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The idea trap: the political economy of growth divergence

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Abstract

The paper develops an economic–political model to explain why the convergence hypothesis fails even though good economic policies seem to be a sufficient condition for strong economic growth (Sachs, J., Warner, A., 1995a. Economic convergence and economic policies. NBER Working Paper No. 5039. National Bureau of Economic Research, Cambridge, MA.). The model has three variables: growth, policy, and ideas, which take on discrete values "good", "mediocre", or "bad". Positive feedback from growth to ideas gives rise to multiple equilibria. In one, the "idea trap", bad growth, bad policy, and bad ideas mutually support each other; better policies would work, but are endogenously unlikely to be tried. The paper then illustrates the model's empirical plausibility by reinterpreting some otherwise puzzling historical episodes.

JEL classification: O40; D72; O10
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1. Introduction

If the market mechanism is suspect, the inevitable temptation is to resort to greater and greater intervention, thereby increasing the amount of economic activity devoted to rent seeking. As such, a political "vicious circle" may develop. People perceive that the market mechanism does not function in a way compatible with socially approved goals because of competitive rent seeking. A political consensus therefore emerges to

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intervene further in the market, rent seeking increases, and further intervention results Krueger (1974, p. 302).

Even though the convergence hypothesis fails empirically for the world as a whole (Barro, 1991; Barro and Sala-i-Martin, 1992; DeLong, 1988; Li, 1999; Keefer and Knack, 1997), good economic policies are virtually a sufficient condition for strong economic growth (Sachs and Warner, 1995a,b; Olson, 1996; Ben-David, 1998a, 1993; Knack and Keefer, 1995; Dollar, 1992; Abrams and Lewis, 1995).[1] What appears to drive non-convergence is the fact that poor countries persistently have bad policies. Still, no matter how well it fits the facts, this story is puzzling from a theoretical perspective (Rodrik, 1996). If the road to prosperity is at once feasible and obvious, why are not all countries—or at least all democracies—already on it?

The current paper presents a simple political–economic model of the interaction of growth, policy, and ideas to explain this puzzle. Growth, policy, and ideas are mutually reinforcing, given a key assumption about the impact of growth on ideas. Countries tend to have either all "good", all "mediocre", or all "bad" values. An important implication is that social forces do *not* inexorably drive economically unsuccessful countries to reform. In my model, policy "turn-arounds" instead arise due to large random disturbances that shock economies into better equilibria. While this conclusion is somewhat counter-intuitive, it is much more consistent with the empirical failure of the convergence hypothesis than the optimistic "learning" model (Williamson, 1994a).

The current paper's model belongs to a broader family of political–economic models with multiple equilibria or "traps" (Arthur, 1994a; David, 1994). In some, such as Ben-David (1998b), Greif (1994), Azariadas and Drazen (1990), Becker et al. (1990), and Nelson (1956), "poverty traps" are the product of bad initial economic conditions, not bad policies. This can happen with increasing returns, low levels of trust, or if savings rates depend on the level of per-capita income. But in the modern world, many countries are *already out* of the "poverty trap". Why is not openness to the world economy enough to permit those that remain trapped to escape (Dollar, 1992)? Foreign trade lets small countries exploit increasing returns. Foreign firms with solid reputations are the natural "honest brokers" for low-trust societies. Foreign investment can compensate for low domestic savings rates.

In other multiple equilibria models, growth and policy interact. In Murphy et al. (1993), there is a high-rent-seeking, low-growth equilibrium and a low-rent-seeking, high-growth equilibrium; Krueger (1993) similarly argues that import-substitution policies spark a vicious political–economic cycle, while export-led growth does the opposite. The main problem with these stories is they tend to treat policy as unresponsive to public opinion, even in democracies. Are interest groups really able to permanently foist bad policies on a recalcitrant citizenry?

[1] On the international level, Barro (1991) and Barro and Sala-i-Martin (1992) do find supporting evidence for *conditional* convergence given initial human capital. But as Sachs and Warner (1995a,b) emphasize, this remains a profoundly pessimistic conclusion for poor countries with little human capital.

The main novelty of the current paper's model is that it makes "ideas"—and their sensitivity to economic performance—the linchpin of multiple equilibria. By "ideas" I essentially mean *policy-relevant public opinion*. Ideas determine how people vote, but by assumption have no effect on day-to-day behavior.[2] They impinge only on collective choice, not private choice.[3] My model assumes away all strategic interactions between political players, treating government as a faithful servant of the public, and elections as an accurate barometer of its wishes. There is no direct feedback to policy from growth; rather, policy is a function of ideas, and growth can only influence policy *indirectly* by altering ideas about what appropriate policies are.[4] When there is "positive feedback" from growth to ideas, multiple equilibria exist and the mutual interaction of growth, policy, and ideas closely matches the stylized facts. Countries can then fall into "idea traps", where bad growth, bad policy, and bad ideas mutually reinforce each other.

My account is probably most similar to Kuran and Sunstein's (1999) "availability cascades". They argue that vivid anecdotes, risk over-estimation, media attention, public policy, and inefficient outcomes mutually support each other. This gives rise to multiple regulatory equilibria based partly on historical accident instead of unique regulatory equilibria based on objective risk. It is only distantly related, however, to Kuran's (1995) model of preference falsification. For Kuran, sincere conformity can be the long-run effect of pressure for outward conformity, leading, as in my model, to multiple belief equilibria. In my model, however, the central mechanism is the sensitivity of ideas to economic performance, not pressure for conformity.[5]

Others in the development literature have seen ideas as exogenous drivers of policy unrelated to objective circumstances, not optimal endogenous responses (Sachs and Warner, 1995b, esp. pp. 10–19; Olson, 1996; Waterbury, 1993; Bates and Krueger, 1993a). Sachs and Warner (1995b) for example argue that "socialist and SLI [state-led industrialization] policies should be understood mainly as 'policy experiments' (albeit

[2] Admittedly, there are a number of possible slippages between public opinion and voting. Voter participation is one. Insincerity induced by social pressure is another (Kuran, 1995). Moreover, it is worth pointing out that in primitive tribes, the distinction between private and collective choice blurs. With poor exit options and only a few dozen people, informal enforcement of tradition can take the place of official policies in more developed societies (Edgerton, 1992). The model ignores such complications for the sake of simplicity.

[3] In contrast, many analyses (e.g. Greif, 1994) of the interaction between culture and the economy implicitly take the opposite approach, exploring the effect of culture on private decision-making while ignoring its effect on policy. The robust international connection between good policies and economic growth suggests, however, that if culture impedes growth, it primarily does so through governmental channels.

