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Rates of adoption and compliance in dairy farming

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Introduction

Predicting the extent and rate of adoption by farmers of agricultural innovations is central to evaluating the benefits to be had from research, marketing and extension programs. It is also crucial to assessing the likely response of farmers to policies offering incentives for, or compelling, the use of particular agricultural technologies and practices.

In a previous paper we described an approach to predicting rates of adoption and compliance with respect to agricultural technologies and practices (Kaine and Wright 2015). The approach drew on the dual-process model of consumer decision-making and a method for classifying innovations in farm systems. The approach results in two-dimensional maps based on the complexity and relative advantage of agricultural practices or technologies.

The implications of the approach for predicting rates of adoption of innovations, and the role of incentives and extension in influencing those rates, were discussed using the economic concept of 'stickiness'. The implications of the approach for predicting rates of compliance with policies regulating the use of farm practices and technologies were also considered.

In this paper the results of testing this approach by conducting a survey of dairy farmers in the Waikato and Waipa are reported. We asked 200 farmers, chosen at random, about the complexity and relative advantage of various farm practices, and how long it took to try and then adopt them. The ideas and methods used here could be applied to any agricultural industry in any region.

Stickiness in the adoption of practices

Kaine and Wright (2015) proposed that the adoption of more complex innovations by farmers requires greater motivation, time and effort than does the adoption of simple innovations. The adoption of more complex innovations takes longer simply because they are inherently more difficult to understand and to integrate into the farm system (Kaine et al. 2012). The greater time and effort involved in adopting them means that their adoption involves greater overall costs and risks and is thus more sensitive to the strength of the motivation to adopt them. In other words, complex innovations are intrinsically 'stickier' than simple innovations: farmers will be more resistant to adopting (or being compelled to abandon) complex innovations than simpler innovations. Stickiness thus impacts on the speed of adoption or abandonment but not the ultimate extent.

These propositions have important implications for policies intended to promote change in farming technologies and practices. With respect to *voluntary* change, differences in the 'stickiness' of technologies and practices translate both into differences in the rate of their adoption and in the potential for incentives and extension to influence that rate (see Figure 1).

For example, differences in the rate of adoption of simple innovations will most likely reflect differences in the relative advantage they offer; that is, their superiority over current technology or practice. In these circumstances the role for extension is limited to raising awareness of the new practice. The rate of adoption of simple innovations is likely to be quite sensitive to the provision of incentives because simple innovations are relatively inexpensive and low risk. The rate of adoption of simple innovations with a large relative advantage will be 'swift': there will be minimal stickiness. The rate of adoption of simple innovations with a small relative advantage will be slower; their rate of adoption could be described as 'syrupy'. The syrupy nature of the adoption arises when, despite being easy to adopt, the relative advantage is so low that motivation to adopt is weak: a degree of indifference exists.

In contrast, differences in the rate of adoption of complex innovations will reflect differences in the time and effort involved, as well as differences in the relative advantage they offer. Complex innovations with a large relative advantage are 'sluggish': their rate of adoption may be relatively slow. Their complexity makes swift adoption less likely. The rate of adoption of complex innovations with a small relative advantage could be especially slow still; their adoption may even be 'stalled' permanently.

With respect to *compulsory* change, variations in the 'stickiness' of practices and technologies may translate into differences in the likelihood and intensity of opposition to a policy, differences in apparent compliance, differences in the rate of real compliance, and differences in the potential for incentives and extension to influence compliance (see Figure 2).

With regard to simple practices and technologies, the rate of compliance with a policy compelling their use (or their abandonment) is likely to be high while the likelihood and intensity of opposition to the policy is likely to be low. This will be especially so if the relative advantage of adoption (or cost of abandonment) of the change in practice or technology is small. In these circumstances, the role for extension is likely to be limited mainly to raising awareness of the policy. Compliance is likely to be 'swift'.

Compliance with respect to changing simple practices and technologies with a larger loss in relative advantage may be high, eventually, but could happen more slowly; could be more 'syrupy'. The greater the loss in relative advantage, the greater will be the motivation to delay compliance. The rate of compliance and degree of opposition to the policy is likely to be quite sensitive to the provision of incentives, particularly where the change in practice or technology entails a substantial loss in relative advantage.

