# Dynamic Coordination with Present Bias: Procrastination Can Be Efficient\*

Deivis Angeli<sup>†</sup>

Dartmouth College

 $March\ 2025$ 

How does present bias affect welfare when agents want to coordinate over time? To answer that, I analyze a dynamic coordination model under quasi-hyperbolic discounting, documenting a novel mechanism through which present bias can be adaptive. The key trade-off for agents in dynamic coordination models is whether to follow a currently-popular standard (receiving substantial network externalities from other current users) or to adopt a new standard with a higher intrinsic quality, hoping that others will follow. Guimaraes and Pereira (2016) showed that exponential discounters begin adopting the new standard when its quality is too low to justify the transition costs, since an early adopter does not account for the negative externality caused on those who stay in the old standard. This paper shows that present bias can act as a kludge, since it makes agents overweight their individual transition costs, shifting behavior in the same direction that the planner would suggest.

**Keywords:** dynamic coordination, network effects, technology adoption, present bias, quasi-hyperbolic discounting, welfare

JEL Codes: E71, C73, O33 Declaration of Interest: none

<sup>\*</sup>Earlier drafts were titled "Dynamic Coordination with Network Externalities: Procrastination Can Be Efficient."  $^{\dagger}$  deivisangeli@gmail.com

### 1 Introduction

Problems of dynamic coordination are common; in many situations, an action becomes more attractive as it becomes popular. For instance, take social networks. If most of your friends were on Facebook – providing you with network externalities – rather than on the late Google +, then even if Google + had higher intrinsic quality, Facebook could be preferred if you do not expect your friends to migrate any time soon. Many technology adoption problems, like the widespread use of QWERTY keyboards instead of possibly more efficient standards (David, 1985), involve this same kind of dynamic coordination issue.

Dynamic coordination models show that, given the externalities, individual incentives are not aligned to maximize welfare. Perhaps counter-intuitively, Guimaraes and Pereira (2016) (henceforth GP) shows that a central planner would only allow exponential discounters to adopt an unpopular technology when its intrinsic quality is higher than what would be enough to justify private adoption. This implies, for instance, that if we observe unconstrained coordination on QWERTY keyboards, it is efficient. The source of the inefficiency is that individuals choose to adopt an unpopular keyboard without accounting for the fact that this decreases the externality received by those still using QWERTY. And while network externalities build up as society transitions to the new standard, this takes time, leading to a welfare loss. Hence, temporal trade-offs are key, suggesting that more realistic discussions about dynamic coordination should take into account actual discounting behavior, which might not be exponential.

An extensive literature documents the regularity with which economic agents are present biased rather than exponential discounters. For instance, people procrastinate, failing to make costly investments even if ex-ante they would prefer investing, under exactly the same circumstances. This behavioral trait has been studied in multiple contexts, e.g., distributing effort over time, consumption, and exercising (see Ericson and Laibson 2019 for a review). A simple argument suggests that present bias could actually help fix the inefficiency articulated by GP: Consider the trade-off faced by a potential early adopter of an unpopular action. That person has to weigh the extra happiness coming from more intrinsic quality (from now on) against a (temporary) decrease in the received externalities. Present-biased agents would overweight that temporary decrease and ask for more intrinsic quality than exponential discounters before becoming early adopters, as a planner would suggest.

This paper studies the welfare implications of present bias in dynamic coordination problems by including quasi-hyperbolic discounting in the GP framework. The main result confirms the laid out intuitions: Present bias shifts individual decisions in the same direction a planner would suggest. Hence, a little present bias always restricts the set of states of the world (combinations of relative intrinsic quality and popularity of a network) in which a society would move towards adopting a socially inefficient standard.

Also, I show that the more acute the coordination problem is, the more present-biased a society should be in order to avoid inefficiencies. More precisely, I find that the amount of present bias needed to emulate the planner's solution is increasing in the long-term discount rate and decreasing in the speed at which a transition can happen.<sup>1</sup> Hence, there is an argument for present bias co-evolving with human societies: The more people needed to coordinate, the more intense the present bias trait could be.

All results hold not only for an overlapping generations formulation, but also with infinitely-lived agents who get random chances to reevaluate their choices and play Markov strategies, *regardless of their level of sophistication* about their present bias. That is because the dynamics of the system are essentially the same in all cases, since infinitely-lived agents have no way of affecting the future payoffs of their future selves.

The main contribution of this paper lies in discussing a socially adaptive role for present bias – its modeling contributions are minor, since I heavily rely on the machinery developed by Frankel and Pauzner (2000) and Guimaraes and Pereira (2016). Instead of relying only on individual-based explanations (Chakraborty, 2021; Dasgupta and Maskin, 2005), this paper shows that decision-making in groups can also generate situations in which present bias is adaptive. As present bias increases coordination efficiency by "artificially" increasing the effective discount rate, which may generate downsides in other domains, the trait can be seen as a kludge, a haphazard or accidental adaptation to an (evolutionary) problem.

This paper also speaks to two broader literatures. First, by exploring how present bias affects dynamic coordination and welfare in such situations, I contribute to the study of behavioral traits interacted with markets or social interactions (e.g., Laibson 1997; Kleinberg et al. 2017; Heidhues and Kőszegi 2010, 2017; Gans and Landry 2019; Meunier and Schumacher 2020; Bohren and Hauser 2021; Kaufmann et al. 2024), and how such traits can be adaptive in equilibrium (e.g., Schwardmann and Van der Weele 2019). Second, it speaks to a broader literature on dynamic coordination problems which includes applications to business cycles (Frankel and Burdzy, 2005; Guimaraes and Machado, 2018), technology adoption (Crouzet et al., 2019; Guimaraes and Pereira, 2016), currency trading (Plantin and Shin, 2018), and neighborhood choice (Frankel and Pauzner, 2002). If agents in any of these coordination problems are present biased, my results suggest that it might make the realized equilibrium closer to socially optimal.

