BART DE LANGHE and STEFANO PUNTONI*

The marketplace is replete with productivity metrics that put units of output in the numerator and one unit of time in the denominator (e.g., megabits per second [Mbps] to measure download speed). In this article, three studies examine how productivity metrics influence consumer decision making. Many consumers have incorrect intuitions about the impact of productivity increases on time savings: they do not sufficiently realize that productivity increases at the high end of the productivity range (e.g., from 40 to 50 Mbps) imply smaller time savings than productivity increases at the low end of the productivity range (e.g., from 10 to 20 Mbps). Consequently, the availability of productivity metrics increases willingness to pay for products and services that offer higher productivity levels. This tendency is smaller when consumers receive additional information about time savings through product experience or through metrics that are linearly related to time savings. Consumers' intuitions about time savings are also more accurate when they estimate time savings than when they rank them. Estimates are based less on absolute than on proportional changes in productivity (and proportional changes correspond more with actual time savings).

Keywords: time perception, numeracy, productivity, efficiency, heuristics and biases

Productivity Metrics and Consumers' Misunderstanding of Time Savings

Almost a century ago, John Maynard Keynes (1930) predicted the emergence of a "leisure society" with ample free time. Reality turned out to be very different. Overwork is common for most middle-class people today, and "luxury" means having time to spare (Surowiecki 2014). Time-poor consumers want to spend less time printing articles, downloading movies, and doing household chores such as cleaning or cooking. They are willing to pay for printers that produce more pages per minute (ppm), Internet connections that download more megabits per second (Mbps), and washing machines and blenders with higher rotations per minute (rpm). The marketplace is replete with productivity metrics that put units of an output in the numerator and one unit of time in the denominator.

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This article highlights a subtle disconnect between the benefit often sought by consumers and the information provided by marketers. Although consumers' goal is to attain a desired output (e.g., a 50-page article) in less time, marketers generally tout how much more can be produced in the same amount of time (e.g., 30 vs. 20 ppm). Increases in productivity are related to time savings, but the relationship is curvilinear. Consider Ann, who prints 100 pages each day and currently owns a printer that prints 10 ppm. Ann wants to buy a new printer to decrease print time. She considers two printers with print speeds of 20 and 50 ppm. Ann may be surprised to learn that upgrading from 10 to 20 ppm implies a time savings of 5 minutes for her task (100/10 – 100/20 = 5), whereas a three-times-larger speed upgrade from 20 to 50 ppm implies a further time savings of only 3 minutes (100/20 – 100/50 = 3).

Our main goal is to examine how productivity metrics affect consumer decision making. The key finding is that productivity metrics inflate the perceived attractiveness of products and services that offer higher productivity levels. This effect is attenuated by product experience and the availability of metrics that are linearly related to time savings, suggesting that many consumers have incorrect intuitions about the impact

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of productivity increases on time savings. Two heuristics are common. The first is to believe that greater proportional increases in productivity imply greater decreases in time. The second is to believe that greater absolute increases in productivity imply greater decreases in time. Both heuristics are often incorrect, although the absolute heuristic is less accurate than the proportional heuristic. The absolute heuristic is more prevalent when people rank time savings on the basis of productivity information, whereas the proportional heuristic is more prevalent when people generate point estimates of time savings on the basis of productivity information.

THEORY

Research on the psychology of time suggests there is no one-to-one mapping of objective time on subjective time. For example, if we control for objective time, a past event feels more distant when we can think of more related intervening events (Zauberman et al. 2010). Also, two events seem closer in time when we believe the events are causally related (Faro 2010; Faro, McGill, and Hastie 2010), and two events appear more distant in time when they are also separated in space (Kim, Zauberman, and Bettman 2012). Although these cues (i.e., the number of event markers, perceived causality, and spatial distance) provide no direct information about the specific time interval to be judged, they exert an influence because we hold naive theories about the stochastic relationship between these cues and objective time. However, our interpretations of cues that provide direct information about lengths of specific time intervals can also be biased in systematic ways. For example, people tend to perceive a time interval as shorter when its boundary is defined by a date (e.g., your shipping will arrive on date X) than when the interval is defined by the logically equivalent amount of time (e.g., your shipping will arrive in X days). This affects the amount of time people think they will need to accomplish their goals (LeBoeuf and Shafir 2009) as well as the extent to which people discount the future (LeBoeuf 2006).

Productivity is another commonly available cue for time. Internet services that can download more megabits per second require less time to produce desired results. In fact, there is a deterministic relationship between productivity—the expected output given time (E[O|T])—and the expected time to produce an output (E[T|O]), such that E[T|O] = 1/E[O|T]. We can therefore expect that the availability of productivity metrics would enable consumers to accurately assess time savings and make good purchase decisions. We find that this is unfortunately not the case. We should note that saving time is, of course, not the only reason for wanting higher productivity. For example, a consumer might upgrade CPU speed to meet the minimum requirements for playing a computer game, or to impress others. Such motivations lie outside the scope of this article.

Evaluating Time Savings on the Basis of Productivity Metrics

Although no prior research has examined how productivity metrics affect consumers' preferences for time-saving options, there is a broader literature investigating how people learn and estimate nonlinear relationships. At the heart of this literature lies the insight that people tend to linearize nonlinearities (De Langhe, Van Osselaer, and Wierenga 2011; DeLosh, Busemeyer, and McDaniel 1997; Olsson, Enkvist, and Juslin 2006; Slovic and Lichtenstein 1971). Several articles have explored the ramifications of this tendency for decision quality in a number of substantively important consumer contexts. For example, it can lead consumers to mismanage credit card debt (Soll, Keeney, and Larrick 2011), underestimate the benefits of saving money (McKenzie and Liersch 2011), and myopically maximize intrinsically worthless points in loyalty programs (Hsee et al. 2003; Van Osselaer, Alba, and Manchanda 2004). The productivity–time function is a nonlinear relationship of the type y = 1/x. Research has suggested that people are poor at correctly inferring changes in y based on changes in x for these types of functions. They tend to use one of two inaccurate heuristics, one based on proportional differences and one based on absolute differences.