[4] Aside from being more parsimonious, this assumption is consistent with the recurring case study observation that special interests are rarely able to prevent reforms with strong public support. Bates and Krueger (1993a) remark that: "One of the most surprising findings of our case studies is the degree to which the intervention of interest groups fails to account for the initiation, or lack of initiation, of policy reform" (p. 455). Waterbury (1993) offers a plausible explanation: "[I]nterests have tried to defend their particular entitlements, allowing determined change teams at the highest political levels to pick them off one at a time... Interests dependent on the state never developed habits of collective bargaining but, rather, relied on particularistic deal making. When threatened, these same interests resorted to particularistic damage control, repairing leaks in their vessels as the ebbing tide brought all ships down" (p. 264).

[5] Of course, Kuran's account and mine could easily be complementary. Social pressure might be one reason why ideas are sensitive to economic performance.

enormously mistaken and costly ones), rather than as inevitable consequences of the economic structures of the countries in question" (p. 13). Or as Higgs (1987) remarks, "Anyone who has lived among social thinkers knows that ideas have a life of their own... Intellectuals, the specialists in the production and distribution of articulate social thought, are subject to fads; from time to time they are carried away by one notion or another for no apparent reason" (p. 53). The assumption of "positive feedback" that underlies my "idea trap" is just one step more extreme: Countries' attraction to "mistaken and costly policy experiments" is not random, but actually decreasing in their rate of growth.

This story is admittedly vulnerable to a rational expectations critique (Rodrik, 1996; Wittman, 1995). The underlying premise of the current paper, however, is that in economic models of *politics*, such a priori critiques are misplaced (Caplan, 2001a). Why? Because *sensible public opinion is a public good* (Akerlof, 1989; Brennan and Lomasky, 1993; Caplan, in press). Citizens of countries where good ideas prevail partake in the benefits of economic growth—whether or not their own ideas are good or bad. In markets, a failing entrepreneur has strong incentives to figure out what he is doing wrong, and change his ways. The same does not hold in politics; given the infinitesimal probability that one vote changes policy, there is no incentive at the margin for one voter to identify and correct mistaken beliefs about effective policy. Admittedly, the public-good nature of ideas does not imply which specific systematic errors will prevail, but it does deprive standard theoretical objections to such possibilities of much of their appeal.

There are of course a number of fully rational, internally consistent theories of why even democracies adopt and retain bad economic policies (Rodrik, 1996). Risk aversion (voters prefer the bad policies in place to a reform gamble that might make policy even worse) and time preference (reforms have long-term benefits but short-term costs) are the simplest. Rodrik points out, however, that these simple explanations are rarely satisfactory: "Once one makes allowance for the likelihood that the counterfactual—no reform—produces even worse results in the short run, the consequences of reform actually look pretty good" (1996, p. 29). Other, more complex theories (e.g. Fernandez and Rodrik, 1991; Alesina and Drazen, 1991; Labán and Sturzenegger, 1994) avoid this difficulty.[6] But they still require implausible configurations of public opinion: What appear to be sincere ideological judgments about socially beneficial policy have to be reinterpreted as strategic posturing (Caplan, 2001a). According to each of these theories, if everyone were honest, a majority would admit that changing policies would make most people better off relative to the political equilibrium. In any case, as long as one agrees that rational expectation models of policy failure leave important facts unexplained, my model can be seen as a complement to—not a substitute for—standard approaches.

The paper is divided into four sections. The next section lays out the model's assumptions, proves four main theorems about the deterministic behavior of the model, and presents simulations illustrating the model's properties in a stochastic world. The third

[6] Sachs' (1990) model of "populism cycles" occupies an interesting intermediate position. Like some other "war of attrition" models, his account links counter-productive policies to class conflict in inegalitarian societies. But he still concludes that populist policies quickly become harmful even for their firmest proponents, the urban poor. Thus, his fundamental explanation for policy failure is "that these leaders, and even more their followers, did not understand the riskiness of the course that they selected" (p. 159).

section reconsiders a number of case studies through the model's lens. The fourth section concludes the paper.

2. The model

2.1. Assumptions

Assume that the behavior of an economy at time t can be captured by three discrete variables: growth G_t, policy P_t, and ideas I_t. These variables may be seen as indices: G_t for the rate of economic growth, P_t for the quality of government policies, and I_t for the quality of public opinion about policy. In a given period, each of these variables takes on the "good" value of 1, the "mediocre" value of 0, or the "bad" value of -1. "Good" growth means that real per-capita output is increasing at a relatively rapid rate. "Good" policy means that the government's economic policies are relatively favorable for growth. Finally, ideas are "good" when the public (i) on average expects policies to work as well as they actually do, *and* (ii) ranks policies primarily by their impact on growth (rather than equity, national sovereignty, etc.). From a slightly different perspective, one might think of "good" ideas as being, in Williamson's (1994b) words, "the common core of wisdom embraced by all serious economists" (p. 18). While the model does not depend on the specifics of pro-growth policies, my *examples* do rely on the professional consensus in favor of secure property rights, international openness, and free-market policies generally (Sachs and Warner, 1995a; Caplan, 2001b, 2002).[7]

There are three basic equations that characterize the "laws of motion" of this model economy. First, growth is a function of lagged growth, lagged policy, and a shock:

$$G_t = \left\{ \begin{array}{lll} 1 & & > k \\ 0 & \text{if } \alpha_1 G_{t-1} + \beta_1 P_{t-1} + s_{1,t} & \geq -k \text{ and } \leq k \\ -1 & & < -k \end{array} \right\}. \tag{1}$$

Second, policy is a function of lagged policy, lagged ideas, and a shock.

$$P_t = \left\{ \begin{array}{lll} 1 & & > k \\ 0 & \text{if } \alpha_2 P_{t-1} + \beta_2 I_{t-1} + s_{2,t} & \geq -k \text{ and } \leq k \\ -1 & & < -k \end{array} \right\}. \tag{2}$$

[7] I would like to thank an anonymous referee for raising this issue.

Third, ideas are a function of lagged ideas, lagged growth, and a shock.

$$I_t = \left\{ \begin{array}{lll} 1 & & > k \\ 0 & \text{if } \alpha_3 I_{t-1} + \beta_3 G_{t-1} + s_{3,t} & \geq -k \text{ and } \leq k \\ -1 & & < -k \end{array} \right\}. \quad (3)$$

k and $-k$ are the cutpoints between good, mediocre, and bad outcomes; $\max|\alpha_i - |\beta_i|| < k < \min(\alpha_i; |\beta_i|)$. Except for β_3, all of the coefficients α_i and β_i lie strictly between 0 and 1. The autocorrelation of recent and past values of each variable can be interpreted as the product of adjustment costs; alternately, this could reflect diverse and somewhat persistent influences that are not explicitly modeled.[8] All of the shocks s_i are normally distributed with variance σ_i^2 and zero mean. They are uncorrelated over time and with each other.