I organize the rest of the paper as follows. Section 2 presents the model and derives its equilibria with  $^{-1}$ The latter does not apply when a society can transition between standards very quickly, but in such case there is no real coordination problem.

present bias and a generic utility function. Section 3 describes the equilibria for a linear utility model, and Section 4 analyzes its welfare in that case, delivering the main results. Section 5 concludes the paper.

### 2 Set Up

This section introduces the model and describes the possible equilibria with a generic utility function. The framework presented here is equivalent to the one in Frankel and Pauzner (2000) (henceforth FP) but for the discount function. Guimaraes et al. (2020) provides an accessible introduction to the same dynamic coordination framework, with notation similar to what I use in this paper. Results in this section follow almost immediately from FP and Burdzy et al. (1998) after noting that the discount function does not change the essence of the trade-offs.

#### 2.1 The Discount Function

I model present bias using a quasi-hyperbolic discount function. In discrete time models, such discount function would be  $\beta^{\mathbb{1}_{t>\tau}}r^{t-\tau}$ , with  $(\beta, r) \in [0, 1]^2$ . When  $\beta \in [0, 1)$ , we have present bias.<sup>2</sup> While there are multiple ways of extending this to continuous time, for simplicity, I use

$$D(t-\tau) = \beta^{\mathbb{1}_{t-\tau \ge 1}} e^{-\rho(t-\tau)},$$

where 1 is the indicator function and the length of the "present" is still one unit of time.<sup>3</sup> From the point of view of an agent at time  $\tau$ , all utility incurred after one unit of time is discounted by  $\beta$ . When  $\beta = 1$ , Dis the regular exponential discount function.

#### 2.2 Dynamic Coordination with Present Bias

Time is continuous, and at any moment there is a continuum of individuals  $i \in [0, 1]$ . Newborn *i* chooses  $a_{it} \in \{0, 1\}$  once and for all, and is substituted at rate  $\delta$  (this assumption is somewhat relaxed in the next subsection). The flow utility of changing to action 1 is  $\Delta u(\theta_t, n_t)$ , which is continuously differentiable and increasing in both arguments. That is, the benefit of choosing action 1 over 0 increases with the intrinsic

 $<sup>^{2}</sup>$ This discount function was introduced by Phelps and Pollak (1968) and widely used later on. See Cohen et al. (2020) for a review of other models of present bias.

<sup>&</sup>lt;sup>3</sup>Empirical evidence suggests that we should think of the length of the present as very short (e.g., see Ericson and Laibson (2019) and Frederick et al. (2002)). See Webb (2016) for more on modelling present bias in continuous time. The results presented here are similar if we use  $D(t - \tau, \lambda) = \begin{cases} e^{-(\hat{\beta}/\lambda + \rho)(t - \tau)} & \text{if } t - \tau \leq \lambda \\ e^{-\hat{\beta} - \rho(t - \tau)} & \text{if } t - \tau > \lambda \end{cases}$ , with  $\lambda$  as the length of the present.

relative quality of action 1,  $\theta_t$ , and with the number of individuals taking action 1,  $n_t$ . A newborn at time  $\tau$  is uncertain about the path of  $(\theta_t, n_t)$ , so she (the newborn) maximizes her utility by choosing 1 if

$$\mathbb{E}\left[\int_{\tau}^{+\infty} e^{-\delta(t-\tau)} D(t-\tau) \Delta u(\theta_t, n_t) \, dt\right] > 0.$$
(1)

Assume for a moment that  $\theta_t$  is constant over time, and that there are levels of  $\theta$  low and high enough,  $\underline{\theta}$  and  $\overline{\theta}$ , so that picking 0 or 1 is optimal regardless of  $n_{\tau}$ . Then there are thresholds in the  $\Theta \times [0, 1]$  space delineating dominance regions (dashed lines in Figure 1). To the left of the most optimistic threshold about action 1 – defined by expecting all others to pick 1 from  $\tau$  on – agents play 0. To the right of the most pessimistic threshold, they must play 1. Such thresholds,  $\theta^{opt}$  and  $\theta^{pes}$  are implicitly defined by:

$$\int_{\tau}^{+\infty} e^{-\delta(t-\tau)} D(t-\tau) \Delta u(\theta^{opt}(n_{\tau}), n_{\tau}^{\uparrow}(t)) dt = 0$$
(2a)

$$\int_{\tau}^{+\infty} e^{-\delta(t-\tau)} D(t-\tau) \Delta u(\theta^{pes}(n_{\tau}), n_{\tau}^{\downarrow}(t)) dt = 0$$
(2b)

where  $n_{\tau}^{\uparrow}(t) = 1 - (1 - n_{\tau})e^{-\delta(t-\tau)}$  is the most optimistic path for action 1 and  $n_{\tau}^{\downarrow}(t) = n_{\tau}e^{-\delta(t-\tau)}$  is the most pessimistic.

If instead  $\theta_t$  suffers shocks following a random walk, then:

**Proposition 1** [FP, Theorem 1] Assume that  $d\theta_t = \mu dt + \sigma dZ_t$ , where  $Z_t$  is the standard Brownian motion and that dominance regions exist. There is a unique decreasing function  $\theta^*(n_{\tau})$  such that if  $\theta_{\tau} < \theta^*(n_{\tau})$ , in equilibrium everyone chooses 0. Conversely, if  $\theta_{\tau} > \theta^*(n_{\tau})$ , everyone chooses 1.