According to the proportional heuristic, larger proportional changes in the cue imply larger changes in the outcome. Thus, consumers might believe that a 33% change in productivity (e.g., from 20 to 30 ppm [(20 – 30)/30])[1] results in a 33% change in time to complete a task. This is correct. However, to accurately estimate time savings, we need to take into account not only the proportional time change but also the *base time*. Consider that someone who saves 33% on a 6-minute task (e.g., by increasing printing speed from 20 to 30 ppm on a 120-page paper) saves more time (2 min vs. 1 min) than someone who saves 33% on a 3-minute task (e.g., by increasing printing speed from 40 to 60 ppm on a 120-page paper). The proportional heuristic does not take into account these differences in base time. Such neglect of base value has been documented in the context of deal perception; many consumers mistakenly believe that a price increase of 25% followed by a decrease of 40% implies a higher final price compared with an immediate price decrease of 25% (Chen and Rao 2007; Chen et al. 2012). Use of the proportional heuristic for intuitively approximating nonlinear functions of the type y = 1/x has been documented in studies aimed at improving traffic safety (Eriksson, Svenson, and Eriksson 2013; Peer and Gamliel 2012, 2013; Svenson 1970, 2008, 2009).

According to the absolute heuristic, larger absolute changes in the cue imply larger changes in the outcome. Hence, consumers may believe that an upgrade from 20 to 30 ppm provides smaller time savings than an upgrade from 40 to 60 ppm, because the absolute difference in print speed for the first upgrade (30 – 20 = 10) is smaller than that for the second upgrade (60 – 40 = 20). The prominence of absolute differences is consistent with the broader literature on attribute sensitivity. For example, a 20-point difference on a 100-point scale has a larger impact on preferences than a one-point difference on a five-point scale (Burson, Larrick, and Lynch 2009). The absolute heuristic for intuitively approximating nonlinear functions of the type y = 1/*x* has been documented in studies aimed at improving intuitive estimates of gas consumption (Larrick and Soll 2008).

Our key contention is that reliance on the absolute and proportional heuristics leads consumers to overestimate time savings associated with productivity increases at the high end

[1]There is some disagreement about whether people anchor on the faster speed (i.e., (20 – 30)/30 = 33%; e.g., Svenson 1970) or the slower speed (i.e., (20 – 30)/20 = 50%; e.g., Peer and Gamliel 2012). In this article, we determine proportional differences following Svenson (1970). The ranking of options and conclusions from our studies are independent of whether the faster or slower speed is used in the denominator.

of the productivity range, and to increase their willingness to pay for these increases. Another goal of this article is to gain insight into when consumers are more likely to rely on proportional reasoning versus absolute reasoning. Although both can lead to inaccurate assessments of time savings, the absolute heuristic fares worse. For example, both heuristics fail to recognize that an upgrade from 20 to 30 ppm implies larger time savings than an upgrade from 40 to 60 ppm. According to the proportional heuristic, these two upgrades are perceived to lead to the same time savings; according to the absolute heuristic, the upgrade that actually leads to smaller time savings (from 40 to 60 ppm) is perceived to lead instead to *larger* time savings.

Overview of Studies and Key Findings

In Study 1, we asked participants to evaluate Internet connections in the presence versus absence of productivity metrics (i.e., speed in Mbps). We find that consumers value a speed increase that shaves 6 seconds off a 10-second download more than an increase that shaves 6 seconds off a 16-second download. This is consistent with the principle of decreasing marginal utility. However, the difference is larger when productivity metrics are provided to consumers, suggesting that consumers misunderstand the relationship between productivity and time. Moreover, the effect of productivity metrics is reduced when additional cues for time savings are provided through product experience or through metrics that are linearly related to time savings. These moderations suggest that consumers indeed rely on productivity metrics to gauge time savings (as opposed to valuing productivity increases per se). Study 2 generalizes these findings to a choice context in which participants are presented with food processors that are either specified in terms of productivity metrics (i.e., rotations per second) or not specified. Study 3 examines the extent to which people rely on proportional versus absolute changes in productivity when gauging time savings. We find that people's tendency to rely on the proportional versus the absolute heuristic depends on whether they are asked to generate point estimates for time savings. When the task probes people to estimate time savings, people tend to engage more in proportional reasoning. Instead, when the task probes people to merely rank time savings, people tend to engage more in absolute reasoning.

Consumers' decisions between time-saving options are most likely based on an ordinal comparison of time savings (e.g., "I think an upgrade from 10 to 20 ppm will save me more/less time than an upgrade from 20 to 40 ppm") rather than point estimates of time savings (e.g., "I think an upgrade from 10 to 20 ppm will save me X minutes and a upgrade from 20 to 40 ppm will save me Y minutes"). Because ordinal comparisons are influenced more by absolute reasoning, and absolute reasoning is more flawed than proportional reasoning in the context of productivity and time, the universality of productivity metrics in today's marketplace is especially worrying.

STUDY 1: INTERNET CONNECTIONS

Study 1 examines how the availability of productivity metrics affects consumers' willingness to pay for Internet services. We expect that consumers who are provided with productivity metrics for the speed of the connection will value decreases in download time from a small base (e.g., from 10 to 4 seconds) more than identical decreases in download time from a large base (e.g., from 16 to 10 seconds), more so than consumers who are not provided with productivity metrics. This is because time savings between values closer to 0 require a larger proportional and absolute increase in productivity compared with identical time savings between values further from 0.

As we noted earlier, consumers might value productivity increases for reasons other than time savings. For example, they might seek a status benefit from high-performance products, or they might blindly desire any attribute described by companies. If this were true, the effect of the availability of productivity metrics would be the same regardless of whether actual time savings were made apparent to the consumer. To confirm that consumers' willingness to pay is inflated by a misunderstanding of the relationship between productivity and time savings, the study design therefore includes two additional between-participant manipulations. First, we manipulate whether participants are informed about the time it takes each service to download 1 gigabyte (e.g., 200 seconds). This information is simply the inverse of productivity information. It puts units of time in the numerator and a unit of output in the denominator. We refer to this information as a "time metric" because it is linearly related to actual time savings. Second, we manipulate whether participants judge willingness to pay before or after they experience how long it takes each service to download a 50-megabyte file.

In summary, the study uses a 2 (base: large vs. small) × 2 (productivity metrics present: no vs. yes) × 2 (time metrics present: no vs. yes) × 2 (experience: no vs. yes) mixed design. The first factor was manipulated within participants: all participants indicated their willingness to pay for two different Internet connections, one that implied time savings versus a large base and another that implied identical time savings versus a small base. The other three factors were manipulated between participants.