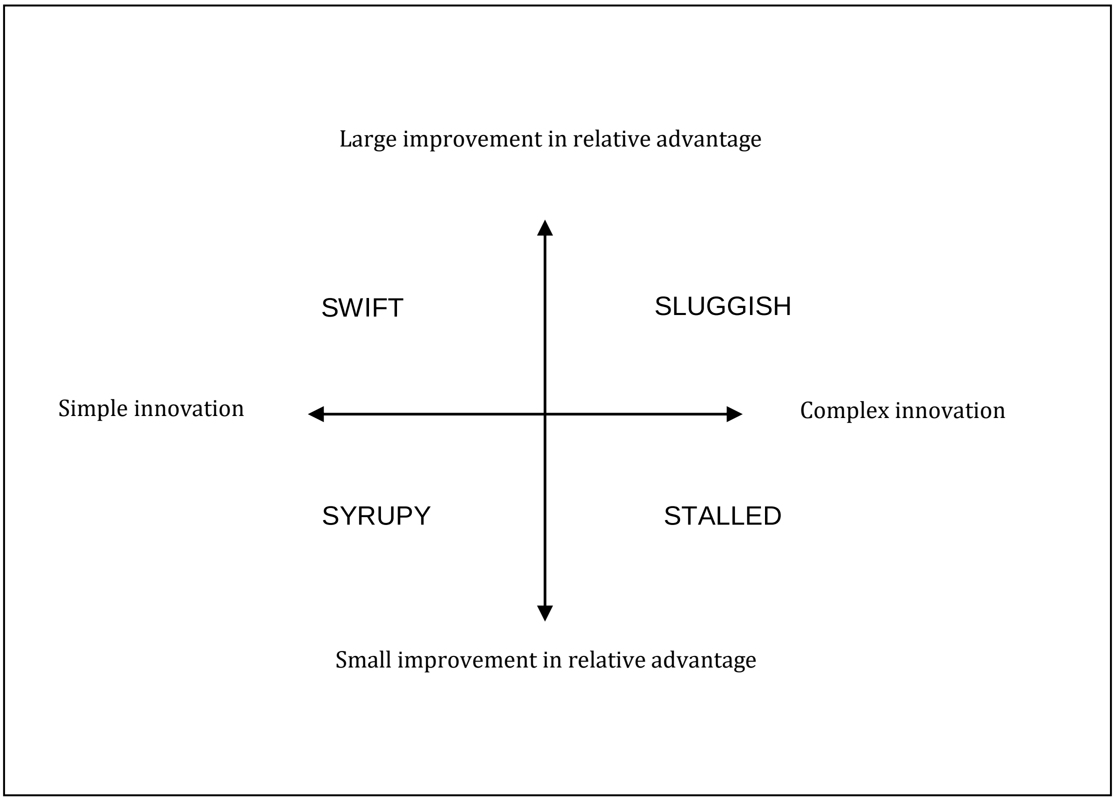

Figure 1: Stickiness in the rate of adoption

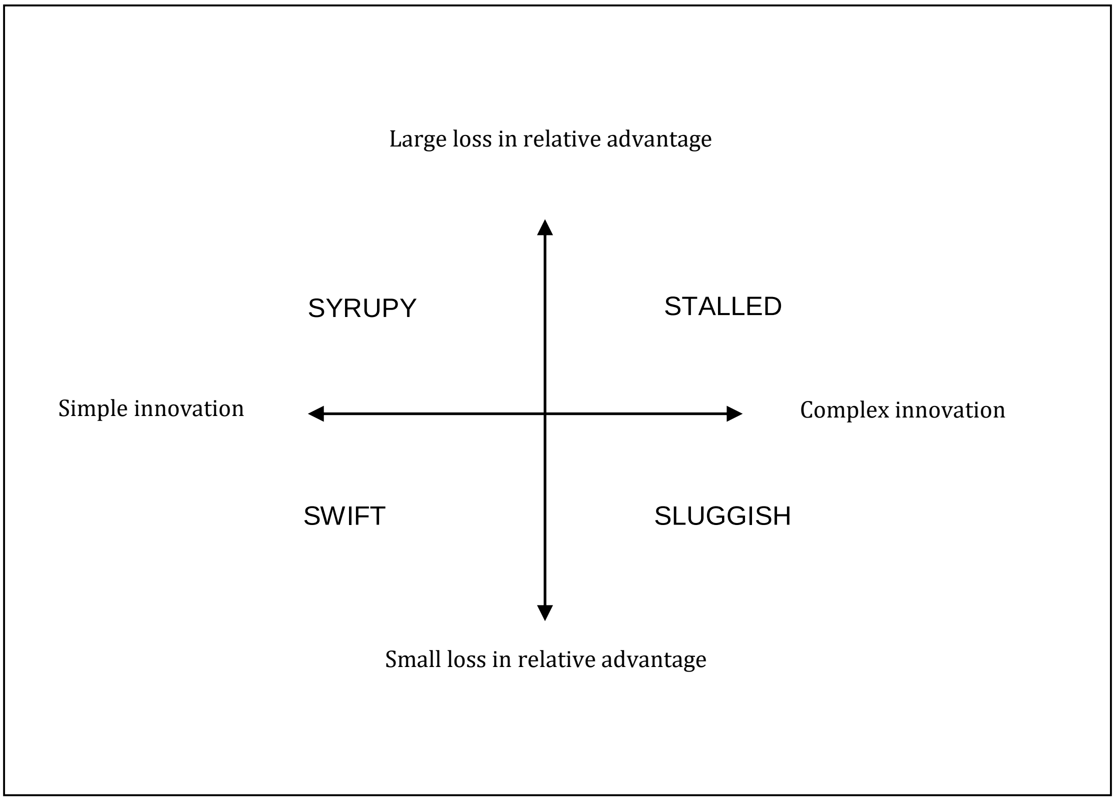

Figure 2: Stickiness in the rate of compliance

With regard to changing complex practices and technologies, the rate of compliance with a policy compelling their use (or their abandonment) is likely to be lower than with simple practices and technologies. Furthermore, the likelihood and intensity of opposition to the policy is likely to be higher. This will be especially so if the loss in relative advantage resulting from changing the practice or technology is large.

Compliance with respect to changing complex practices and technologies with a small loss in relative advantage is likely to be moderate but ‘sluggish’. Compliance with respect to changing complex practices and technologies with a large loss in relative advantage will be low and ‘stalled’.

The greater the emotional investment in originally adopting a complex innovation, and the relative advantage it offered, the correspondingly stronger the resistance to abandoning the innovation will be, and the greater the likelihood of outrage. Relatedly, where a policy compels adoption of a complex practice or technology, the greater the emotional investment in adopting that innovation, and the smaller the relative advantage it offers, the correspondingly stronger the resistance to using the innovation will be, and the greater the likelihood of opposition, even outrage.

In these circumstances, farmers will seek to block or modify the policy, or delay its implementation. They will seek ways of appearing to comply with the letter of the policy while avoiding complying with its intent.

Methods

To test these propositions we conducted a survey of farmers. While budget and time considerations meant that the survey was limited to investigating dairy technologies and practices in the Waikato and Waipa regions, the ideas and methods used here could be applied to any agricultural industry in any region.

Interviewees identified a technology or practice from Table 1 that they had adopted.[1] They were then asked in relation to that technology or practice to rate their agreement with the statements in each scale using the following categories: strongly disagree, disagree, not sure, agree and strongly agree.[2] Interviewees were also asked to indicate the period of time from when they first heard about the technology or practice till they decided to try it, and the period of time between first trying the technology or practice and finally committing to using it.

Interviewees were then requested to answer the same set of questions in relation to a technology or practice that they identified from Table 2. Finally, interviewees were asked to provide information on their property area, size of milking herd, age, education, and years in dairy farming.

The questionnaire used in the survey was based on Kaine et al. (2012) and was piloted using a mix of face-to-face and telephone interviews with 21 randomly selected Waikato and Waipa dairy farmers. Following some minor revisions, a market research company administered the final version of the questionnaire by telephone to 180 randomly selected Waikato and Waipa dairy farmers.