The first two equations capture the straightforward features of the model. In Eq. (1), the intuition is simply that good policies cause higher growth than bad policies—a virtual tautology. In Eq. (2), it is that economic policy conforms to public opinion. This could be driven by the usual median voter mechanism, or by more complicated political processes.[9] The random shock in Eq. (2) can accommodate various frictions; for example, infrequent elections might allow temporary mismatches between policy and ideas.[10]

The model's novelty hinges on Eq. (3). The coefficient β_3, which captures the effect of growth on ideas, is allowed to be either positive or negative, lying strictly between -1 and $+1$.[11] This allows the model to capture two opposing intuitions. In the first case, there is *negative* feedback from growth to ideas: $\beta_3 < 0$. At least initially, this seems like the more plausible possibility: When growth is low, people rethink their beliefs about what policies work. They "learn from their failures", as almost all-learning algorithms posit (e.g. Camerer and Ho, 1999; Arthur, 1994b), so the quality of their ideas improves. When growth is good, in contrast, people become more willing to experiment with dubious policies, perhaps in pursuit of non-economic goals such as greater equity.

In the second—and perhaps counter-intuitive—case, there is *positive* feedback from growth to ideas: $\beta_3 > 0$. When economic outcomes are bad, people's economic beliefs perversely become less—not more—realistic. Rather than "learning from their failures", they become more committed to making failed policies work, one way or another.[12] On the

[8] The inclusion of only one lag is meant to be illustrative; adding more lags will unsurprisingly increase the stability of steady-state equilibria.

[9] In non-democratic countries, the relevant ideas might well be the ideas of controlling elites, rather than the general population.

[10] I would like to thank an anonymous referee for raising the question of electoral timing.

[11] β_3 cannot equal 0 because the cut-point k is restricted to be strictly greater than 0 and strictly less than the absolute value of β_3. Allowing $\beta_3 = 0$ does little to change the results. With $\beta_3 = 0$ and no shocks, all values of I_t become stable. The fixed quality of ideas then drives policy, which in turn drives growth, yielding the same three SSEs that exist when β_3 is strictly positive.

[12] Sachs (1994), for example, argues that in high-inflation settings, emotionally appealing but ineffective populist policies gain *extra* support: "The confusion, anxiety, and the profound sense of bewilderment about market forces are inevitable when breadwinners must worry whether income will be enough next week to feed the family... You cannot think straight in the midst of hyperinflation. The society becomes unglued" (p. 507). See also Sachs (1990).

other hand, if outcomes are good, the quality of ideas improves. When people see policies working, they are more likely to be won over by their economic logic. Positive feedback has far more in common with various forms of cognitive bias (Rabin, 1998) than it does with conventional learning models.

The central argument of this paper is that the latter case of positive feedback is the empirically interesting one. If feedback is negative ($\beta_3 < 0$), there is a unique steady-state equilibrium, in which growth, policy, and ideas are all mediocre.[13] Thus, with negative feedback, there is convergence in income *growth*. Adding an arbitrarily small catch-up effect to Eq. (1) would imply eventual convergence in income *levels*. Similarly, no tendency exists for some countries to select consistently better policies than others, and beliefs about effective policies show no distinctive, persistent national patterns.

On the other hand, if feedback is positive ($\beta_3 > 0$), there are *three* steady-state equilibria: One where growth, policy, and ideas are all good, one where they are all bad, and one where they are all mediocre. This means that growth rates persistently differ over time: year after year, some countries enjoy high growth, while others suffer from low or even negative growth. Since income growth rates diverge, adding an arbitrarily small catch-up effect to Eq. (1) is not enough to make income levels converge.[14] The quality of policies and ideas would likewise persistently vary across countries.

In sum, the model with positive feedback is remarkably consistent with the accumulated empirical evidence on growth and economic policy. Yet there is also *direct* empirical evidence—admittedly suggestive rather than demonstrative—that growth has a beneficial effect on ideas. The Survey of Americans and Economists on the Economy (1996) (henceforth SAEE) and Blendon et al. (1997) ask professional economists and randomly selected members of the American general public a large number of questions about positive economics. This data provides one plausible way to operationalize "good" versus "bad" ideas: The smaller the magnitude of the gap between the public's and professional economists' average beliefs, the better the public's ideas. Using the SAEE's battery of questions, and even controlling for the potential confounding effects of self-interest and ideology, Caplan (2002) shows that this gap is large. Economists predictably see far greater benefits of international trade, flexible labor markets, and free markets generally than the typical member of the public does.

Yet the size of this belief gap varies widely for different sub-groups of non-economists. For the purposes of the current paper, the most noteworthy of the findings in Caplan (2001b) is that both recent and expected income *growth*—but not income levels—make

[13] James Vreeland, in comments delivered at the Public Choice Society meetings, suggested an alternate way to model "learning": instead of having negative feedback, why not have ideas change if growth is *not* good, and otherwise remain fixed? This essentially turns the unique SSE from (0,0,0) to (1,1,1). Similarly, if ideas change only if growth is bad, and otherwise remained fixed, both (0,0,0) and (1,1,1) become SSE.

[14] Of course, there will be convergence in any case given a large enough catch-up effect; the point is that with positive feedback the mere existence of strictly positive catch-up effect is not a sufficient condition for convergence.

members of the general public "think more like economists". The impact is extremely robust in both statistical and economic terms. To illustrate the magnitude, imagine comparing an economist with a flat income profile to two non-economists, identical except that recent and expected income growth are positive for one and negative for the other. The average belief gap of the non-economist with positive income growth will only be 64% as large as the belief gap of the non-economist with negative income growth. Adding job security—another good measure of expected economic change—to the scales makes the difference between the most optimistic and the least optimistic greater still. The average belief gap of people with maximal job security, recent income growth, and expected income growth on average is only 54% as large as people's with minimal job security, recent income decline, and expected income decline.

Given the absolute size of the belief gap between economists and the public, reducing its magnitude by roughly one-third to one-half is an impressive change. Assuming that these cross-sectional results hold up over time and across countries, one can infer that public opinion diverges *less* from economists' consensus judgments when growth is rapid, and *more* when growth is slow. The current policy consensus of economists admittedly remains an imperfect benchmark for "good" ideas even after controlling for self-interest, ideology, and so on. But it is still what Williamson (1994b) calls "a natural reference point" (p. 18). At minimum, the SAEE's evidence provides *some* concrete evidence that positive feedback is more than a mere theoretical possibility.

2.2. Deterministic steady-state equilibria

This section analyzes steady-state equilibria in the deterministic version of the model, where $\sigma_i^2 = 0\ \forall i$.