Method

Participants were recruited from Amazon's Mechanical Turk (MTurk; N = 805 U.S. residents; 363 female respondents; M_{age} = 33.07, SD = 10.81) and presented with Internet connections from three different Internet services.[2] We orthogonally manipulated three between-participant factors. First, we manipulated whether participants were provided with productivity metrics of the connection. Participants who were provided with productivity metrics were informed that the download speed was 25 Mbps for the first service, 40 Mbps for the second, and 100 Mbps for the third. Second, we manipulated whether participants were provided with time metrics. Those who were provided with time metrics were informed that the download time for 1 GB was 320 seconds for the first service, 200 seconds for the second, and 80 seconds for the third. Third, we manipulated whether participants evaluated the services before or after experiencing it. For participants who evaluated the services after experience, we simulated how long it takes each service to

[2]In all studies, we aimed for round sample sizes (here, 800); however, due to MTurk's operating procedures, the realized sample sizes can deviate slightly (here, 805).

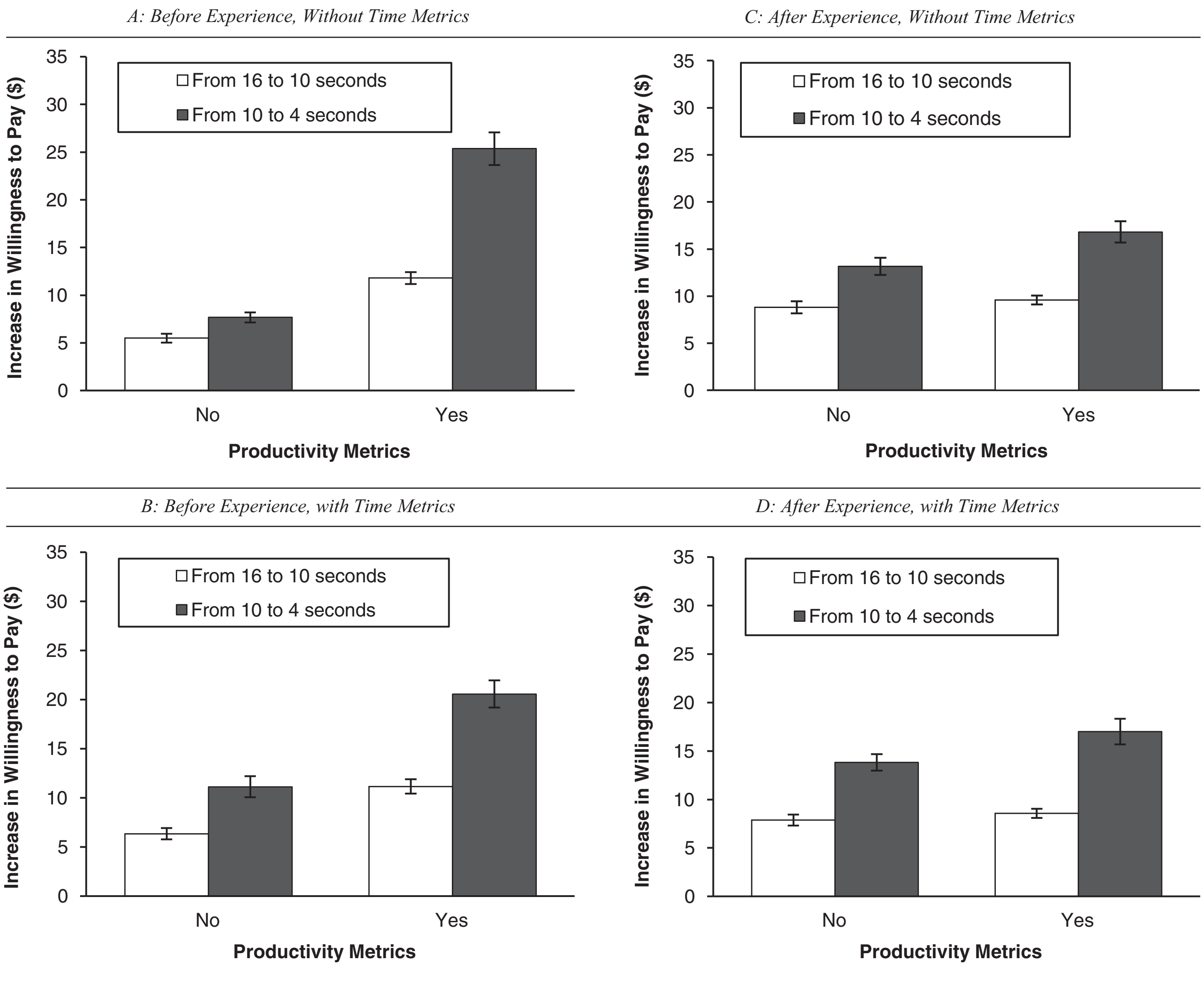
download a 50-megabyte file. Given the download speeds referenced previously, simulated download times were 16 seconds for the first service, 10 seconds for the second, and 4 seconds for the third.

We informed all participants that the fair price of the first service was $25 and asked them how much they would be willing to pay for the other two services. We told them that the second service was better than the first because it also offered "software that provides protection against identity theft and viruses" and that the third service was better than the second because it also offered "free access to millions of hotspots nationwide." We added these features because the services would otherwise be undifferentiated for participants who evaluated the services before experience and were not provided with productivity and time metrics. These features are constant across conditions and thus not confounded with the manipulation of productivity metrics. Ten participants were willing to pay less for better services and one participant's willingness to pay was 11 standard deviations above the mean. We excluded data from these participants before analysis.

Results

Our dependent measures are willingness to pay for a decrease in download time from 16 to 10 seconds (i.e., willingness to pay for the second service minus the fair price of $25 for the first service) and willingness to pay for a decrease in download time from 10 to four seconds (i.e., willingness to pay for the third service minus willingness to pay for the second service). Figure 1 illustrates the results. The white bars indicate willingness to pay for a decrease in download time from a large base (i.e., from 16 to 10 seconds), and the black bars indicate willingness to pay for a decrease in download time from a small base (i.e., from 10 to 4 seconds). Panel A shows the effect of productivity metrics before experience and in the absence of

Figure 1
RESULTS FOR STUDY 1



time metrics. When productivity metrics are present, willingness to pay for a decrease in download time from a small base is much higher than willingness to pay for a decrease in download time from a large base, and the difference is much greater than when productivity metrics are not present. A comparison of Panel A and Panel B shows that the effect of productivity metrics is less pronounced when time metrics are also provided. Similarly, a comparison of Panels A and C shows that the effect of productivity metrics is less pronounced after (vs. before) experience. Finally, a comparison of Panels C and D shows that time metrics do not moderate the effect of productivity metrics after experience, suggesting that time metrics are a substitute for actual experience.