The questionnaire contained scales intended to measure:[3]

- The **relative advantage** of technologies and practices (Rogers 2003);
- The **complexity** of technologies based on the difficulty of integrating the technology or practice into the farm system;
- The **novelty** of the technology (Gatignon et al. 2002);

[1] Using a randomised starting point, the list of technologies and practices in the table was read to interviewees until they identified a technology or practice they had adopted. That technology or practice was the subject for subsequent questioning. The same procedure was followed with respect to the technologies and practices in Table 2.

[2] For the data to be analysed the categories were assigned values 1=strongly disagree, 2=disagree, 3=not sure, 4=agree, 5=strongly agree.

[3] The terms in bold are the scale labels.

Table 1: Technologies and practices (a)

Technology or practice
New type of fertiliser
No longer apply nitrogen fertiliser in winter
Slow release nitrogen fertiliser
Cultivating along contours rather than up and down the slope
Fencing stock out of waterways or wetlands
New pasture varieties
Different breed of livestock
Round bale technology
Round bale silage
Artificial Insemination

Table 2: Technologies and practices (b)

Technology/practice
A feed pad
90 day effluent storage
Direct drilling of crops
Cut and carry pasture management
Increased land application area for effluent
Constructing a wetland
Grazing heifers off farm
Grazing cows off farm in winter
Growing a summer crop (e.g. chicory)
Different calving period (e.g. split calving)
Feeding palm kernel
Embryo transfer technology

- The impact of the technology or practice on the **architecture** of the farm system based on the extent to which adopting the technology or practice affected the management of various farm-sub-systems (Henderson and Clark 1990);
- The **stickiness** of the technology or practice based on the disruption and costs entailed in abandoning the technology or practice;
- The **anticipated emotions**, **anticipatory emotions** and affect towards **means** associated with the technology or practice (Bagozzi 2006a, b);
- The need to acquire **new skills** and knowledge to adopt the technology or practice (Gatignon et al. 2002);
- The role of **experience** in adopting the technology or practice; and
- The **decision effort** (the time and energy) invested in deciding to adopt the technology or practice (Bagozzi 2006a, b).

Results

Preliminary assessments of the internal consistency or reliability (Carmines and Zeller 1979) of the various scales are reported in Table 3. The estimated reliabilities are satisfactory for the most part, especially for the scales measuring the key concepts of relative advantage, complexity and stickiness. The scales measuring anticipatory emotions and experience are relatively weak in these terms: we cannot be so sure that they measure only what we are seeking nor that they do so persistently from farmer to farmer.

In Table 4 the correlations between the structural scales are reported. All of the statistically significant correlations are of the expected sign, which is promising. As expected, relative advantage is correlated positively with stickiness, novelty, architecture, decision effort, new skills and knowledge, and experience.

Table 3: Scale reliabilities

Scale	Reliability*
Relative advantage	0.81
Complexity	0.84
Stickiness	0.71
Novelty	0.68
Architecture	Not applicable
Decision effort	0.77
New skills and knowledge	0.82
Experience	0.61
Anticipatory emotions	0.56
Anticipated emotions	0.82
Affect towards means	0.67

Note: * Reliabilities were estimated using Cronbach's Alpha (Carmines and Zeller 1979).

Table 4: Scale correlations (structural)

	Relative advantage	Complexity	Stickiness	Novelty	Architecture	Decision effort	New skills
Complexity	.04	-					
Stickiness	.55*	.06	-				
Novelty	.40*	.36*	.37*	-			
Architecture	.25*	.28*	.18*	.27*	-		
Decision effort	.24*	.30*	.17*	.33*	.24*	-	
New skills	.22*	.42*	.18*	.50*	.27*	.51*	-
Experience	.14*	.10*	.11*	.15*	.16*	.36*	.16*

Note: * indicates statistically significant, two-tailed correlation at the 0.05 level

Complexity is correlated positively with novelty, architecture, decision effort, new skills and knowledge, and experience. Complexity was not correlated with relative advantage, a reassuring result as the relative advantage of a technology or practice should relate to its superiority over the technology or practice it replaces, not its inherent complexity. Architectural change is correlated positively with decision effort, and new skills and knowledge. There is statistically significant correlation between novelty, decision effort, new skills and knowledge, and experience.