#### **Proof.** See Appendix.

Hence, when  $\theta_t$  follows a Brownian motion, there is a unique threshold in between the dominance regions defining the equilibrium play. This is essentially the same equilibrium characterization as in FP, except that the shape of the decision thresholds may differ. When  $\theta_t$  moves slowly over time, we can allow for a more flexible drift and, more importantly, find a simple expression for the unique decision threshold.<sup>4</sup>

**Proposition 2** [FP, Theorem 2] Let  $d\theta_t = \alpha \psi(t, \theta_t) dt + \sigma dZ_t$ , where  $\psi$  is continuously differentiable and  $\psi(t, \theta)$  is bounded over t for each  $\theta$ . If  $(\alpha, \sigma^2) \to \mathbf{0}$ , then the threshold  $\theta^*$  solves:

$$(1-n_{\tau})\int_{\tau}^{+\infty} e^{-\delta(t-\tau)}D(t-\tau)\Delta u(\theta^*(n_{\tau}), n_{\tau}^{\uparrow}(t))\,dt + n_{\tau}\int_{\tau}^{+\infty} e^{-\delta(t-\tau)}D(t-\tau)\Delta u(\theta^*(n_{\tau}), n_{\tau}^{\downarrow}(t))\,dt = 0$$
(3)

<sup>&</sup>lt;sup>4</sup>Not only the drift term can be made flexible, but the result holds regardless of what  $\frac{\alpha}{\sigma^2}$  converges to.

#### **Proof.** See Appendix.

Understanding the intuition behind the result in Proposition 2 will be helpful through the paper, since it tells us about the direction and speed at which we should expect transitions to occur. Consider a point on the unique threshold,  $(\theta^*(n_\tau), n_\tau)$ . If  $\theta_t$  drifts to the left or to the right of  $\theta^*$ , it will do so more and more slowly as  $(\alpha, \sigma^2) \rightarrow \mathbf{0}$ . Nevertheless,  $n_t$  still moves at the rate at which people get chances to reevaluate their action times the share of people who change action, i.e., rate  $\delta(1 - n_t)$  to the right of  $\theta^*$ , and  $-\delta n_t$ to the left. So the  $n_t$  dynamics are basically either  $n_\tau^{\uparrow}(t)$  or  $n_\tau^{\downarrow}(t)$ . The probability it is  $n_\tau^{\uparrow}(t)$  approaches  $1 - n_\tau$ , proportional to the speed at which the economy would bifurcate upwards, and the converse goes for  $n_\tau^{\downarrow}(t)$ . So the unique indifference threshold ( $\theta^*$  in Figure 1) is just a weighted average of the aforementioned pessimistic and optimistic thresholds, weighted by the probability the economy would go up or down.

Figure 1: Linear Representation of the Decision Thresholds



Notes: In the plane, the relative quality of action 1 increases to the right, and the share of individuals choosing action 1 increases upwards. The solid-line threshold is for the case of small shocks,  $\theta^*$ . Dashed lines show decision thresholds for the most optimistic and pessimistic beliefs about whether others will adopt action 1.  $\underline{\theta}$  is the highest ( $\overline{\theta}$  is the lowest)  $\theta$  for which an individual would pick 0 (1) regardless of  $n_{\tau}$ .

#### 2.3 Procrastination and Infinitely-lived Agents

Suppose that instead of being substituted at rate  $\delta$ , agents now reevaluate their choices at that rate.

Sophisticated agents. Model each individual in the society as a succession of selves. As usual in this type of intrapersonal games (e.g., Harris and Laibson 2013), we may consider equilibria where agents define strategies only on the payoff-relevant states ( $\theta_t$ ,  $n_t$ ). This precludes past selves from influencing future selves, because a single player's action does not affect the state of the economy. Since a current self cannot affect the choice of a future self, the optimal decision rule is the same as the one followed by the finitely-lived agents (1). That also allows for the existence of dominance regions, and the remaining results follow.

Naive agents. Consider a society where agents believe their future selves will be exponential discounters (i.e., all agents are naive). Now take a single agent picking at time  $\tau$ . As she is atomistic and perceives that her future selves will choose consistently (as their interests are aligned with their own future selves), her current choice at  $\tau$  does not affect her future selves' choice. Hence, she follows the same choice rule as the finitely-lived agents (1). In equilibrium, she must have correct expectations about how  $n_t$  reacts to  $\theta_t$ . So, in any equilibrium, she must believe other people act according to the *present-biased* choice rule (as agents are homogeneous). If all agents indeed have such asymmetric beliefs, then we have a Nash equilibrium with the same choice thresholds as before. While these asymmetric expectations about one's own and other's future selves may seem arbitrary in theory, lab evidence suggests this is not an unlikely scenario (Fedyk, 2024).