To analyze the statistical significance of this pattern of results, we subjected the data to a 2 (base: 16 vs. 10 seconds) × 2 (productivity metrics present: no vs. yes) × 2 (time metrics present: no vs. yes) × 2 (experience: no vs. yes) mixed analysis of variance (ANOVA; see Table 1). This analysis revealed a four-way interaction ($F(1, 786) = 4.67$, $p < .05$), indicating that the simple three-way interaction among base, productivity metrics, and time metrics is significant before experience ($F(1, 386) = 9.51$, $p < .01$) but not after experience ($F(1, 400) = .04$, $p = .84$). The significant three-way interaction among these variables before experience indicates that the simple two-way interaction between base and productivity metrics is stronger when time metrics are not provided ($F(1, 201) = 55.50$, $p < .001$) than when they are provided ($F(1, 185) = 8.67$, $p < .01$). The values of these interactions indicate that the difference in willingness to pay for a decrease in download time from a small base versus from a large base is greater in the presence of productivity metrics. The nonsignificant simple three-way interaction among base, productivity metrics, and time metrics after experience indicates that the simple two-way interactions between base and productivity metrics are the same regardless of whether time metrics were provided ($F(1, 400) = 7.37$, $p < .01$). This suggests that consumers' evaluations of download times are affected by productivity metrics even after experiencing the download time, and that time metrics provide no additional information beyond what is learned from experience.

In summary, Study 1 shows that the presence of productivity metrics inflates the difference between consumers' willingness to pay for time savings from a small base relative to identical time savings from a large base. This effect is attenuated (although not completely eliminated) after consumers have the opportunity to actually experience the time savings. We also find that the effect of productivity metrics is attenuated when consumers are provided with time metrics (a substitute for experience). This suggests that the effect of the presence of productivity metrics on willingness to pay can be traced to a misunderstanding of the relationship between productivity increases and time savings.

Table 1

ANOVA RESULTS FOR STUDY 1

	Degrees of Freedom	*Mean Squares*	*F-Value*
Between-Subject Effects			
Productivity metrics (P)	1	13,402	121.70***
Time metrics (T)	1	33	.30
Experience (E)	1	92	.83
P × T	1	656	5.96*
E × P	1	5,561	50.50***
E × T	1	0	.00
E × P × T	1	520	4.72*
Error	786	110	
Within-Subject Effects			
Base (B)	1	19,357	359.84***
B × P	1	2,831	52.62***
B × T	1	10	.18
B × E	1	99	1.84
B × P × T	1	318	5.90*
B × E × P	1	704	13.08***
B × E × T	1	118	2.20
B × E × P × T	1	251	4.67*
Error	786	54	

*$p < .05$.
***$p < .001$.

STUDY 2: FOOD PROCESSORS

Study 2 extends the findings of Study 1 to a choice context. We asked participants to choose one of four food processors that varied in terms of motor performance. We orthogonally manipulated the presence versus absence of productivity metrics (i.e., revolutions per second, or rps) and time metrics (seconds per revolution, or spr) that indicate variation in motor performance (and thus food preparation time) across food processors. On the basis of Study 1, we expect participants to choose more expensive food processors when productivity metrics are present. Mimicking the moderating effect of time metrics and experience in Study 1, this effect should be smaller when time metrics are also available. Providing time metrics of motor performance versus not providing them should increase (vs. decrease) spending depending on whether productivity metrics are present. If productivity metrics are not present, providing information about motor performance with time metrics (vs. providing no information about motor performance) offers consumers a reason to choose a more expensive food processor and should thus increase spending. If productivity metrics are present, the presence of time metrics should decrease spending (consistent with the results of Study 1). Study 2 also examines whether our findings depend on the number of attributes. For some participants, the food processors featured three additional attributes; for other participants, these attributes were not mentioned.

Method

Participants were recruited from MTurk (N = 811 U.S. residents; 343 female respondents; $M_{age} = 31.26$, $SD = 9.97$) and randomly assigned to one condition of a 2 (productivity metrics present: no vs. yes) × 2 (time metrics present: no vs. yes) × 2 (additional attributes: no vs. yes) between-participants design. We gave all participants the model numbers of four food processors (DLC-8S vs. DLC-12DC vs. DLC-703 vs. DLC-207N) and their respective selling prices ($100 vs. $150 vs. $200 vs. $250). Participants indicated the model they would purchase if they were interested in buying a food processor. We manipulated whether or not participants received information about the food processors' motor performance. Those who received this information were presented with data as revolutions per second (2.5 vs. 3.33 vs. 4.17 vs. 5), data as seconds per revolution (.4 vs. .3 vs. .24 vs. .2), or both. Participants were informed that motor performance "determines the time you need to process food." For generalizability, we also manipulated whether participants were presented with three additional attributes of the food processors. Those presented with three additional attributes were informed about color options (black/white/red vs. black/white/red/green/blue vs. black/white/red/green/blue vs. black/white/red/green/blue), number of pieces (three vs. three vs. three vs. four), and capacity in cups (10 vs. 10 vs. 10 vs. 10). These additional attributes are constant across the conditions that include additional attributes, and thus they are not confounded with the manipulation of productivity metrics.