Definition 1. (G_t,P_t,I_t) is a steady-state equilibrium (SSE) if and only if $(G_t,P_t,I_t)=(G_{t-1},P_{t-1},I_{t-1})$.

Definition 2. There is negative feedback if and only if $\beta_3 < 0$.

Definition 3. There is positive feedback if and only if $\beta_3 > 0$.

Then the following theorems hold:

Theorem 1. *If there is negative feedback, then (G,P,I)=(0,0,0) is a steady-state equilibrium.*

Proof. In a SSE, $(G_t,P_t,I_t)=(G_{t-1},P_{t-1},I_{t-1})$. From Eqs. (1)–(3), $(G_t,P_t,I_t)=f(\alpha_1 G_{t-1}+\beta_1 P_{t-1},\alpha_2 P_{t-1}+\beta_2 I_{t-1},\alpha_3 I_{t-1}+\beta_3 G_{t-1})$. Thus, for SSE, $(G_t,P_t,I_t)=f(\alpha_1 G_t+\beta_1 P_t,\alpha_2 P_t+\beta_2 I_t,\alpha_3 I_t+\beta_3 G_t)$. Designate $f(\alpha_1 G_t+\beta_1 P_t,\alpha_2 P_t+\beta_2 I_t,\alpha_3 I_t+\beta_3 G_t)=f(\cdot)$. Then for $(G,P,I)=(0,0,0)$, substitution reveals: $f(\cdot)=f(0,0,0)$. Since $-k \le 0 \le k\ \forall i$, $f(\cdot)=(0,0,0)$. □

Theorem 2. *If there is negative feedback, then (G,P,I)=(0,0,0) is the unique steady-state equilibrium.*

Proof. See Table A1 in Appendix A. □

Thus, if bad growth improves the quality of ideas, the mediocre equilibrium is the only steady-state equilibrium. Countries will not have persistently good or persistently bad economic performance year after year. This is essentially a convergence result: regardless of initial conditions, there is a unique stable outcome for all countries. Now strictly speaking, this is only convergence in income growth rates. But adding even a small catch-up effect to Eq. (1), such that income growth is also a decreasing function of income level, would be enough to guarantee the ultimate convergence of income levels. One could even reinterpret "good" growth as "good given the country's income level"; then the observed growth rate would be increasing in G_t but decreasing in last period's income level.

Why is (0,0,0) the unique steady-state equilibrium? Suppose one partitions the 26 other candidate SSE into three groups, as shown in Table A1. The 12 equilibria in group 1 cycle, so they can all be ruled out as SSE. Similarly, the 12 equilibria in group 2 all decay into one of the equilibria in group 1. Finally, the 2 equilibria in group 3 decay into the unique SSE (0,0,0).

Theorem 3. *If there is positive feedback, then (G,P,I)=(1,1,1), (0,0,0), and (−1, −1, −1) are all steady-state equilibria.*

Proof. First, for (G,P,I)=(0,0,0), substitution still reveals: $f(\cdot)=f(0,0,0)$. Since $-k \leq 0 \leq k$ $\forall i$, $f(\cdot)=(0,0,0)$. □

Next consider (G,P,I)=(1,1,1), and recall that with positive feedback, $\beta_3>0$. By substitution, $f(\cdot)=f(\alpha_1+\beta_1,\alpha_2+\beta_2,\alpha_3+\beta_3)$. Then since $k<\min(\alpha_i;\beta_i)$, $k<(\alpha_i+\beta_i)$ $\forall i$. Thus $f(\cdot)=(1,1,1)$.

Finally, take (G,P,I)=(−1, −1, −1). By substitution, $f(\cdot)=f(-\alpha_1-\beta_1,-\alpha_2-\beta_2,-\alpha_3-\beta_3)$. Then note that, $-k>-\min(\alpha_i;\beta_i)$ so $-(\alpha_i+\beta_i)<-k$ $\forall i$. Thus, $f(\cdot)=(-1,-1,-1)$.

Theorem 4. *If there is positive feedback, then (G,P,I)=(1,1,1), (0,0,0), and (−1, −1, −1) are the only steady-state equilibria.*

Proof. See Table A2 in Appendix A. □

Intuitively, in each of these equilibria, the three variables are self-reinforcing. Good policy leads to good economic growth, good ideas in the electorate elicit good policy from politicians, and good growth keeps the citizenry wedded to good ideas. Bad policy, conversely, means bad economic growth. Bad ideas sustain bad policies. Bad growth in turn shores up voters' commitment to bad ideas. Mediocre values of growth, policy, and ideas are correspondingly stable over time.

Why are there no additional SSE? It is again illuminating to partition the remaining candidate steady-state equilibria into groups, as shown in Table A2. In group 1, there are no SSE because the sole good or bad value pulls up or drags down one of the mediocre

values. Suppose growth is good, but the quality of policy and ideas is mediocre. One period later, growth remains good, and policy remains mediocre, but ideas rise from mediocre to good due to the boost from high growth in the previous period. So group 1 equilibria decay into group 2 equilibria. Yet there also are no SSE in group 2: the extreme values always pull up or drag down the remaining mediocre value. They decay into either the good or the bad SSE. Group 3's members are not SSE either: Given a mix of good and bad variables, one good and one bad variable have to "cancel" each other out; group 3 equilibria decay into group 1 equilibria. Finally, the group 4 equilibria cycle: Each group 4 equilibrium decays into another group 4 equilibrium.

2.3. Simulations with random shocks

The preceding theorems hold with probability 1 when there are no random shocks. But qualitatively, they continue to provide insight into stochastic versions of the model. If $\beta_3 < 0$, then initial conditions have little long-term effect on the quality of growth, policy, or ideas. The SSE equilibrium where $(G,P,I)=(0,0,0)$ is the modal outcome. In contrast, if $\beta_3>0$, initial conditions have a lasting impact on growth, policy, and ideas. The distribution of outcomes is trimodal, with spikes at $(-1,-1,-1)$, (0,0,0), and (1,1,1), but the relative heights of these three spikes is extremely sensitive to starting values. Countries that begin in the good equilibrium have a high probability of remaining there over long periods of time; countries in the bad equilibrium similarly tend to stay where they started. Nevertheless, if a country can break out of the bad equilibrium, it is highly likely to stay out. It is easy to stay on the track of economic progress, but hard to get there.

This section presents Monte Carlo evidence for four different simulations to illustrate how the direction of feedback interacts with initial positions. Each simulation examines a country's behavior over 100 periods and is repeated 10,000 times. In all four cases, $\alpha_i = 0.45\ \forall i$, $\beta_1 = \beta_2 = 0.4$, and $k = 0.39$. The shocks are normally distributed with mean zero and a standard deviation of 0.2.