**Procrastination.** These infinitely-lived present-biased agents procrastinate, in the sense that their future selves may fail to take the action they would ex-ante like under a given unfolding of events. To make it clear, consider the case of small shocks, with an agent making an ex-ante decision over what to pick at the point over the decision threshold  $\theta^*$  with  $n_t = 0$  at some  $\tau' > \tau + 1$  (i.e., when her self at time  $\tau$  no longer feels present bias). Since Proposition 2 says that in such case the economy will bifurcate upwards with probability one, the trade-offs are easy to consider. Note that while an agent making a choice "on the spot" at the point ( $\theta^*(0), 0$ ) would be indifferent, the agent making the ex-ante decision strictly prefers locking into choosing action 1. That is because, when on the spot, present bias increases the weight on perceived costs (initial loss of externalities) and decreases the weight on gains (better intrinsic quality from now on). Hence, ex-ante, without the distortions, she perceives a higher utility. A similar reasoning applies to other points over  $\theta^*$ , so the ex-ante agent has a steeper desired decision threshold: In the future, she would like to adopt the competing technology for lower values of its intrinsic quality, but fails to do so when the future comes, due to present bias.

### 3 Linear Model: QWERTY vs. DSK

To study welfare implications, I use a linear utility specification as in GP. This serves only to make the expressions more tractable; the general results derived in the previous section, e.g., the identical dynamics in the cases with finitely-lived or infinitely-lived naive or sophisticated agents, still apply.

Let actions be to use QWERTY (Q) or DSK (D), and flow utilities be  $u^Q(\theta_t^Q, n_t) = \theta_t^Q + \nu(1 - n_t)$  and  $u^D(\theta_t^D, n_t) = \theta_t^D + \nu n_t$ . The relative utility flow of DSK over QWERTY is  $\Delta u(\theta_t, n_t) = \theta_t + \gamma n_t$ , with

 $\theta_t := \theta_t^D - \theta_t^Q - \nu \in \mathbb{R} \equiv \Theta$  and  $\gamma := 2\nu > 0.5$  Since we will later conduct comparative statics on  $\beta$ , I will also use notation making it explicit that decision thresholds depend on such  $\beta$ .

**Proposition 3** For an economy where the intrinsic relative quality is fixed, the choice thresholds are

$$\theta^{opt}(\beta, n_{\tau}) = -\gamma \left(1 - \Omega(\beta)\right) - \gamma \Omega(\beta) n_{\tau} \tag{4a}$$

$$\theta^{pes}(\beta, n_{\tau}) = -\gamma n_{\tau} \Omega(\beta), \tag{4b}$$

where  $\Omega: [0,1] \to \left[\frac{\rho+\delta}{\rho+2\delta}, \frac{\rho+\delta}{\rho+2\delta}\frac{1-e^{-(\rho+2\delta)}}{1-e^{-(\rho+\delta)}}\right] \subseteq \left[\frac{1}{2}, 1\right]$  is a strictly decreasing function such that:

$$\Omega(\beta) = \frac{\rho + \delta}{\rho + 2\delta} \frac{1 - (1 - \beta)e^{-(\rho + 2\delta)}}{1 - (1 - \beta)e^{-(\rho + \delta)}}$$

**Proof.** One can find these by solving equations (2a) and (2b) for the specific linear utilities. ■

As  $\Omega' < 0$ , present-biased agents have thresholds flatter than the dynamically consistent in the  $\Theta \times [0, 1]$ plane (see dotted and dashed lines, respectively, in Figure 2). Again, that is because present-biased agents overweight the cost of a transition to the standard they expect to become popular in the future, requiring extra quality to justify a transition. To see that, consider the point in the optimistic threshold when  $n_{\tau} = 0$ without present bias,  $(\theta^{opt}(1,0),0)$ . An optimistic agent without present bias is indifferent at that point, but a present-biased agent with the same beliefs would strictly prefer QWERTY, since she overweights the transition costs (the temporary loss in externalities). Hence,  $\theta^{opt}(1,0) < \theta^{opt}(\beta,0)$  for  $\beta < 1$ . Such transition costs become smaller when we consider the same trade-offs at higher  $n_{\tau}$ , and  $\theta^{opt}(1,1) = \theta^{opt}(\beta,1)$  for any  $\beta$ since there is no expected transition when  $n_t = 1$ . The pessimistic threshold also becomes flatter with lower  $\beta$ , but, since the expected transition goes in the opposite direction, we have  $\theta^{pes}(1,0) = \theta^{pes}(\beta,0)$ . Hence, more present bias induces a decrease in the multiple equilibria area in  $\Theta \times [0, 1]$ .

Using Proposition 2, I can combine equations (4a) and (4b) to get the unique threshold in the case with small shocks:

$$\theta^*(\beta, n_\tau) = -\gamma \left(1 - \Omega(\beta)\right) - \gamma \left(2\Omega(\beta) - 1\right) n_\tau.$$
(5)

I will focus on this threshold (5) for the rest of the paper. Since  $\Omega' < 0$ , this threshold also gets flatter as  $\beta$ 

<sup>5</sup>The specified externalities are symmetric for each action, but the qualitative results below still hold for small asymmetries.

decreases. When  $\beta = 1$  we have no present bias and the equation simplifies to

$$\theta^*(1, n_\tau) = -\frac{\gamma\delta}{\rho + 2\delta} - n_\tau \frac{\gamma\rho}{\rho + 2\delta}.$$
(6)

It is then straightforward to check that the threshold with present bias crosses the one without present bias exactly at their midpoint  $(\theta^*(1, \frac{1}{2}), \frac{1}{2})$ .<sup>6</sup> Hence, increases in present bias rotate this threshold counterclockwise around its midpoint.

### 4 Welfare Analysis

Consider a central planner who weighs every individual equally, makes choices for the newborns, and exponentially discounts utility.<sup>7</sup> GP shows that this planner makes a newborn pick DSK if

$$\mathbb{E} \int_{\tau}^{+\infty} e^{-(\rho+\delta)(t-\tau)} \left( \underbrace{\theta_t + \gamma n_t}_{\text{Private }\Delta u} + \underbrace{\gamma\left(n_t - \frac{1}{2}\right)}_{\text{Externality}} \right) dt > 0.$$
(7)

Intuitively, the decision rule (7) contains the "selfish" flow utility plus the flow externality caused on others.