Stickiness is strongly correlated with relative advantage, as expected. While stickiness is not correlated with complexity, it is statistically significantly correlated with novelty and architecture; which are correlated with complexity. This suggests there is a non-linear relationship between stickiness and complexity: stickiness is slow to rise with complexity but then accelerates as complexity rises further. On the whole these results are as expected.

In Table 5 the correlations between the motivational scales are reported. As expected, the correlations between these scales are statistically significant and positive. Basically, the greater was respondents' satisfaction with means, the greater was their confidence that adoption would be successful, and the greater their emotional engagement with the outcome, be it success or failure. Also, the greater was respondents' confidence that adoption would be successful, the greater was their emotional engagement with the outcome.

In Table 6 the correlations between the structural and motivational scales are reported. All of the statistically significant correlations seem plausible, notably:

- Greater relative advantage is associated with greater satisfaction with means, greater confidence that adoption will be successful, and greater emotional engagement with the outcome, be it success or failure.

Table 5: Scale correlations (motivation)

	Affect towards means	Anticipatory emotions	Anticipated emotions
Anticipatory emotions	.46*	-	
Anticipated emotions	.49*	.28*	-

Note: * indicates statistically significant, two-tailed correlation at the 0.05 level

Table 6: Scale correlations (continued)

	Affect towards means	Anticipatory emotions	Anticipated emotions
Relative advantage	.49*	.19*	.50*
Complexity	-.41*	-.26*	-.11*
Stickiness	.19*	.09*	.42*
Novelty	-.01	-.12*	.28*
Architecture	.06	-.12*	.13*
Decision effort	.06	-.07	.18*
New skills	-.12*	-.24*	.18*
Experience	.18*	.22*	.26*

Note: * indicates statistically significant, two-tailed correlation at the 0.05 level

- Greater complexity is associated with lower satisfaction with means and less confidence that adoption will be successful, but greater emotional engagement with the outcome. The same pattern of associations applied with respect to the need for new skills and knowledge.
- The greater the stickiness of a technology or practice, the higher was satisfaction with the means of adoption and the greater was emotional engagement with the outcome. In other words, the greater was respondents' satisfaction with the process and outcomes of adopting a technology or practice, the greater the disruption they perceived would follow from having to abandon it.
- The greater the effort invested in deciding to adopt a technology or practice, the greater was emotional engagement with the outcome.
- The greater the novelty of the technology or practice, the less confident were respondents that adoption would be successful, but the greater was their emotional engagement with the outcome.
- Similarly, the greater the architectural impacts of adopting a technology or practice, the less confident respondents were that adoption would be successful, but the greater was their emotional engagement with the outcome.

The stickiness maps for the adoption of the various technologies and practices is presented in Figures 3 through 18.[4] Overall, the placement of technologies and practices across the quadrants seems reasonable, with an inspection of the figures revealing that most of the technologies and practices were classified into the 'swift' or 'sluggish' quadrants of the map indicating that they were low-to-high in complexity and medium-to-high in relative advantage.

[4] The axes are drawn at the average score for the sample.