Table 1 shows how the four simulations differ. In Simulation 1, feedback is negative—$\beta_3 < 0$, and the initial values are mediocre—$(G_1,P_1,I_1)=(0,0,0)$. In Simulation 2, feedback is still negative, but the initial values are good—$(G_1,P_1,I_1)=(1,1,1)$. In Simulation 3, feedback is positive and the initial values are mediocre. Finally, in Simulation 4, feedback remains positive, but the initial values are good.

First consider each simulation's *mean values* for growth, policy, and ideas over time (Table 2). When the initial values are (0,0,0), the direction of feedback makes almost no difference at any point. At each time horizon, the average values of growth, policy, and ideas for Simulations 1 and 3 are virtually identical. The opposite holds when the initial

Table 1
Simulation properties

Feedback—β_3	Initial position—(G_1,P_1,I_1)	
	Mediocre	Good
Negative	Simulation 1	Simulation 2
Positive	Simulation 3	Simulation 4

Table 2
Mean simulation values

	Simulation 1			Simulation 2			Simulation 3			Simulation 4		
(G_1,P_1,I_1)	(0,0,0)			(1,1,1)			(0,0,0)			(1,1,1)		
β_3	Negative			Negative			Positive			Positive		
t	G_t	P_t	I_t	G_t	P_t	I_t	G_t	P_t	I_t	G_t	P_t	I_t
1	0.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000	0.000	1.000	1.000	1.000
10	−0.006	−0.006	0.008	−0.473	−0.179	0.303	−0.003	−0.012	−0.006	0.936	0.938	0.932
25	−0.008	−0.003	0.009	−0.047	0.044	0.099	0.003	−0.001	0.003	0.863	0.862	0.860
50	0.000	0.006	−0.002	−0.009	−0.004	0.000	−0.002	−0.001	0.002	0.749	0.747	0.750
100	−0.007	−0.006	−0.001	−0.018	−0.013	0.006	0.007	0.009	0.006	0.573	0.573	0.571
Mean	−0.001	−0.001	−0.001	0.031	0.009	−0.012	0.001	0.001	0.001	0.758	0.758	0.758

values are (1,1,1). The feedback's direction then makes an enormous difference. By period 25, the average values of all three variables for Simulation 2 are less than 0.1, while for Simulation 4 their average values all remain close to 0.9.

Intuitively, for countries that start out in the mediocre equilibrium, there is almost no effect of ideas on growth, positive or negative. Thus, the sign of β_3 is unimportant. But for countries that start in the good equilibrium, feedback matters tremendously. If the feedback is negative, then the mean values of all three variables rapidly tumble down: good growth reduces the quality of ideas, which reduces the quality of policy, which reduces growth. If the feedback is positive, in contrast, the variables mutually support each other, buffering the system against random shocks. At the end of 100 periods, the average quality of growth, policy, and ideas is almost identical for the first three simulations, but sharply better for the fourth. The joint effect of a good start and a positive feedback loop is dramatic.

Next, note the *percentage* of good, mediocre, and bad equilibria for each simulation as a function of time (Table 3). So long as there is negative feedback, the good and bad equilibria are rare, regardless of the starting values. (0,0,0) is clearly the unique SSE. Most signs that Simulations 1 and 2 had different starting values fade away by period 25, and none remain by period 50. In contrast, note how different the results are for Simulation 1 versus Simulation 3. Their mean values are, as shown in Table 2, almost

Table 3
Percentage of good (1,1,1), mediocre (0,0,0), and bad equilibria (−1,−1,−1)

	Simulation 1			Simulation 2			Simulation 3			Simulation 4		
(G_1,P_1,I_1)	(0,0,0)			(1,1,1)			(0,0,0)			(1,1,1)		
β_3	Negative			Negative			Positive			Positive		
t	%G	%M	%B	%G	%M	%B	%G	%M	%B	%G	%M	%B
1	0.00	100.00	0.00	100.00	0.00	0.00	0.00	100.00	0.00	100.00	0.00	0.00
10	1.52	42.64	1.35	1.08	18.08	2.91	11.97	41.27	12.45	88.31	1.76	0.04
25	2.38	28.51	2.06	2.52	25.52	1.81	31.41	17.59	31.42	82.49	4.33	1.39
50	2.30	26.42	2.22	2.21	27.77	2.26	39.38	7.48	39.50	76.24	5.89	5.66
100	2.05	27.12	1.89	1.78	26.52	2.19	41.07	5.77	40.39	67.68	5.55	14.00
Mean	2.00	31.63	2.02	3.10	24.66	2.26	33.47	16.09	33.41	77.51	4.63	6.05

Table 4
Persistence probabilities

	Simulation 1	Simulation 2	Simulation 3	Simulation 4
(G_1,P_1,I_1)	(0,0,0)	(1,1,1)	(0,0,0)	(1,1,1)
β_3	Negative	Negative	Positive	Positive
(1,1,1)	0.043	0.041	0.968	0.969
(0,0,0)	0.854	0.856	0.854	0.852
$(-1,-1,-1)$	0.043	0.044	0.968	0.966
Others	0.256	0.254	0.281	0.289

identical. But their distributions look completely different. In Simulation 1, random disturbances combined with negative feedback frequently shock economies *out* of the mediocre SSE, but almost never shock them *into* the good or bad equilibria. In Simulation 3, random disturbances combined with positive feedback quickly create high probabilities of falling into the good or bad equilibria. By period 25, countries are more likely to have gotten into the good or bad equilibria than they are to have remained in their mediocre starting point.

The contrast between Simulations 3 and 4 is also striking. Recall that the only difference between these simulations is their initial positions. But after 100 periods, the consequences of this difference remain plainly visible. In almost 70% of countries with a good start, the good SSE persists after 100 periods, and only 14% have fallen into the bad SSE. But in countries with a mediocre start, just over 40% are in the good SSE after 100 periods, with a roughly equal percentage in the bad SSE.

Last, consider the probability that a specific configuration of growth, policy, and ideas at time t persists into time $t+1$. Since the observed persistence probabilities are virtually constant over time, Table 4 displays only the mean persistence probabilities averaged over all periods, breaking down the results for the good, mediocre, bad, and all other equilibria. The persistence probabilities are clearly independent of initial values, but strongly depend on the sign of β_3. With negative feedback, the probability that a good or bad equilibrium persists is under 5%; with positive feedback, this probability is greater than 96%.

Overall, then, adding noise leaves the qualitative results of the model intact; the theorems proven for the deterministic version of the model are not knife-edge results. With negative feedback, there is a single SSE, and initial conditions have little impact on average performance. With positive feedback, there are three SSE, and average performance depends strongly on initial conditions.

