Using only landlines would minimize the number of telephone units required; however, landline phones and their companion technologies are much less energy-efficient than cellphones. Using only cellphones would maximize the number of telephone units required; and though the energy cost per unit is reduced, the overall increase in units may have deleterious consequences. Therefore, we optimize the variables lm to yield the best communications strategy from an energy perspective.

只使用座机将会降低移动电话的需求,但是,座机及其相关周边设备所使用的科技,其节能能力要远比移动电话来得低.只使用移动电话会最大化每个单位(家庭?)移动电话需求量,所以尽管每部移动电话的能源消耗减少了,但是每个单位总体的能源消耗却上升了.因此,我们引入lm来从能源角度达到最优的沟通策略.

We could modify the above summations to consider roles played by cellphones that are not achievable by a landline. For example, suppose that a single landline cannot serve a large family. If n is the number of people a single landline can serve in a household, we may assume that a family of m with one landline will need to purchase (m-n) cellphones. Then we have

我们可以通过考虑移动电话所具有而座机所没有的功能来修正我们的结论.举例来说,设想下只有一个座机无法满足一个巨大家庭的需要.如果n代表每个座机在家庭中可以服务的人数,我们假定一个有m个成员的家庭如果只有一个座机,则需要购买(m-n)个移动电话,那么我们将有如下式子:

$$T_c = \sum_{m=1}^{7} m(1-l_m)H_m + \sum_{m=n+1}^{7} l_m H_m (m-n),$$

where the second term gives the fraction of families too large to be served by a single landline. Implicit in this formula is an assumption that no family obtains a second landline. This is reasonable, since the average number of landlines per household in the U.S. is only 1.118 [Eisner 2008].

这个式子中,第二条件代表了那些无法通过一个座机满足需求的大家庭的比例.这个式子中不清晰的的是关于没有家庭拥有第二台座机的假设.实际上这是很合理的,因为美国每个家庭的座机拥有量才1.118台[Eisner 2008].

Likewise, we could further complicate the cost function by asserting that not every family member requires a cellphone if a landline is absent. However, we find that such a modification does not enrich the conclusions of our optimization.

同样的,我们可以通过描述并非每个家庭在没有座机的情况下都需要移动电话,来更深入的将消耗复杂化.然而,我们发现,这样的修正并不能使得我们丰富我们的最优化的结论.

Results
结论

Energy Consumption
能源消费

Using the above information, we create an energy consumption function:

用以上信息,我们可以得到总能源消耗等式如下:

$$E(t) = E_c(t) + E_l(t).$$

To make this specific, we must estimate parameter values for A...G in (1) and (2). Using an optimization algorithm described in the methods section below, we arrive at the conclusions in Table 3 .

为了使得结果更确切一些,我们估计了在等式(1)和(2)参数A到G,,使用了一个最优化算法(在下面的部分有描述)来得到结论如Table3所示:

Table 3.
Values of parameters, as fitted from data in Eisner [2008].

Parameter	Value
A	1.1263
B	1.0924
C	0.0423
D	27
E	0.0109
F	0.1587
G	30

Moreover, functions can be described for parameters for El and Ec. Table 4 and 5 give values for the variables and parameters in Table 1 and 2.

而且,能源消耗功能可以被描述为参数E1和E2.表格4和5给出了表格1和2中的参数:

Table 4.
Values for variables in **Table 1**. Source: Rosen et al. [2001].

Variable	Value
$P(t)$	Population growth as predicted by the Census Bureau
$p_l(t)$	As defined in **(1)**
$h(t)$	$1.89\text{E}^{-3}t + 1.076, t \leq 40; -1.20\text{E}^{-3} + 1.152, t > 40$
$\pi_a(t)$	$1 - \pi_b(t) - \pi_c(t)$
$e_a(t)$	20 kWh
$\pi_b(t)$	$\max(0{,}1.45\text{E}^{-2}t - 1.45\text{E}^{-1}), t \leq 40; .44{,}t > 40$
$e_b(t)$	28 kWh
$\pi_c(t)$	$\max(0{,}1.07\text{E}^{-2}t - 1.07\text{E}^{-1}), t \leq 40; .32{,}t > 40$
$e_c(t)$	36 kWh
$\pi_d(t)$	$\max(0{,}2.31^{-2}t - 2.31\text{E}^{-1}), t \leq 40; .69{,}t > 40$
$e_d(t)$	36 kWh

Table 5.
Values for variables and parameters in **Table 2**. Source: Rosen et al. [2001].