Results

In Figure 2, we plot the average amount spent by condition. We analyzed the data with a 2 (productivity metrics present: no vs. yes) × 2 (time metrics present: no vs. yes) × 2 (additional attributes: no vs. yes) between-participants ANOVA (see Table 2). The analysis revealed an effect of productivity metrics ($F(1, 803) = 56.96$, $p < .001$), indicating that the average participant spent more when motor performance was specified with productivity metrics ($M_{\text{productivity metrics: no}} = 139$ vs. $M_{\text{productivity metrics: yes}} = 161$). This effect was qualified by an interaction with time metrics ($F(1, 803) = 32.65$, $p < .001$) and an interaction with additional attributes ($F(1, 803) = 8.20$, $p < .01$). The two-way interaction with time metrics indicates that the effect of productivity metrics was larger when time metrics were not provided ($M_{\text{productivity metrics: no}} = 126$ vs. $M_{\text{productivity metrics: yes}} = 165$; $t(803) = 9.38$, $p < .001$) than when they were provided ($M_{\text{productivity metrics: no}} = 152$ vs. $M_{\text{productivity metrics: yes}} = 157$; $t(803) = 1.30$, $p = .20$). The two-way interaction with additional attributes indicates that the effect of productivity metrics on spending was smaller when food processors differed only in terms of motor performance ($M_{\text{productivity metrics: no}} = 144$ vs. $M_{\text{productivity metrics: yes}} = 158$; $t(803) = 3.32$, $p < .001$) versus when they also differed along the three other attributes ($M_{\text{productivity metrics: no}} = 133$ vs. $M_{\text{productivity metrics: yes}} = 165$; $t(803) = 7.34$, $p < .001$). Although we did not anticipate the latter interaction effect, it does suggest that the positive effect of productivity metrics on spending is robust (and even stronger as the number of attributes increases). These two-way interactions were not qualified by a three-way interaction ($F(1, 803) = 1.85$, $p > .17$).

The analysis also revealed an effect of time metrics ($F(1, 803) = 8.87$, $p < .01$), indicating that the average participant spent more money when motor performance was specified with time metrics ($M_{\text{time metrics: no}} = 145$ vs. $M_{\text{time metrics: yes}} = 154$). This effect was qualified by an interaction with productivity metrics ($F(1, 803) = 32.65$, $p < .001$; see previous paragraph) and an interaction with additional attributes ($F(1, 803) = 5.91$, $p < .05$). The two-way interaction with productivity metrics indicates that the effect of time metrics on spending was positive when productivity metrics were not provided ($M_{\text{time metrics: no}} = 126$ vs. $M_{\text{time metrics: yes}} = 152$; $t(803) = 6.16$, $p < .001$) but negative when they were provided ($M_{\text{time metrics: no}} = 165$ vs. $M_{\text{time metrics: yes}} = 157$; $t(803) = -1.93$, $p = .05$). In other words, when consumers are provided with productivity metrics (as is typically the case in the marketplace), the presence of time metrics reduces spending. This is consistent with our hypothesis that in the absence of time metrics, consumers fail to realize that additional increases in productivity provide ever-smaller time savings. The two-way interaction of time metrics and additional attributes indicates that the effect of

Figure 2
RESULTS FOR STUDY 2

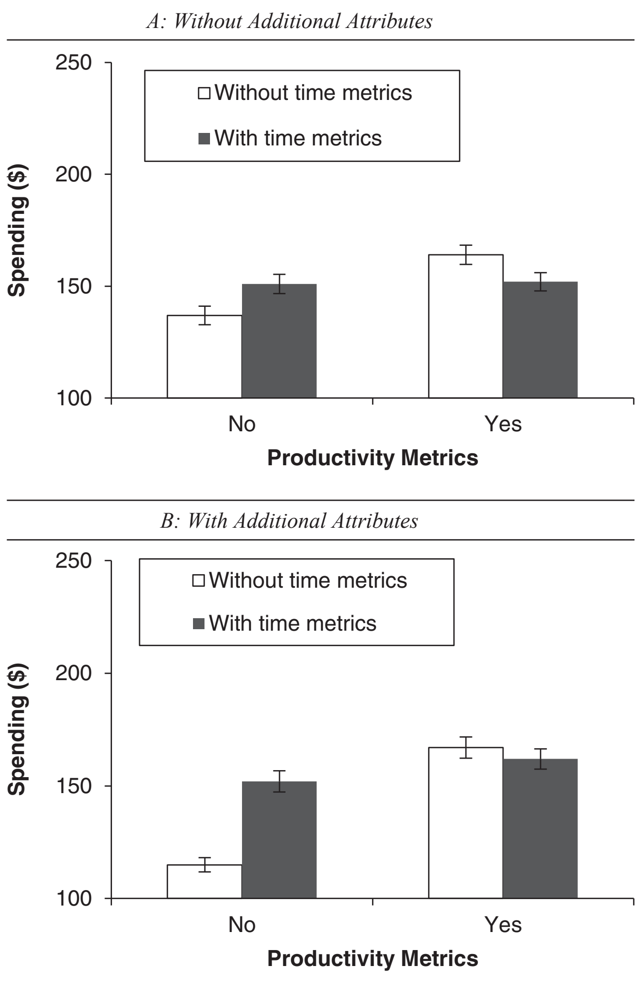


Table 2
ANALYSIS OF VARIANCE RESULTS FOR STUDY 2

Between-Subject Effects	*Degrees of Freedom*	*Mean Squares*	*F-Value*
Productivity metrics (P)	1	103,836	56.96***
Time metrics (T)	1	16,164	8.87**
Additional attributes (A)	1	1,020	.56
P × T	1	59,519	32.65***
A × P	1	14,946	8.20**
A × T	1	10,770	5.91*
A × P × T	1	3,381	1.85
Error	803		

*$p < .05$.
**$p < .01$.
***$p < .001$.

time metrics on spending was smaller when food processors differed only in terms of motor performance ($M_{\text{time metrics: no}}$ = 150 vs. $M_{\text{time metrics: yes}}$ = 152; t(803) = .39, p = .70) versus also in terms of the additional attributes ($M_{\text{time metrics: no}}$ = 140 vs. $M_{\text{time metrics: yes}}$ = 157; t(803) = 3.81, p < .001). As indicated earlier, the three-way interaction was not significant. In summary, Study 2 shows that productivity metrics increase spending, that time metrics reduce the effect of productivity metrics, and that these effects occur regardless of whether options vary along just one or multiple attributes.

STUDY 3: PRINTERS

In the previous studies, we examined the effect of productivity metrics on willingness to pay and choice, assuming that consumers' understanding of the relationship between productivity and time is flawed. Although the interaction effects of productivity metrics with time metrics and experience in the previous studies are consistent with this assumption, Study 3 directly examines consumers' understanding of the productivity–time relationship. Prior research has documented both proportional and absolute reasoning when people deal with nonlinear relationships of the type y = 1/x. Some studies have suggested that people are most sensitive to proportional differences (Svenson 1970), whereas others have suggested that people are more sensitive to absolute differences (Larrick and Soll 2008). This raises a question: When do consumers rely more on proportional changes versus absolute changes in productivity? This question is important not only for theoretical reasons; as we discussed earlier, the absolute heuristic is less accurate than the proportional heuristic.