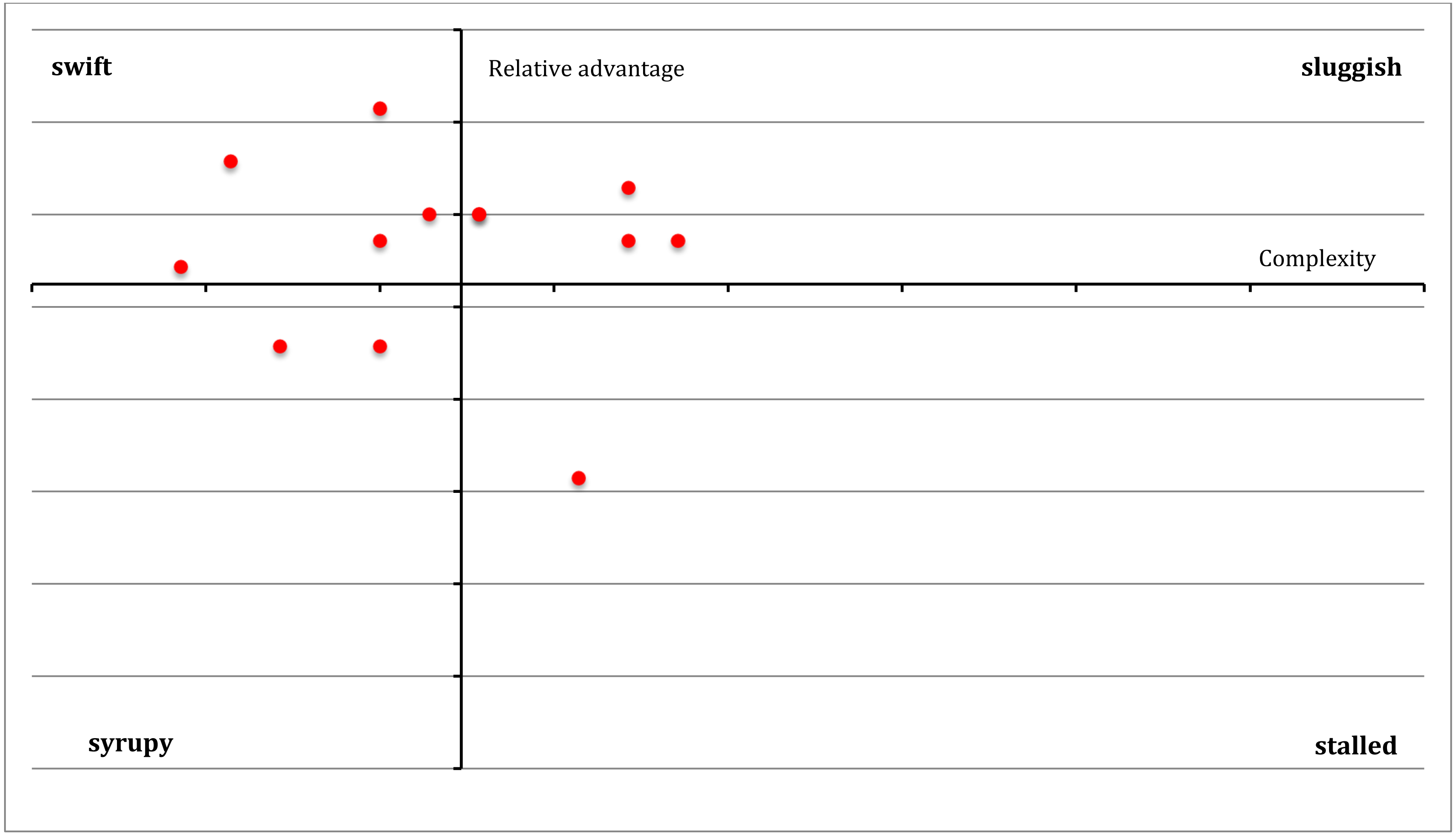

Figure 3: Stickiness in the adoption of a new type of fertiliser

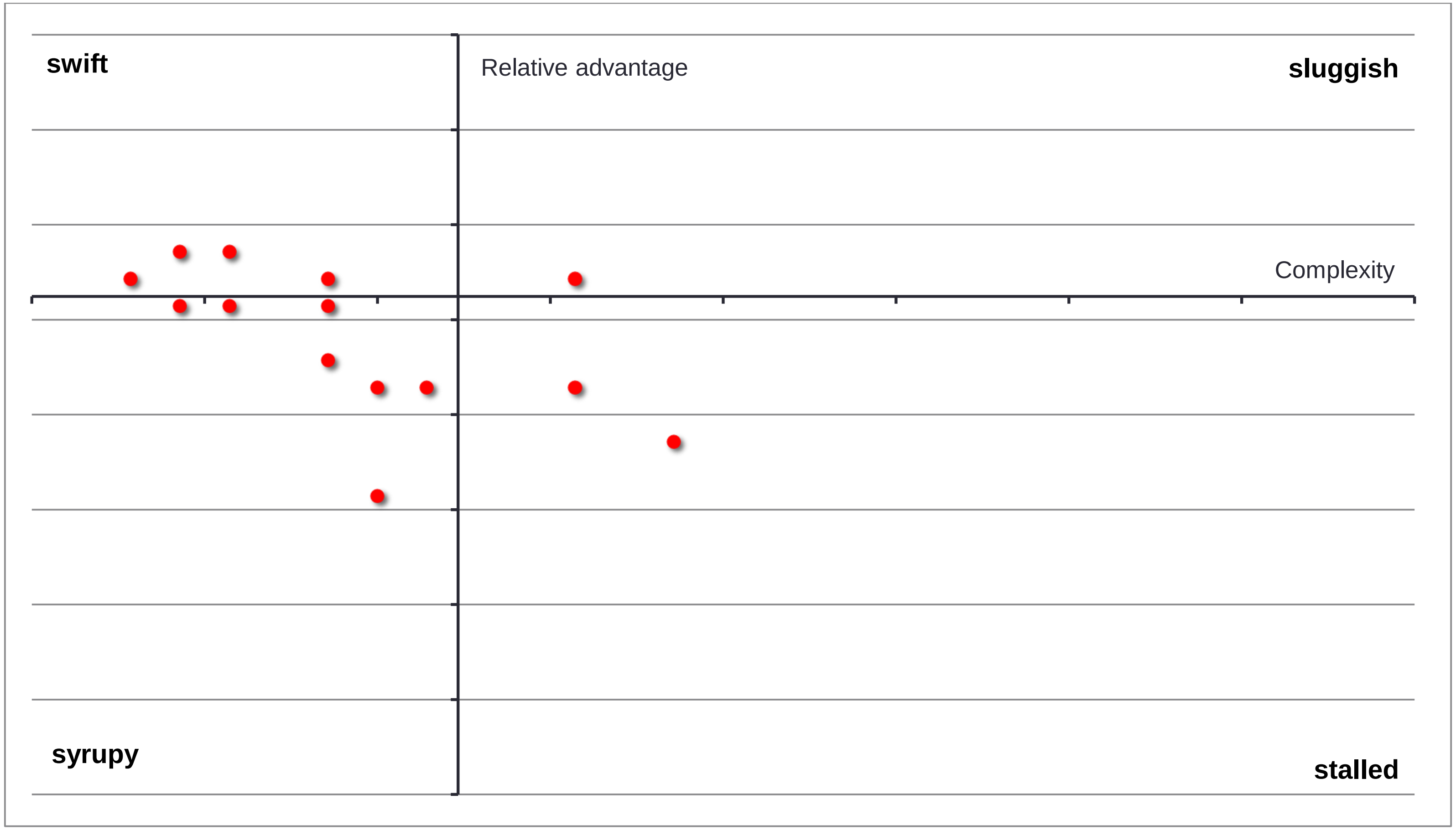

Figure 4: Stickiness in the adoption of slow release nitrogen fertilisers

Some more complex technologies and practices were placed in the 'sluggish' quadrant, most notably changing calving period, feedpads and (for some respondents) fencing stock out of waterways and wetlands. Not surprisingly, very few respondents had adopted technologies and practices that were placed in the 'stalled' quadrant, the exceptions being discontinuing applying nitrogen fertiliser in winter (Figure 5) and, for some respondents, fencing stock out of waterways and wetlands (Figure 18).

Overall, the placement of technologies and practices, relative to each other, seems plausible with manifestly simpler technologies and practices placed in the swift or syrupy quadrants and the more obviously complex technologies and practices placed in the syrupy and sluggish quadrants. For example, intuitively simpler technologies, such as slow release fertilisers (Figure 4), a new pasture variety (Figure 6) or a new breed of cattle (Figure 7), are primarily placed in the left hand quadrants whereas patently more complex technologies and practices, such as changing calving period (Figure 8) and installing feed pads (Figure 15), tend to be placed in the right hand quadrants. For example, the mean scores for complexity and architecture were statistically significantly lower for adopting slow release fertiliser than for installing feed pads or changing calving pattern (see Table 7).

More formally, actions that involve switching among similar forms of a particular farm input, such as adopting a new type of fertiliser (Figure 3), pasture variety (Figure 6) and purchased feed like palm kernel (Figure 12), were perceived as being simpler than actions which involve substitution between inputs, such as discontinuing applying nitrogen fertiliser (Figure 5) or reconfiguring the farm system by changing calving period (Figure 8). For example, mean scores for complexity and architecture were statistically significantly higher for changing calving period compared to adopting a new type of fertiliser, changing pasture variety or adopting palm kernel (see Table 7).