Variable	Value
$p_c(t)$	as defined in **(2)**
E_{c1}	$0.365(4 \cdot 2 + 0.6 \cdot 24)$ kWh
E_{c2}	$-0.0283e^{\frac{-(t-1993)}{17.1573}} + 0.00037$ kWh
f_C	365
C_{charge}	4 W
t_{charge}	2 hr
C_{standby}	0.6 W
t_{standby}	24 hr
R_{cell}	0.0037 kWh
$R(t)$	$-7.639e^{-(t-1993)/17.1573} + 0.0999$

From our model, we expected that by 2050 cellphones will have completely replaced landlines in the U.S. Thus, we estimate steady-state energy consumption as E(90) = 2.99 TWh/yr, equivalent to 1.7 million bbl/yr of oil.

从我们的模型中,我们估计到2050年,移动电话将彻底代替座机在美国的使用.因此,我们估计稳定状态的能源消费为E(90) = 2.99 TWh/yr,等同于1.7 million bbl/yr of oil.

Energy Optimization Results
能源最优化结果

From our optimization results for the distribution of telephone types in the Pseudo U.S., we find that it is almost always preferable to have a cellphone-only state, in terms of energy efficiency. Even assuming a landline can service an unlimited number of people in a household, our optimization finds that only for families of size 7 or larger it is energy-efficient to own a single landline and peripherals in place of a cellphone for each family member.

从我们对于伪美国电话类型的分布的最优化结果来看,我们发现该国家几乎总是偏向只使用移动电话,考虑到节约能源的话.即便座机可以给家里的无数人提供服务,我们的最优化模型发现,最有家庭的规模大于7个人的时候,拥有一部座机才比家庭中每个人都拥有一部移动电话来得节约能源.

The cost of leaving cellphone chargers on standby when not active would amount to approximately 62% of the total YEC, or 862,000 bbl/yr of oil.

留下不充电的充电器(待机状态),大概会占据年能源消耗的62%,换言之,既是862,000 bbl/yr的石油.

Energy Waste by Other Household Electronics
其他家用电器的能源浪费

We also discuss the impact of leaving devices plugged in when the device is not in use. From Rosen et al. [2001], we adopt the following approach. First, we investigate the average wattage used in standby mode by the devices under consideration and the time spent in standby mode, respectively. Then we find saturation and penetration values to find the total energy expenditure in the U.S. We consider computers, TVs, set-top boxes (digital and analog), wireless set-top boxes, and video-game consoles.

我们同时讨论了设备没充电却插在插座中时所带来的影响(数据来自Rosen et al. [2001]).我们采取了以下方法.首先,我们研究了这些设备在待机状态下的平均电量消耗(瓦特),还同时研究了待机状态下的时间.然后,我们找出美国能源消费的饱和度和渗透率,我们把电脑,电视,,机顶盒(数字和模拟),无线机顶盒,和电子游戏主机都考虑在内

We take the data for the three types of set-top boxes and the video- game console from Rosen et al. [2001]. Furthermore, the average American spends an average of 4.66 hours watching television and 4.4 hours using a computer every day [Bureau of Labor Statistics 2009]. Average power drawn by computers and television sets turns out to be 4 and 5.1 W [Rosen et al. 2001]. The first two columns of Table 6 give our data set. We use that information, along with saturation rates and household penetration rates [Eisner 2008], to arrive at the figures in the third column.

我们使用了3种类型的机顶盒和游戏主机的数据(从From Rosen et al. [2001]).进一

步,平均每个美国人每天花4.66小时看电视,4.4.小时用电脑. [Bureau of Labor Statistics 2009]. 平均每部电脑和电视机的能源消耗分别是4和5.1瓦特([Rosen et al. 2001]).表6的头两列给出了数据.我们使用该信息,还有饱和度和渗透率来得到第三列的数据.

Table 6.

Data used for power consumption of household electronics. Source: Thorne and Suozzo [1998].

Device	Standby time (proportion)	Power drawn in use (W)	Standby power consumption (TWh/yr)
Set-top box, analog	.78	10.5	3.2
Set-top box, digital	.78	22.3	0.6
Wireless receiver	.78	10.2	1.4
Video-game console	.98	1.0	0.5
TV	.80	5.1	10.3
Computer	.81	4	3.3

We conclude that wasteful energy expenditure due to appliance standby in the U.S. consumes approximately 11.4 million bbl/yr of oil.

我们得出结论,附加设备待机状态的能源浪费达到了大约11.4 million bbl/yr 的石油

Future Predictions
未来预测

Assuming moderate economic and population growth, Table 7 shows results for the Pseudo U.S., using population projections from the U.S. Census Bureau [1996a; 1996b].

设想一个适度的经济和人口增长.表格7显示了伪美国的结果,使用了U.S. Census Bureau [1996a; 1996b]的人口项目数据.

Table 7.

Projected energy use in Pseudo U.S.