In the case of small shocks, using Proposition 2, the planner's decision threshold is:

$$\theta^P(n_\tau) = \frac{\gamma \rho - 2\gamma \delta}{2(\rho + 2\delta)} - \frac{2\gamma \rho}{\rho + 2\delta} n_\tau.$$
(8)

Comparing (6) with (8), it is easy to check that the planner's threshold is a counter-clockwise rotation of the individual threshold around its midpoint, being less steep than  $\theta^*$  for a non-present-biased individual.<sup>8</sup> That must be the case because (i) the externality is symmetric for both networks and (ii) accounting for the negative externality of leaving people behind in an initially-popular standard in the planner's choice rule (7) requires higher intrinsic quality to justify a transition.

Welfare Criterion. I use the same welfare criterion described above for the case with present-biased agents, i.e., the planner maximizes the sum of the individual utilities, but with  $\beta = 1$ . That is a reasonable criterion since it is the criterion that present-biased individuals would pick to maximize social utility if they

<sup>&</sup>lt;sup>6</sup>That happens because, due to the agent's impatience, she will ask for more intrinsic quality from the network she expects society to adopt in the future. The flipping point happens exactly at  $n_t = \frac{1}{2}$  because at that point: (i) the bifurcation probabilities are the same and (ii) the expected future externalities of each keyboard balance out (under symmetric externalities).

 $<sup>^{7}</sup>$ It is assumed that the planner cannot change what everybody is doing at once. He can only dictate what an agent chooses when that agent gets a chance to choose. The unconstrained planner would simply make all agents pick the higher intrinsic quality standard.

<sup>&</sup>lt;sup>8</sup>In fact, exactly half as steep.



Figure 2: Comparative Statics of the Introduction of Some Present Bias

Notes: The figure compares a society without present bias to a situation with some small amount of present bias.  $\theta^*$  is the small shocks threshold for a population with no present bias, and  $\theta^*(\beta, n_{\tau})$  is the one for a population with some present bias, but not enough to create new inefficiency regions. When a society enters the shaded area, present bias prevents it from following an inefficient path. Dashed and dotted lines are the optimistic and pessimistic thresholds under fixed  $\theta$  for no present bias and some present bias, respectively.

pick it early enough before the world is put in motion and before each self learns their identities. Another justification is that it would be hard to argue that humans *want* to be dynamically inconsistent. They just cannot help it, and a benevolent planner would ignore that myopia.

Now I can state the main result: Introducing a little present bias increases the area in the state space over which a society picks the efficient standard.

**Proposition 4** Under vanishing shocks and trends, for any value of the parameters  $(\rho, \delta, \gamma) \in \mathbb{R}^3_+$ , there is some level of present bias  $\beta \in [0, 1)$  such that the area contained in  $\Theta \times [0, 1]$  in which individuals do not follow the planner's recommendation is restricted in relation to the case without present bias.

**Proof.**  $\Omega'(\beta) < 0$  for any  $\beta \in [0,1]$ , so any small decrease in  $\beta$ , starting from  $\beta = 1$ , continuously makes the threshold less steep in the  $\Theta \times [0,1]$  space. As the planner's threshold is always less steep than the dynamically consistent individual's threshold if  $(\rho, \delta, \gamma) \in \mathbb{R}^3_+$ , then there is always  $\tilde{\beta} \in [0,1)$  such that  $2\frac{\partial \theta^*(1,n_\tau)}{\partial n_\tau} \leq \frac{\partial \theta^*(\tilde{\beta},n_\tau)}{\partial n_\tau} < \frac{\partial \theta^*(1,n_\tau)}{\partial n_\tau}$ , i.e.,  $2(1-2\Omega(1)) \leq 1-2\Omega(\tilde{\beta}) < 1-2\Omega(1)$ . As the three thresholds always cross in their midpoints  $(n = \frac{1}{2})$ , we have the desired result.

In fact, if

$$\rho e^{\rho} \le e^{-\delta} (3\rho + 2\delta + 2e^{-\delta}(\rho + \delta)) \tag{9}$$

then we can find  $\beta^*$  that makes the individuals' threshold exactly equal to the planner's threshold:

$$\beta^* = 1 - \frac{\rho e^{\rho}}{e^{-\delta} (3\rho + 2\delta - 2e^{-\delta}(\rho + \delta))} \tag{10}$$

Equation (9) roughly says that the discount and substitution rates cannot be too high for  $\beta^*$  to exist. In case (9) does not hold, any  $\beta \in [0, 1)$  prevents socially inefficient choices (see Proposition 5 in the Appendix).

If inequality (9) is strict, the present-biased individual's threshold can be flatter than the planner's: there is a high enough level of present bias such that the coordination in the lower quality action (QWERTY in our example) is inefficient. In this case, different from GP, observing coordination on QWERTY does not imply efficiency.