In Svenson (1970), participants were presented with different travel speeds and distances, and their task was to estimate travel times. Estimates were most consistent with the proportional heuristic. In Larrick and Soll (2008), participants were presented with several vehicle pairs and each vehicle's miles per gallon. Participants were not explicitly asked to estimate fuel savings but instead merely to rank options in terms of fuel savings. Ranks were most consistent with the absolute heuristic. Accordingly, we hypothesize that when the judgment task elicits *point estimates* of time savings, people often realize that absolute increases in productivity cannot imply identical absolute decreases in time, and thus they standardize differences across scales with the proportional heuristic. However, when the judgment task elicits *relative comparisons* of time savings, we expect people to use a simpler decision strategy based on absolute differences.

In Study 3, we presented participants with pairs of printers that vary in terms of print speed. Participants were given one of two tasks: (1) to first estimate time savings for each pair and then rank options by time savings, or (2) to immediately rank options by time savings without estimating. This structure enables us to compare participants across conditions on the same dependent measure. We predict that rankings after estimation correspond more with proportional changes in productivity but that immediate rankings done without estimating correspond more with absolute changes in productivity.

Method

Participants were recruited from MTurk (N = 153 U.S. residents; 61 female respondents; M_{age} = 30.69, SD = 9.18) and randomly assigned to an estimate-then-rank condition or an immediately-rank condition. Three respondents gave the same estimate for each pair (e.g., always 15 minutes), and three respondents gave very extreme estimates (e.g., 1,500 minutes). We excluded data from these respondents before analysis. The final data set consisted of 147 participants. Participants in the estimate-then-rank condition gave five estimates and five ranks; participants in the immediately-rank condition gave five ranks.

Participants were asked to imagine that five consumers, each printing about 100 pages per day, recently changed their old printers for new, faster ones. We then presented participants with five pairs of print speeds. Table 3 presents the five pairs of old and new print speeds. Actual time savings were largest for Pair A (Δ = 13.33 min), followed by Pair B (Δ = 4.29 min), Pair C (Δ = 3.33 min), Pair D (Δ = 2.45 min), and Pair E (Δ = 1.71 min). The proportional change in print speeds was largest for Pair A (Δ = .67 min), followed by Pair C (Δ = .5 min), Pair E (Δ = .31 min), Pair B (Δ = .30 min), and Pair D (Δ = .29 min). The absolute change in print speeds was largest for Pair C (Δ = 15 min), followed by Pair A (Δ = 10 min), Pair E (Δ = 8 min), Pair D (Δ = 5 min), and Pair B (Δ = 3 min).

Results

Estimates. Before analyzing subjective ranks, which is the main dependent measure in Study 3, we assessed whether participants in the estimate-then-rank condition were able to accurately estimate time savings. Based on Svenson (1970), we expect estimates to be consistent with the proportional heuristic, and thus systematically biased. As can be seen from Table 3, participants on average underestimated larger time savings associated with productivity increases from a small base (i.e., pairs A and B) and overestimated smaller time savings associated with productivity increases from a high base (i.e., pairs C, D, and E). At the individual level, no participant provided more than three estimates within 10% of the actual time savings. The mean absolute error between estimated and actual time savings was 3.07 (SD = 3.32), corresponding with a mean absolute percentage error of 89.29% (SD = 104.47). To better understand the judgment process at the individual level, we computed two correlations for each participant, one between estimated time savings and proportional changes in productivity, and another between estimated time savings and absolute changes in productivity. Estimates correlated more strongly with proportional changes in productivity (r = .75) than with absolute changes in productivity (r = .45; t(60) = 5.22, p < .001). Thus, although average estimates increased with actual time savings, they were far from accurate, and they corresponded with the proportional heuristic.

Ranks. We first analyzed the data aggregated across participants. As can be seen from Table 3, the subjective ranks for Pairs A–E averaged across participants who first estimated time savings corresponded more with proportional (r = –.98; lower ranks indicate greater perceived time savings, so the correlation is negative) than with absolute changes in print speed (r = –.79). Instead, subjective ranks for Pairs A–E averaged across participants who immediately

Table 3
OVERVIEW OF STIMULI AND RESULTS FOR STUDY 3

Pair	Print Speed (P) P_1	Print Speed (P) P_2	Difference in Print Speed Absolute: $P_2 - P_1$	Difference in Print Speed Proportional: $(P_2 - P_1)/P_2$	Time Savings Actual	Time Savings Subjective Estimate	Time Savings Subjective Rank After Estimation	Time Savings Immediate Subjective Rank
A	5	15	10	.67	13.33	11.02	1.49	2.10
B	7	10	3	.30	4.29	3.73	3.92	4.72
C	15	30	15	.50	3.33	6.54	2.05	1.52
D	12	17	5	.29	2.45	3.61	3.84	3.85
E	18	26	8	.31	1.71	3.69	3.70	2.80

ranked time savings corresponded more with absolute (r = −.96) than with proportional changes in print speed (r = −.73). This analysis at the aggregate level thus suggests that rankings done after estimation are more consistent with the proportional heuristic, whereas immediate rankings are more consistent with the absolute heuristic.

We then analyzed the data at the individual level. We examined the extent to which each participant's subjective ranks were consistent with actual time savings, proportional changes in productivity, and absolute changes in productivity. For example, if a participant ranked Pair B before Pair C, this would be consistent with actual time savings (4.29 > 3.33; see Table 3), but not with proportional (.3 < .5) and absolute changes in productivity (3 < 15). If a participant ranked Pair A before Pair C, this would be consistent with actual time savings (13.33 > 3.33) and proportional changes in productivity (.67 > .5) but not with absolute changes in productivity (10 < 15). We assessed consistency across all ten combinations of the five pairs for each of the three judgment rules. Consistent ranks were scored as 1 and inconsistent ranks as 0. We thus have 30 consistency scores for each participant (ten for actual time savings, ten for absolute changes in productivity, and ten for proportional changes in productivity). To assess a participant's sensitivity to each rule, we can sum the number of the participant's comparisons that are consistent with each rule (to obtain a score for each rule that ranges between 0 and 10).