3. Historical applications

This paper's model with positive feedback is consistent with most of the econometric evidence on growth and policy. But is it a plausible account of actual historical experiences? In particular, at least initially, the model seems to be at odds with much of the case study literature on economic development and policy reform. This section applies the model to some historical examples to try to overcome this impression. Examples are of

course not meant to be decisive empirical tests; the point is only to illustrate how otherwise puzzling events might be fruitfully reinterpreted using this paper's model.

One important point to bear in mind during these exercises is the difference between two conditional probabilities: the P(history of bad economic performance|policy reform), and the P(policy reform|history of bad economic performance). The first probability is near unity almost by definition. As Rodrik (1996) observes:

> [T]here is a strong element of tautology in the association of reform with crisis. Reform naturally becomes an issue only when current policies are perceived to be not working. A crisis is just an extreme instance of policy failure. That policy reform should follow crisis, then, is no more surprising than smoke following fire. Furthermore, the hypothesis is virtually nonfalsifiable: if an economy in crisis has not yet reformed, the frequently proffered explanation is that the crisis has not yet become "severe enough" (p. 27).

It is the second conditional probability, P(policy reform|history of bad economic performance), that figures critically in the current paper's model. If economic performance is bad, are voters more likely to realize what policies would improve matters, and elect politicians to carry them out? Or do voters become more likely to stay faithful to their policy vision, and express dissatisfaction by voting for new politicians who promise to make long-standing policies "work"? If the latter case is typical, and the former case exceptional, then saying that countries change course *because* earlier policies failed is misleading. And in practice, it is hard to predict when policy reform will happen. Knowing only how badly a country's policies have failed is surprisingly uninformative. For example, in Waterbury's (1993) study of policy reform in Egypt, India, Mexico, and Turkey, it is striking that reforms have been much more radical in Mexico and Turkey, even though policy failures in Egypt and India are palpably greater. Similar lessons can be drawn from other comparative case studies (Bates and Krueger, 1993b; MacIntyre and Jayasuriya, 1992). In sum, the long-term persistence of bad policies suggests that the P(people realize their favored policies are ineffective|those policies are ineffective) is low. So when public opinion *does* turn against earlier policies, this "realization" is best interpreted as a random positive shock to ideas, not "inevitable" learning from experience.

Similarly, my model suggests an alternate way to understand trans-national ideological and policy trends. Many observers have been surprised and puzzled by, for example, the rapid move towards freer trade around the world (Rodrik, 1994). If countries changed course because they "learned" that import-substitution policies were inefficient, why did it take them so long to realize it, and what extra information did they acquire that finally exposed their mistakes? Instead of seeing this as public opinion around the world "automatically" learning from experience, the current model highlights the possibility that random ideological shocks—good and bad—are correlated across countries. Part of the mechanism is probably the shared educational experiences and continuing dialogue of each country's policy experts; communication leads to ideological spillovers. From this perspective, the initial move to import-substitution policies in LDCs can be interpreted as a negative cross-national ideological shock, and the more recent move towards free trade as a positive cross-national ideological shock. Cross-national trends were not coincidental, but in neither case was ideological shift an inevitable response to the evidence.

It is also worth noting that the model is not globally stable; whether feedback is positive or negative, it is possible for society to be caught in a cycle. One might be tempted to dismiss this as a theoretical curiosity. It could be argued, however, that this captures a genuine phenomenon, the cyclicality of ideas.[15] For instance, free-market economics was relatively popular at the turn of the century, lost out to Keynesianism, and has recently revived as the "Washington consensus". Similar stories could be told about protectionism in Britain from 1800 to the present, or the popularity of state ownership and nationalization. Exploring idea cycles in detail must be left for future research, but it is interesting that my model allows for them.

3.1. The Great Depression

Why did the Great Depression last so long? Even with highly inflexible markets, government inaction would be an unsatisfying explanation. One could then ask why policy failed to respond to new conditions. Moreover, it is hard to deny that there *were* drastic policy changes during the Great Depression. Why were these policies able to gain so much popular support, but so unable to deliver rapid economic recovery?

Through the lens of the current paper's model, the most promising hypothesis to consider is that the Great Depression shocked affected countries from a good or mediocre steady-state equilibrium into the "idea trap" of bad growth, bad policy, and bad ideas. But is this a plausible reading of the historical record? Bernanke (1995) and Eichengreen (1992) note that the initial stages of the Great Depression were marked by sharp monetary declines throughout the world. In a few countries, this seems to have been driven by a policy shock. This is clearest in the United States, where the Fed's weak response to monetary contraction was tightly linked with the unexpected death of Governor Benjamin Strong in October of 1928. As Friedman and Schwartz (1963) explain, Strong's successor "had neither the standing in the System nor the personal force to get his policy views accepted in the face of active opposition or even plain inertia" (p. 414). These policy shocks in turn led to sharply negative growth. In other countries, the monetary contraction stemmed not from policy changes, but from growth shocks in the form of gold outflow prompted by domestic and international disturbances (Eichengreen, 1992).

Thus, the early phase of the Great Depression can be seen, depending on the country, as either a negative policy shock that led to lower growth, or as a direct negative growth shock. Yet what is most interesting from the standpoint of the current paper's model is the endogenous response of ideas to the downturn (Higgs, 1987, pp. 159–195). In the United States, Schlesinger (1959) explains that "[F]aith in a free system was plainly waning. Capitalism, it seemed to many, had spent its force... The only hope lay in governmental leadership of a power and will which representative institutions seemed impotent to produce. Some looked enviously on Moscow, others on Berlin and Rome..." (p. 3). Bernanke (1995) observes that throughout the world, the depression "increased pressure on governments to intervene in the economy in

[15] I would like to thank an anonymous referee for this insight.

ways that inhibit adjustment" (p. 24). An array of counter-productive policies won new popularity: labor market regulations to keep nominal wages from falling, pro-union legislation to push real wages up, and industrial and agricultural policy to raise the price level by restricting production. Sensing political opportunities, politicians rapidly responded to the public's new ideas about effective economic policy. This began on a moderate scale during the Hoover administration, then rapidly expanded under Roosevelt. "The National Recovery Act, the cornerstone of Roosevelt's First New Deal, also contributed, perversely, to the slow recovery of American output and employment", explains Eichengreen. "By January 1934, 80 percent of American industry was covered. All of these codes established minimum wages of 40 cents an hour, and many revised upward the entire structure of industry wages" (1992, p. 344). Thus, it appears that sharply negative growth reduced the quality of ideas, policies worsened because politicians competitively responded to voter demand, and bad policies in turn retarded the recovery.