Figure 2 depicts a situation with some present bias, but not enough to equate the agents' and planner's thresholds (i.e.,  $\beta < \beta^*$ ). In the shaded region, present bias keeps society on the efficient path. In other words, if a society found itself in that region and individuals were not present biased, people would choose the socially inefficient keyboard, and society would drift towards coordinating in the "wrong" keyboard, decreasing welfare. In a sense, present bias partially internalizes the unaccounted externalities imposed on those who take long to change standards, doing so by increasing the weight on the temporary loss of externalities associated with a transition. In the area between  $\theta^P(n_{\tau})$  and  $\theta^*(\beta, n_{\tau})$ , both present-biased and non-present-biased societies choose the "wrong" keyboard, because present bias

#### 4.1 When is Present Bias Helpful?

Whether a given society will experience a meaningful welfare improvement with the introduction of present bias will depend on initial conditions. If  $(\theta_{\tau}, n_{\tau})$  lies in the shaded region in Figure 2, there will be immediate welfare gains, since a transition with negative social value would be avoided. If the initial state is far away from any decision threshold, present bias might make little difference, since it might take a very long time to reach an area in which it matters for choices. To analyze when (and how much) present bias is helpful without imposing a prior distribution over the possible initial states, I analyze what range of  $\beta$  can prevent inefficient actions, noting that any  $\beta \in (0, \beta^*)$  is potentially helpful. As we know from equation 10 that  $\beta^*$ depends only on  $\rho$  and  $\delta$ , I analyze its dependence on those two parameters.

**Reparametrization.**<sup>9</sup> It is easier to interpret the results if we reparametrize the length of the present to  $\frac{1}{365}$ . So we can think of the length of the present as one day, and  $\rho$  and  $\delta$  can be interpreted as yearly rates. Take as baseline the case with  $\rho = 0.02$  and  $\delta = 1$ , i.e., the long-term discount rate is 2% a year, and individuals reevaluate their choices about once a year. This requires  $\beta^*$  to be nearly 0.22 to equalize the planner's and individual's threshold, and any  $\beta \in [0.22, 1)$  would help avoid socially damaging equilibria.

 $<sup>^{9}</sup>$ This reparametrization is not necessary for reaching the qualitative results described in this section. See Proposition 5 in the Appendix for a general description of the comparative statics.

Figure 3a illustrates how  $\beta^*$  depends on  $\rho$  for levels of  $\delta$  near the baseline case above. When  $\rho \to 0$ , agents are completely patient. In this case, the planner's decision threshold approaches a vertical line (only the long-term matters). Hence, for discount rates close to zero, even low amounts of present bias induce too much discounting and damages welfare. As  $\rho$  increases, the level of present bias that completely internalizes externalities also increases. That happens for two main reasons: (i) an increase in  $\rho$  is more important to the planner than for the individual, so increasing present bias can make the individual's threshold catch up with the planner's, and (ii) a given variation in  $\beta$  becomes less relevant for individual choice when  $\rho$  increases, because more discounting happens in the present. For  $\rho$  high enough, all the curves in Figure 3a reach  $\beta^* = 0$  (see Proposition 5 in the Appendix).

In Figure 3b we see the relationship between  $\beta^*$  and  $\delta$  for different values of  $\rho$  when  $\delta \leq 10$ . When  $\delta \rightarrow 0$ , decisions are "final": agents are stuck with their decisions for a long time and externalities become very important, as transitions take a long time to unravel. Hence, any level of present bias is helpful. As the substitution/reevaluation rate increases, the importance of externalities in transitions decrease and not as much present bias is needed to internalize them, hence the increasing relationship in Figure 3b.<sup>10</sup> Hence, if a society is impatient (high  $\rho$ ) and rarely reevaluates their keyboard choices or their social media use, present bias is likely increasing coordination efficiency.

Transitioning from one standard to another is more costly when the substitution/reevalution rate  $\delta$  is low (because a transition takes longer), and when the discount rate  $\rho$  is high (because the transition costs happen early in the transition). So present bias is more likely to be helpful exactly when coordination problems are more acute.

### 5 Discussion and Conclusion

#### 5.1 Present Bias as a Kludge

Present bias increases efficiency by increasing the "realized" discount rate without changing long-term desires. A simple increase in the discount rate of an exponential discounter would generate a flattening of the decision thresholds similar to the one induced by present bias. But, if agents have a higher discount rate, so should their benevolent planner. Hence, increasing the exponential discount would not prevent inefficiencies – except

<sup>&</sup>lt;sup>10</sup>When  $\delta \to +\infty$  frictions vanish, any transition occurs almost instantly. In that case, present bias becomes mostly irrelevant for the agent's choice, exactly because transitions happen instantly, *in the present*. This means present bias has little power to change actions and internalize externalities in such cases, so  $\beta^*$  decreases to 0 for very high substitution rates. This case is less interesting since coordination loses importance. See Proposition 5 in the Appendix for a complete characterization of the comparative statics and Figure 4 for how  $\beta^*$  depends on  $\delta$  over a wider domain.



Figure 3: The Bigger the Coordination Problem, the More Present Bias a Society Can Use

if we arbitrarily postulate that the planner problem has a lower "optimal" discount rate. Present bias can then be seen as a simple mechanism "tricking" people into socially better choices.

Increasing that realized discount rate is not an optimal (or even unique) solution to the coordination problem, as it can generate inefficiencies in other domains (e.g., see Beshears et al. (2022)). Nevertheless, it may have conferred sufficiently high individual benefits (e.g., Dasgupta and Maskin 2005) and coordination advantages to present-biased societies – as shown in this paper – to allow this trait to persist. Hence, present bias can be seen as a kludge, a haphazard or accidental adaptation to an issue. As I show that the more acute the coordination problem is, the more present bias it can use, the trait might have even accentuated over time if coordination was an issue of major and increasing importance in early societies (Ely, 2011).