However, some comparisons imply a stronger violation of the underlying judgment rule than others. For example, ranking Pair B before Pair C implies a more severe violation of the absolute rule than ranking Pair A before Pair C ([15 – 3] = 12 > [15 – 10] = 5). Similarly, ranking Pair B before Pair A implies a more severe violation of the proportional rule than ranking Pair C before Pair A ([.67 – .3] = .37 > [.67 – .5] = .17). To account for this difference in discriminability, we created relative weights.[3] We used the difference between the pairs in terms of the underlying judgment rule and divided this by the sum of all differences (such that the sum of weights is equal to 1). For example, the relative weight for the absolute rule for the comparison between Pairs B and C is .21 (12/[7 + 5 + 5 + 2 + 12 + 2 + 5 + 10 + 7 + 3]), much higher than the relative weight for the comparison between Pairs A and C (.09 = 5/[7 + 5 + 5 + 2 + 12 + 2 + 5 + 10 + 7 + 3]). This analysis yields a weighted percentage score ranging between 0 and 1 and penalizes stronger violations more than weaker violations.

In the estimate-then-rank condition, the weighted percentage score for the proportional heuristic (M = .89) is higher than the weighted percentage score for the absolute heuristic (M = .79; t(60) = 4.35, $p < .001$) and for the actual time savings rule (M = .82; t(60) = 4.00, $p < .001$). In the immediate-rank condition, the weighted percentage score for the absolute heuristic (M = .90) is higher than the weighted percentage score for the proportional heuristic (M = .83; t(85) = 4.06, $p < .001$) and for the actual time savings rule (M = .65; t(85) = 8.95, $p < .001$).

In summary, Study 3 confirms that consumers are unable to accurately compute time savings associated with productivity increases. When people ranked time savings after estimating, observed ranks tended to reflect proportional differences. When people ranked time savings without first estimating, observed ranks tended instead to reflect absolute differences. In other words, unless they are explicitly asked to generate point estimates of time savings, people are mostly sensitive to absolute changes in productivity.

GENERAL DISCUSSION

Theoretical Contribution

Consumers regularly upgrade to new versions of a product because they want a desired output in less time. Instead of directly providing consumers with information about the time needed to produce one unit of the output (e.g., minutes per page), marketers tout product performance with productivity metrics, indicating the output produced in one unit of time (e.g., pages per minute). This article is the first to examine how productivity metrics affect consumers' assessment of time savings and their willingness to pay. Although there is a deterministic relationship between productivity metrics and time savings, consumers tend to overestimate the benefits of productivity increases at high productivity levels relative to the benefits of productivity increases at low productivity levels (Study 3). Moreover, productivity metrics make consumers more willing to pay for time savings close to 0 than for identical time savings further from 0 (Study 1). When additional information about time savings is provided through product experience (Study 1) or through metrics that are linearly related to time savings (Studies 1 and 2), consumers value time savings more evenly and are willing to spend less for productivity increases at high productivity levels.

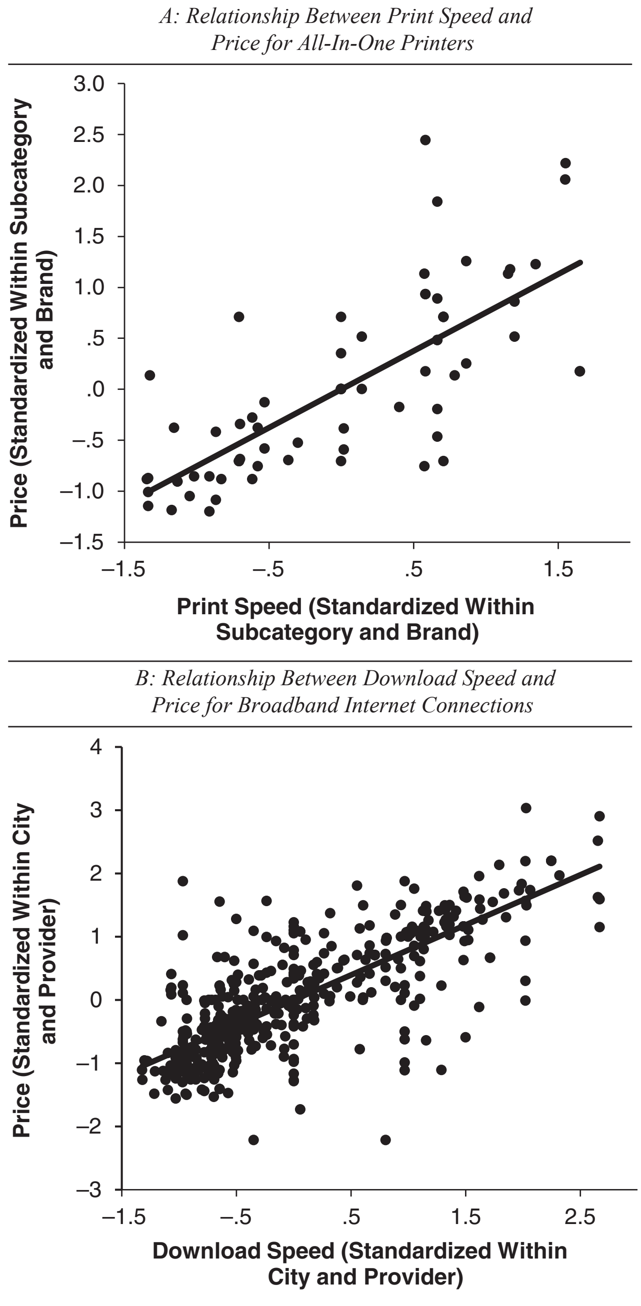
[3]We thank the Associate Editor for this suggestion.