Similar developments may be found in France. As Eichengreen notes, many expected voter-driven policy change would be for the worse. "According to the opposition, investors feared that removal of the gold standard constraints, rather than permitting the adoption of sensible reflationary measures, opened the door for the Popular Front Government to pursue all manner of irresponsible fiscal and financial policies" (1992, p. 383). Even though France finally adopted reflationary policies to reverse the earlier monetary contraction, other new measures roughly offset their benefits. Bernanke (1995) provides an incomplete enumeration:

> Examples of interventionist measures by the French government included tough agricultural import restrictions and minimum grain prices, intended to support the nominal incomes of farmers (a politically powerful group of debtors); government-supported cartelization of industry, as well as import protection, with the goal of increasing prices and profits; and measures to reduce labor supply, including repatriation of foreign workers and the shortening of workweeks. These measures (comparable to New Deal-era actions in the United States) tended to block the downward adjustment of wages and prices (pp. 24–25).

It is unsurprising that bad growth led to a public demand for policy *change*. What is remarkable is the *sort* of the changes that won new favor. Public opinion regarding policies to inhibit market adjustment grew more favorable precisely when—due to the high unemployment rate and earlier decline in the money supply—they were most likely to be counter-productive. In contrast, there was weak political pressure for efficiency-*enhancing* courses governments might have taken instead. Commitment to reflation to reverse the monetary contraction was at most moderate; the political support for mandating large nominal wage cuts to adjust to the contracted money supply was non-existent.

3.2. Reform in Chile

The path of reform in Chile from 1970 to the present provides another interesting illustration. Under the Allende regime, policies that were at best shortsighted seemed

to win and even retain popular support (Sachs, 1990). Yet after the return to democracy, there was little voter demand to restore Allende's policies. If the policies were harmful to most Chileans, why were they adopted in the first place? If they were actually beneficial for most Chileans, why has democracy failed to revive them?

This is another instance where the "idea trap" provides a novel perspective. To begin with, it is noteworthy that in spite of the sharp deterioration of economic conditions in the final year of the Allende regime, its critics had little confidence that the next electoral cycle would lead to a decisive reversal of misguided populist policies. Instead, many expected a *perverse* political response to the crisis, with bad conditions becoming the excuse for more determined pursuit of failing policies. Some of these critics justified the Pinochet coup as a measure to pull out of this downward spiral: in Jose Piñera's words—"to prevent Chile from turning into another Cuba" (quoted in Stallings and Brock, 1993, p. 83).

Even after the coup, however, subsequent developments were surprising. Historically, there was no reason to expect a military government to favor free-market reforms. As Piñera (1994, p. 226) puts it, "In almost every case they [military governments] have increased the power and extended the reach of the state, while incidentally also enriching the ruling junta itself". The generals' decision to back the "Chicago Boys" and insulate them from rent-seeking pressures can thus be seen as a positive—and long-lasting—policy shock, with the link between public opinion and policy greatly attenuated by the suspension of democratic procedures (Barber, 1995). The quality of policy came to depend on the quality of ideas of a tiny minority of experts, rather than the quality of ideas of the general public.

Policies thus dramatically changed, with major shifts in monetary policy, price and trade liberalization, state ownership, and the pension system (Stallings and Brock, 1993). Admittedly, assessments of the success of the Chicago Boys' new policies vary, especially the hard-line version in place until 1982. But overall, even the critics acknowledge strong long-run benefits of their free-market reforms. Stallings and Brock (1993), for example, describe Chile's contemporary position as "uniquely favorable within Latin America—and perhaps even the Third World" (p. 78).

Probably the most interesting aspect of the Chilean experience has been the feedback from growth to events revealed after the return to democracy. The very fact that it took a dictatorship to implement economic reform might seem like a strong signal that economic reform was not in the interests of a majority of voters. But by this point, the political opposition campaigned only for marginal policy adjustments. The electoral backlash in 1988 was about the Chilean public's rejection of tarnished personalities, not the policies they had implemented. After Pinochet relinquished power to the newly elected government, policy changes were minor. Thus, during the era of the dictatorship, high economic growth won majority support for the new policies, even though Pinochet's advisors had deliberately ignored majority opinion when crafting the reform program. By bringing strong economic growth, the Chicago Boys' policies—which in 1973 had no serious prospect of ever happening under Chilean democracy—had become politically self-sustaining by 1988. As Piñera's observations about military governments indicate, dictatorships are rarely

a solution to the idea trap. But if a dictatorship for whatever reason pushes sensible economic policies, there is a good reason to be optimistic about an eventual return to democracy with prosperity.

4. Conclusions

The implications of this paper's model are probably less pessimistic than they appear. There is nothing about them that rules out rapid growth in *poor* countries. It does not feature a poverty trap, with poor countries destined to remain at a low-income level. Instead, the model implies a *growth* trap, into which rich countries as well as poor ones may fall. Thus, it is consistent with cases like that of Argentina, which began the century as one of the world's richest countries but enjoyed very slow growth in the post-war era (Di Tella and Dornbusch, 1989, pp. 1–2). If low growth lasts long enough, of course, poor countries will superficially appear to be stuck in "poverty", but bad policy will be the critical confounding variable.

The model is however more pessimistic than most of the literature that focuses on the link between low growth and bad policy. Even though poor, low-growth countries *could* mimic the success of Hong Kong or Singapore by copying their policies, it is endogenously unlikely that they will. Nevertheless, while favorable ideological shocks are random are far as countries are concerned, they might to some extent be seen as choice variables for the economics profession. As Harberger (1993) puts it, "[I]n every case of which I have close knowledge, the policy would in all likelihood have failed (or never got started) but for the efforts of a key group of individuals, and within that group, one or two outstanding leaders" (p. 343). Whether by influencing public opinion or directly changing the direction of policy, economists have the potential to jump start self-sustaining progress.

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Appendix A

Proof of Theorem 2: Using Eqs. (1)–(3), it can be seen by inspection that none of the 26 other candidate SSE are in fact SSE. □