#### 5.2 Conclusion

This paper illustrates how some present bias can actually help a group of people to coordinate in an efficient standard – e.g., a technology like a type of keyboard or a social media platform. It formally shows that a psychological trait seen as a damaging bias at the individual level can be adaptive at the group level, prompting us to give it extra thought before ruling that behavioral "biases" are generally damaging.

As present bias can be seen as a kludge, we should be cautious about deriving policy recommendations.

The equilibrium studied in this paper is inefficient with time-consistent agents, and incremental amounts of present bias increase efficiency – up to a point – while creating side effects in other domains (e.g., personal savings, not present in the coordination model). Hence, even in a situation where present bias perfectly "internalizes" the network externalities, giving people mechanisms to generally mitigate their present bias could still be worthwhile. Other mechanisms that make agents demand more intrinsic quality before a migration can also increase coordination efficiency, perhaps with different side effects.

### Acknowlegments

I thank Bernardo Guimarães, Ana Elisa Pereira, Bruno Ferman, Jesse Perla, Michael Peters, Sergei Severinov, Wei Li, Shunya Noda, Vitor Farinha Luz, Michal Szkup, Matt Lowe, Munir Squires, Luis Alejandro Rojas-Bernal, Sebastian Gomez Cardona, Túlio Sálvio, and Gabriel Toledo for their comments and suggestions. This research did not receive any specific grant from funding agencies in the public, commercial, or not-forprofit sectors.

### References

- Beshears, John, James Choi, David Laibson, and Peter Maxted, "Present bias causes and then dissipates auto-enrollment savings effects," in "AEA Papers and Proceedings," Vol. 112 American Economic Association 2014 Broadway, Suite 305, Nashville, TN 37203 2022, pp. 136–141.
- Bohren, J Aislinn and Daniel N Hauser, "Learning with heterogeneous misspecified models: Characterization and robustness," *Econometrica*, 2021, *89* (6), 3025–3077.
- Burdzy, Krzysztof, David M Frankel, and Ady Pauzner, "On the time and direction of stochastic bifurcation," in "Asymptotic Methods in Probability and Statistics," Elsevier, 1998, pp. 483–500.
- Chakraborty, Anujit, "Present bias," Econometrica, 2021, 89 (4), 1921–1961.
- Cohen, Jonathan, Keith Marzilli Ericson, David Laibson, and John Myles White, "Measuring time preferences," *Journal of Economic Literature*, 2020, 58 (2), 299–347.
- Crouzet, Nicolas, Apoorv Gupta, and Filippo Mezzanotti, "Shocks and technology adoption: Evidence from electronic payment systems," *Techn. rep., Northwestern University Working Paper*, 2019.
- Dasgupta, Partha and Eric Maskin, "Uncertainty and hyperbolic discounting," American Economic Review, 2005, 95 (4), 1290–1299.
- David, Paul A, "Clio and the Economics of QWERTY," American Economic Review, May 1985, 75 (2), 332–337.
- Ely, Jeffrey C, "Kludged," American Economic Journal: Microeconomics, 2011, 3 (3), 210-231.
- Ericson, Keith Marzilli and David Laibson, "Intertemporal choice," in "Handbook of Behavioral Economics: Applications and Foundations 1," Vol. 2, Elsevier, 2019, pp. 1–67.
- Fedyk, Anastassia, "Asymmetric naivete: Beliefs about self-control," Management Science, 2024.
- Frankel, David and Ady Pauzner, "Resolving Indeterminacy in Dynamic Settings: The Role of Shocks," The Quarterly Journal of Economics, 2000, 115 (1), 285–304.
- Frankel, David M and Ady Pauzner, "Expectations and the timing of neighborhood change," Journal of Urban Economics, 2002, 51 (2), 295–314.

- and Krzysztof Burdzy, "Shocks and Business Cycles," The B.E. Journal of Theoretical Economics, March 2005, 5 (1), 1–88.
- Frederick, Shane, George Loewenstein, and Ted O'donoghue, "Time discounting and time preference: A critical review," *Journal of economic literature*, 2002, 40 (2), 351–401.
- Gans, Joshua S and Peter Landry, "Self-recognition in teams," International Journal of Game Theory, 2019, 48 (4), 1169–1201.
- Guimaraes, Bernardo and Ana Elisa Pereira, "QWERTY is efficient," Journal of Economic Theory, 2016, 163 (C), 819–825.
- and Caio Machado, "Dynamic coordination and the optimal stimulus policies," The Economic Journal, 2018, 128 (615), 2785–2811.
- \_ , \_ , and Ana E Pereira, "Dynamic coordination with timing frictions: theory and applications," Journal of Public Economic Theory, 2020, 22 (3), 656–697.
- Harris, Christopher and David Laibson, "Instantaneous Gratification," The Quarterly Journal of Economics, 2013, 128 (1), 205–248.
- Heidhues, Paul and Botond Kőszegi, "Exploiting naivete about self-control in the credit market," American Economic Review, 2010, 100 (5), 2279–2303.
- \_ and \_ , "Naivete-based discrimination," The Quarterly Journal of Economics, 2017, 132 (2), 1019–1054.
- Kaufmann, Marc, Peter Andre, and Botond Kőszegi, "Understanding markets with socially responsible consumers," *The Quarterly Journal of Economics*, 2024, p. qjae009.
- Kleinberg, Jon, Sigal Oren, and Manish Raghavan, "Planning with multiple biases," in "Proceedings of the 2017 ACM Conference on Economics and Computation" 2017, pp. 567–584.
- Laibson, David, "Golden Eggs and Hyperbolic Discounting," *The Quarterly Journal of Economics*, 1997, 112 (2), 443–478.
- Meunier, Guy and Ingmar Schumacher, "The importance of considering optimal government policy when social norms matter for the private provision of public goods," *Journal of Public Economic Theory*, 2020, 22 (3), 630–655.