Researchers studying judgment and decision making have made a distinction between proportional and absolute reasoning. Some studies have found reliance on proportional reasoning in contexts where absolute reasoning is more appropriate (Bartels 2006; De Langhe and Puntoni 2015). Other studies have found reliance on absolute reasoning in contexts where proportional reasoning is more appropriate (Burson et al. 2009; Pacini and Epstein 1999; Yamagishi 1997). For some nonlinear cue–outcome relationships (e.g., the productivity–time relationship), both proportional and absolute reasoning are inappropriate and lead people to overestimate changes in the outcome that stem from changes in the cue at higher cue levels relative to changes in the cue at lower cue levels. In contexts where both types of reasoning are inappropriate, some studies have found that consumers are more sensitive to proportional differences (Svenson 1970), whereas other studies have found that they are more sensitive to absolute differences (Larrick and Soll 2008). However, it is not clear from prior literature when people are more likely to rely on one rule versus the other. This article is the first to examine the moderating influence of estimation versus ranking. Study 3 shows that when the task probes people to estimate outcomes (here, time savings), people tend to engage more in proportional reasoning. However, when the task probes people to merely rank outcomes, people tend to engage more in absolute reasoning.

Marketing Implications

Productivity increases offer sharply decreasing returns in terms of time savings, but it is not clear that market prices reflect this nonlinearity. *Consumer Reports* tested the performance of 71 all-in-one printers on nine dimensions (e.g., text quality) and assessed the presence of eight features (e.g., auto-duplexing). As can be seen in Figure 3, Panel A, the simple relationship between print speed, as indicated on manufacturers' websites, and the approximate retail price for these printers is linear.[4] A stepwise regression analysis that controls for the dimensions and features that can vary across printers retained eight variables, here listed from most to least important as a predictor of price: print speed, text cost (i.e., cost per printed page), ink-and-paper cost, Ethernet connectivity, power saving, individual color tanks, copy quality, and auto-duplexing. We regressed price on these dimensions and features, including linear and quadratic effects for print speed. Although the linear term was significant ($\beta = .41$, SE = .11, $p < .001$), the quadratic term was not ($\beta = .06$, SE = .09, $p = .53$). This result is not idiosyncratic to the printer category. The Open Tech Institute reports the download speeds and prices of 508 home broadband Internet connections for 77 providers in 24 international cities in 2014.[5] Figure 3, Panel B shows the simple relationship between download speed and price. A regression of price on the linear and quadratic terms for download speed revealed a significant linear effect ($\beta = .82$, SE = .04, $p < .001$) but again showed no evidence of a quadratic effect ($\beta = -.03$, SE = .03, $p = .27$). In summary, although print/download speed is an important predictor of price, we find no evidence for a curvilinear relationship between speed and price. If the relationship between productivity and market price is linear due to decreasing marginal utility (i.e., consumers valuing time savings closer to 0 more than time savings further from 0), there might not be an issue with the current emphasis on

Figure 3
THE MARKET PRICE OF PRODUCTIVITY



[4]The data set spans 10 brands (e.g., Brother, Canon, Epson) and three subcategories (inkjet, black-and-white laser, and color laser). We standardized all dimensions and features (after dummy-coding), print speed, and selling price, such that all variables have a mean of 0 and a standard deviation of 1 within subcategory and brand. Data were collected on March 21, 2013.

[5]The data set is available at https://data.opentechinstitute.org/dataset/2014-cost-of-connectivity. The data set also includes prices for bundles (e.g., "broadband + phone + TV"). Bundles are not included in our analysis. We standardized download speed and price such that they have a mean of 0 and a standard deviation of 1 within city and provider.

productivity metrics. However, if it is linear because consumers fail to realize that time savings level off dramatically as productivity increases, the current information environment may be more problematic.

In recent years, many industries have adopted standard performance metrics that enable consumers to make "apples-to-apples" comparisons between available offerings. For example, leading printer manufacturers have celebrated the adoption of the ISO ppm speed metric, a standardized measure of ppm, as a positive development for consumers. Such interventions tend to start from the assumption that consumers can easily and accurately translate changes in the common metric to changes in relevant benefits. However, our findings suggest that this assumption is incorrect in the context of productivity metrics and time savings. When metrics and benefits are linearly related, it is easy for consumers to convert changes in the metric into changes in the benefit. For example, if 1 GB of storage is equivalent to 250 songs, consumers can easily realize that 2 GB of storage is equivalent to 500 songs and 4 GB of storage is equivalent to 1,000 songs. But when metrics and benefits are nonlinearly related, consumers are likely to make mistakes. Because consumers tend to linearize the nonlinear relationship between productivity and time, they do not realize that productivity increases imply ever-smaller time savings as base productivity increases, and that companies profit from the prominence of productivity metrics in today's marketplace.

Of course, willfully taking advantage of consumers' flawed understanding of the productivity–time relationship can hardly be viewed as good marketing. In fact, Sheth and Sisodia (2007) describe companies that profit at the expense of consumers as unethical. We believe that the widespread availability of productivity metrics does not stem from a deliberate decision by marketers to take advantage of poor consumer numeracy but rather from a more general product orientation. However, now that our studies document the implications of a productivity focus, the decision to leverage these effects becomes a decision with ethical implications. We hope that governments, consumer advocacy groups, and firms will consider the use of time metrics for communicating product performance.

Further Research and Concluding Remarks

Our article has a number of limitations that offer opportunities for further research. First, we focused on desired output as independent of product performance (e.g., we assumed that a consumer's need to print pages is independent of a printer's speed). However, consumers could start desiring a larger amount of output after upgrading to higher-performing products (e.g., a consumer might decide to print more pages after upgrading to a faster printer). It would be interesting to explore contexts where demand is endogenous to product performance.

Second, we assumed that productivity only serves the purpose of saving time. In many contexts, this is a straightforward assumption, but in others, less so. For example, the food processor's description in Study 2 explicitly informed participants that better motor performance is useful because it reduces the time needed to prepare food. We added this explanation because better motor performance could have otherwise been perceived to serve a different purpose (e.g., enabling specific chemical processes to take place). Future studies should examine the effect of productivity metrics when multiple benefits can be obtained by increasing productivity.

Third, our studies cover the industries of consumer electronics and cooking appliances, but the findings are relevant beyond these contexts. For example, people generally save and invest money to fund personal financial goals, and many banks now offer consumers the possibility to create goal-specific savings plans. A consumer might save to buy a car, pay for a child's college tuition, or enjoy a lengthy retirement (for a discussion on goal-based investing for retirement, see Merton [2014]). When saving toward these goals, consumers can choose between options with different expected returns per unit of time (e.g., annual interest rates). These are measures of productivity and tell consumers how much money they can expect at a given point in the future. In fact, however, consumers might care more about the specific point in the future at which they will have accomplished their goals (e.g., "When can I buy a new car?").

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