Table A1

Candidate SSE (G_t,P_t,I_t)	$\alpha_1 G_t + \beta_1 P_t, \alpha_2 P_t + \beta_2 I_t, \alpha_3 I_t + \beta_3 G_t$	$f(\cdot)$	SSE?
Group 1			
(1,1,1)	$\alpha_1 + \beta_1, \alpha_2 + \beta_2, \alpha_3 + \beta_3$	(1,1,0)	no
(1,1,0)	$\alpha_1 + \beta_1, \alpha_2, \beta_3$	(1,1, − 1)	no
(1,1, − 1)	$\alpha_1 + \beta_1, \alpha_2 - \beta_2, -\alpha_3 + \beta_3$	(1,0, − 1)	no
(1,0, − 1)	$\alpha_1, -\beta_2, -\alpha_3 + \beta_3$	(1, − 1, − 1)	no
(1, − 1, − 1)	$\alpha_1 - \beta_1, -\alpha_2 - \beta_2, -\alpha_3 + \beta_3$	(0, − 1, − 1)	no
(0, − 1, − 1)	$-\beta_1, -\alpha_2 - \beta_2, -\beta_3$	(− 1, − 1, − 1)	no
(− 1, − 1, − 1)	$-\alpha_1 - \beta_1, -\alpha_2 - \beta_2, -\alpha_3 - \beta_3$	(− 1, − 1,0)	no
(− 1, − 1,0)	$-\alpha_1 - \beta, -\alpha_2, -\beta_3$	(− 1, − 1,1)	no
(− 1, − 1,1)	$-\alpha_1 - \beta_1, -\alpha_2 + \beta_2, \alpha_3 - \beta_3$	(− 1,0,1)	no
(− 1,0,1)	$-\alpha_1, \alpha\beta_2, \alpha_3 - \beta_3$	(− 1,1,1)	no
(− 1,1,1)	$-\alpha_1 + \beta_1, \alpha_2 + \beta_2, \alpha_3 - \beta_3$	(0,1,1)	no
(0,1,1)	$\beta_1, \alpha_2 + \beta_2, \beta_3$	(1,1,1)	no
Group 2			
(1,0,0)	$\alpha_1, 0, \beta_3$	(1,0, − 1)	no
(0,1,0)	$\beta_1, \alpha_2, 0$	(1,1,0)	no
(0,0,1)	$0, \beta_2, \alpha_3$	(0,1,1)	no
(− 1,0,0)	$-\alpha_1, 0, -\beta_3$	(− 1,0,1)	no
(0, − 1,0)	$-\beta_1, -\alpha_2, 0$	(− 1, − 1,0)	no
(0,0, − 1)	$0, -\beta_2, -\alpha_3$	(0, − 1, − 1)	no
(1,0,1)	$\alpha_1, \beta_2, \alpha_3, +\beta_3$	(1,1,0)	no
(− 1,0, − 1)	$-\alpha_1, -\beta_2, -\alpha_3, -\beta_3$	(− 1, − 1,0)	no
(1, − 1,0)	$\alpha_1 - \beta_1, -\alpha_2, \beta_3$	(0, − 1, − 1)	no
(0,1, − 1)	$-\beta_1, \alpha_2 - \beta_2, -\alpha_3$	(1,0, − 1)	no
(− 1,1,0)	$-\alpha_1 + \beta_1, \alpha_2, -\beta_3$	(0,1,1)	no
(0, − 1,1)	$-\beta_1, -\alpha_2 + \beta_2, \alpha_3$	(− 1,0,1)	no
Group 3			
(1, − 1,1)	$\alpha_1 - \beta_1, -\alpha_2 + \beta_2, \alpha_3 + \beta_3$	(0,0,0)	no
(− 1,1, − 1)	$-\alpha_1 + \beta_1, \alpha_2 - \beta_2, -\alpha_3 - \beta_3$	(0,0,0)	no

Proof of Theorem 4: Using Eqs. (1)–(3), it can be seen by inspection that none of the 24 other candidate SSE are in fact SSE. □

Table A2

Candidate SSE (G_t,P_t,I_t)	$\alpha_1 G_t + \beta_1 P_t, \alpha_2 P_t + \beta_2 I_t, \alpha_3 I_t + \beta_3 G_t$	$f(\cdot)$	SSE?
Group 1			
(1,0,0)	$\alpha_1, 0, \beta_3$	(1,0,1)	no
(0,1,0)	$\beta_1, \alpha_2, 0$	(1,1,0)	no
(0,0,1)	$0, \beta_2, \alpha_3$	(0,1,1)	no
(− 1,0,0)	$-\alpha_1, 0, -\beta_3$	(− 1,0, − 1)	no
(0, − 1,0)	$-\beta_1, -\alpha_2, 0$	(− 1, − 1,0)	no
(0,0, − 1)	$0, -\beta_2, -\alpha_3$	(0, − 1, − 1)	no
Group 2			
(1,1,0)	$\alpha_1 + \beta_1, \alpha_2, \beta_3$	(1,1,1)	no
(1,0,1)	$\alpha_1, \beta_2, \alpha_3 + \beta_3$	(1,1,1)	no

Table A2 (*continued*)

Candidate SSE (G_t,P_t,I_t)	$\alpha_1 G_t + \beta_1 P_t, \alpha_2 P_t + \beta_2 I_t, \alpha_3 I_t + \beta_3 G_t$	$f(\cdot)$	SSE?
Group 2			
(0,1,1)	$\beta_1, \alpha_2 + \beta_2 + \beta_3$	(1,1,1)	no
(− 1, − 1,0)	$-\alpha_1 - \beta, -\alpha_2, -\beta_3$	(− 1, − 1, − 1)	no
(− 1,0, − 1)	$-\alpha_1, -\beta_2, -\alpha_3, -\beta_3$	(− 1, − 1, − 1)	no
(0, − 1, − 1)	$-\beta_1, -\alpha_2 - \beta_2, -\beta_3$	(− 1, − 1, − 1)	no
Group 3			
(1,1, − 1)	$\alpha_1 + \beta_1, \alpha_2 - \beta_2, -\alpha_3 + \beta_3$	(1,0,0)	no
(1, − 1,1)	$\alpha_1 - \beta_1, -\alpha_2 + \beta_2, \alpha_3 + \beta_3$	(0,0,1)	no
(− 1,1,1)	$-\alpha_1 + \beta_1, \alpha_2 + \beta_2, \alpha_3 - \beta_3$	(0,1,0)	no
(− 1, − 1,1)	$-\alpha_1 - \beta_1, -\alpha_2 + \beta_2, \alpha_3 - \beta_3$	(− 1,0,0)	no
(− 1,1, − 1)	$-\alpha_1 + \beta_1, \alpha_2 - \beta_2, -\alpha_3 - \beta_3$	(0,0, − 1)	no
(1, − 1, − 1)	$\alpha_1 - \beta_1, -\alpha_2 - \beta_2, -\alpha_3 + \beta_3$	(0, − 1,0)	no
Group 4			
(1, − 1,0)	$\alpha_1 - \beta_1, -\alpha_2, \beta_3$	(0, − 1,1)	no
(1,0, − 1)	$\alpha_1, -\beta_2, -\alpha_3 + \beta_3$	(1, − 1,0)	no
(0,1, − 1)	$-\beta_1, \alpha_2 - \beta_2, -\alpha_3$	(1,0, − 1)	no
(− 1,1,0)	$-\alpha_1 + \beta_1, \alpha_2, -\beta_3$	(0,1, − 1)	no
(− 1,0,1)	$-\alpha_1, \alpha\beta_2, \alpha_3 - \beta_3$	(− 1,1,0)	no
(0, − 1,1)	$-\beta_1, -\alpha_2 + \beta_2, \alpha_3$	(− 1,0,1)	no

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