Year	Energy ($\times 10^6$ bbl oil)
2010	1.14
2020	1.24
2030	1.66
2040	1.77
2050	1.89

However, we believe that such an analysis is of limited use. Predicting the future of so many variables for a 50-year period is extremely difficult, especially in the realm of technology, where it is commonplace for innovations to change social paradigms. For example, consider an attempt in the 1950s to model the growth of computer usage. Any such attempt would have been unlikely to foresee personal computers, the Internet, or cellphones (which today are rapidly replacing many of the functions of personal computers). Likewise, the energy cost of cellphones may vary greatly due to changes in technology: Social awareness about energy efficiency may drive them to ever-lesser energy consumption, but also they may gain additional features or be replaced by miniaturized computers that result in more energy consumption.

然而,我们相信这样分析的用途是有限的.预测含有如此多变量的未来50年将变得十分困难.特别是在科技领域,产生改变我们生活习惯的革新出现是再正常不过的.举例来说,在1950年考虑建立一个关于计算机增长的模型,诸如此类的模型都不太可能会预测到个人计算机,网络,或者移动电话的出现(甚至是移动电话迅速代替许多电脑的功能的今天).同样的,移动电话的能源消耗随着科技的变动而会产生巨大变化:关于节约能源的社会认识可能导致移动电话变得越来越节能,但是同时,也可能移动电话得到更多的新功能或者被更小更耗能的电脑代替.

Conclusions

结论

Recommendations

建议

From an energy perspective, we find that it is more efficient to abandon landlines in favor of cellphones. This suggestion is reinforced by the model prediction, which suggests an elimination of landlines in the near future by consumer adoption of a wireless-only lifestyle.

从能源角度来看,我们发现放弃座机而使用移动电话会更节能.这个建议在模型预测中得到了印证,该模型暗示了座机的减少,且在不远的将来将被“无线”生活所取代.

Finally we find that the waste generated by chargers on standby (i.e., not charging a device) are a significant source of energy waste. We therefore advocate that efforts be made to forgo convenience and unplug devices when in standby.

最后,我们发现待机状态下的充电器产生的浪费是一个巨大的能源损失.我们因此建议放弃一点方便,而随手把设备从插座上拔下来.

Model Strengths and Weaknesses

模型优缺点

Strengths

优点

• The model reproduces sigmoidal innovation-adoption behavior without making undue assumptions about the underlying processes.

- 这个模型再现了S形创新采纳曲线,而没有做出过度的基本假设.

• The model incorporates a broad span of indirect sources of energy consumption: battery recycling, commuters with cellphones, landline companion technologies.

模型包含了一个广泛的间接能源消费:电池循环,移动电话座机,座机的相关科技

Weaknesses
缺点

• Our model captures only global adoption behavior. This exclusion of underlying behavior is a detriment in capturing deviations from the standard behavior, as was exemplified by the underestimation in the 1990s, when economic expansion may have driven telephone adoption.

- 我们的模型在抓取了全球范围的采纳行为.如果抓取正常行为的变动的话,对基本假设将是一个危害.就像对于1990年代的低估中显示的一样.经济扩张可能驱使移动电话销售

• Due to lack of data, the model relies on interpolation of data related to cellphone and landline energy costs.

- 由于缺乏相应数据,模型可能会依赖关于座机与移动电话能源消耗的数据的解释.

• For simplicity, the model excluded other possible communications technologies. As noted earlier, paradigm shifts in technology are commonplace yet hard to predict.

- 简单起见,这个模型排除了其他可能的通讯科技的可能.就像早些时候注意到的,行为习惯因为科技的改变而改变是司空见惯的,而且很难预测.

• The perspective excludes other communications technologies.

- 这个模型排除了其他通讯科技

• The model fails to capture any benefit of landlines not provided by cell- phones. It may be that landlines are associated with a certain degree of security, which mediates the current prediction that landlines will be completely abandoned.

- 模型没有成功的抓住座机有而移动电话没有的功能.这可能是座机在一定程度上更安全,如果这样,那关于座机完全被摈弃的预测将会停止.

Future Work
预测

• We believe that a model at the microscopic level that takes into consid eration consumer perceptions and habits, in addition to economic data, would perform the best.

我们相信模型在微观层面考虑了消费者的感知和习惯,如果再加上经济数据,将会达到最好的效果

• We also believe with Bagchi [2008] that modeling cellphones and land- lines as more directly competing products with reference to economic data would provide better data fits and predictions.

我们也相信有Bagchi [2008]关于座机和移动电话的模型可以变得更有竞争力,如果能提供更为精确拟合和预测的经济数据的话

• The analysis is limited to the household level. Landline phones will persist in many businesses, and we believe that this persistence will be a significant factor in energy consumption.

这个分析限于家庭层面.座机电话可能会在许多商业中继续使用,而且我们相信,这样一个使用方式会对能源消费产生至关重要的影响.

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