- Phelps, Edmund S and Robert A Pollak, "On second-best national saving and game-equilibrium growth," *The Review of Economic Studies*, 1968, *35* (2), 185–199.
- Plantin, Guillaume and Hyun Song Shin, "Exchange rates and monetary spillovers," *Theoretical Economics*, 2018, 13 (2), 637–666.
- Schwardmann, Peter and Joel Van der Weele, "Deception and self-deception," Nature human behaviour, 2019, 3 (10), 1055–1061.
- Webb, Craig S., "Continuous quasi-hyperbolic discounting," *Journal of Mathematical Economics*, 2016, 64 (C), 99–106.

### **Online Appendix**

#### Comparative Statics for $\beta^*$

The following proposition formalizes the comparative statics presented in Section 4.1.

**Proposition 5** Let  $\rho > 0$  and  $\delta > 0$ . Under the small shocks case, suppose  $\beta^* \in (0,1)$ , i.e., equation (9) holds with strict inequality. Then

(i) For any  $\delta > 0$ ,  $\frac{d\beta^*}{d\rho} < 0$ ;

(ii) For each  $\rho > 0$ , there exists a unique  $\hat{\delta}_{\rho}$  such that  $\frac{\partial \beta^*}{\partial \delta} > 0$  for  $\delta < \hat{\delta}_{\rho}$  and  $\frac{\partial \beta^*}{\partial \delta} < 0$  when  $\delta > \hat{\delta}_{\rho}$ . And we can also show:

(iii) When  $\rho \to 0$ , any fixed  $\beta < 1$  introduces new inefficiency areas, making a society demand too much quality to start a transition;

(iv) For any  $\delta > 0$ , there is  $\hat{\rho}_{\delta}$  large enough such that for any  $\rho > \hat{\rho}_{\delta}$  any level of present bias prevents inefficient equilibria;

(v) For each  $\rho > 0$ , there is  $\underline{\delta}_{\rho} > 0$  such that present bias is always helpful if  $\delta < \underline{\delta}_{\rho}$ ;

(vi) For any  $\rho > 0$ , there is  $\delta$  large enough such that any level of present bias prevents inefficient equilibria.

**Proof.** Assume (9) holds with strict inequality. Take the  $\rho$ -partial derivative of the LHS of (10). For each  $\delta > 0$ , the derivative's sign is  $sgn(-\rho^2(3-2e^{\delta})-(\rho+1)2\delta(1-e^{\delta}))$ , which is negative, so we have (i). Taking the  $\delta$ -partial derivative of the LHS of (10), we can see it's sign is determined by the sign of  $2(e^{\delta}-1)+\delta(4-2e^{\delta})+\rho(4-3e^{\delta})$ . Notice that when  $\delta \to 0$ , the expression determining the sign is positive. The  $\delta$  derivative of that expression is  $4-2\delta e^{\delta}-3\rho e^{\delta}$ , which is strictly decreasing and eventually strictly negative. This gives us (ii).

When  $\rho \to 0$ ,  $\beta^* = 1$ , so (ii) holds. We get (iii) by combining (i) with the fact that letting  $\rho$  be big makes (9) false. For (iv), notice (9) does not hold when  $\delta \to 0$  since  $e^{\rho} > 1$ . To get (vi), just combine the previous steps with the fact (9) does not hold when  $\delta \to +\infty$ .)

#### Proofs for Propositions 1 and 2

**Proof for Proposition 1.** First, note that Theorem 1 in FP applies both to (a) overlapping generations and (b) infinitely-lived agents rethinking their choices at rate  $\delta$ , as long as agents choose according to choice rule 1 with  $\beta = 1$  (no present bias). The overlapping generations formulation of FP's Theorem 1 applies almost directly to the case when  $\beta \in (0, 1)$ , since it relies on (i) the Brownian motion having the potential to move  $\theta_t$  across a threshold given enough time, (ii) the existence of dominance regions and (iii) the flow utility found in the choice rule 1 (denoted by  $\pi(.,.) - 1$  in FP) being continuously differentiable and monotonic in its arguments. One can interpret the flow utility in this paper as  $\Delta \tilde{u}(\theta, n, t) = \beta^{t-\tau \ge 0} \Delta u(\theta, n)$ , which is then exponentially discounted, as in FP.  $\Delta \tilde{u}$  is monotonic and continuously differentiable in  $\theta$  and n for any t, which guarantees that the decision thresholds are Lipschitz functions, allowing one to apply the findings from Burdzy et al. (1998) and complete the proof. So, the new discount function D preserves all necessary assumptions; it simply downweights utility received after some time.

To extend the proof to cases with infinitely-lived agents, it is enough to guarantee that such agents still follow choice rule 1, since that will generate the same action threshold and dynamics. An abridged proof of FP's Theorem 1 with notation similar to the one used in this paper can be found in Guimaraes et al. (2020).

**Proof for Proposition 2.** Similar to the proof above, it is straighforward to check that the necessary assumptions are maintained when  $\beta \in (0, 1)$ . Equation 3 is equivalent to the one given in the main text in FP before a change of variables. Again, a more straighforward description of the results can be found in Guimaraes et al. (2020).

## 5.3 Supplemental Figures



Figure 4: How  $\beta^*$  depends on  $\rho$  and  $\delta$  Over an Extended Domain