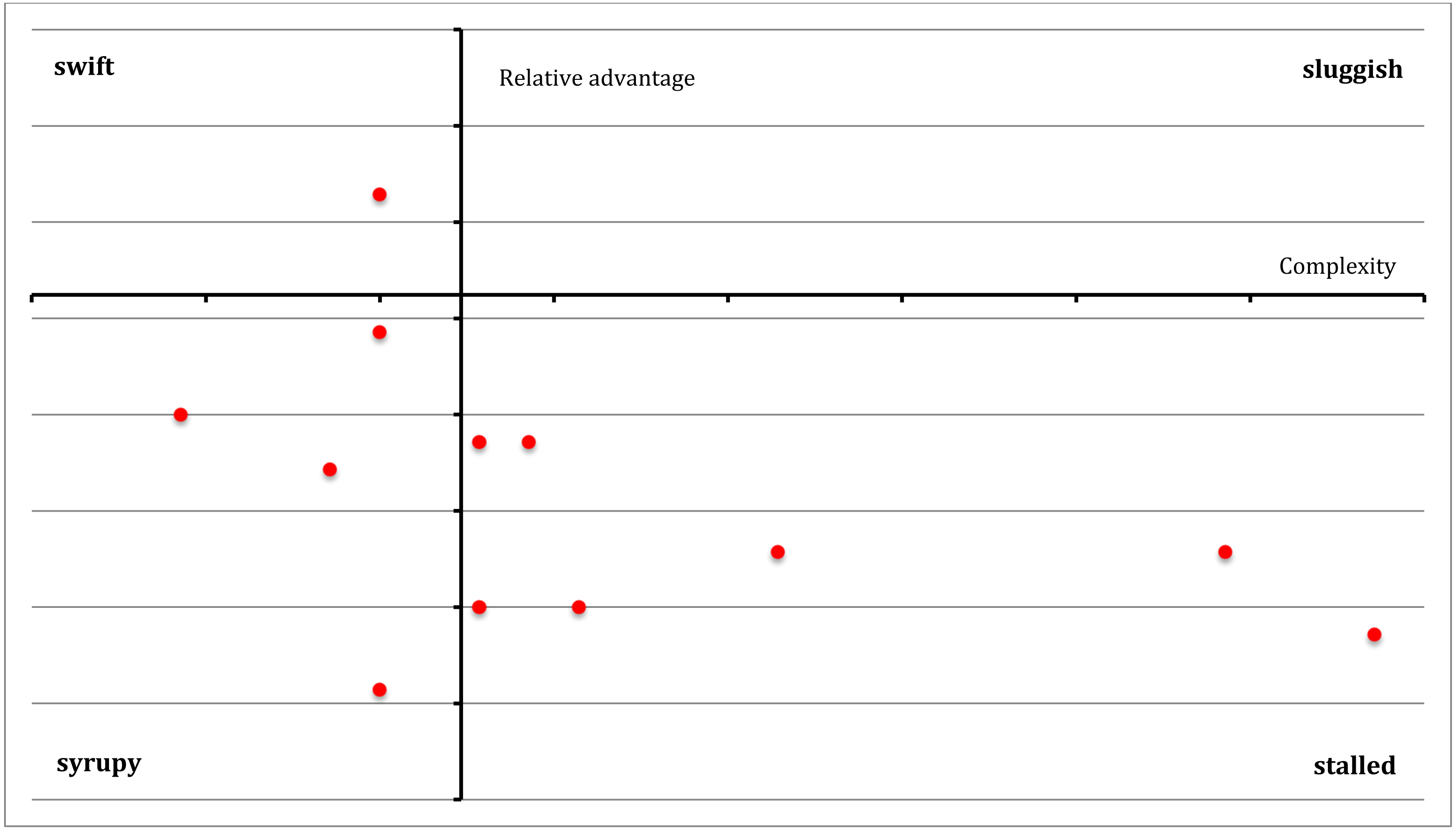

Figure 5: Stickiness in discontinuing nitrogen fertiliser in winter

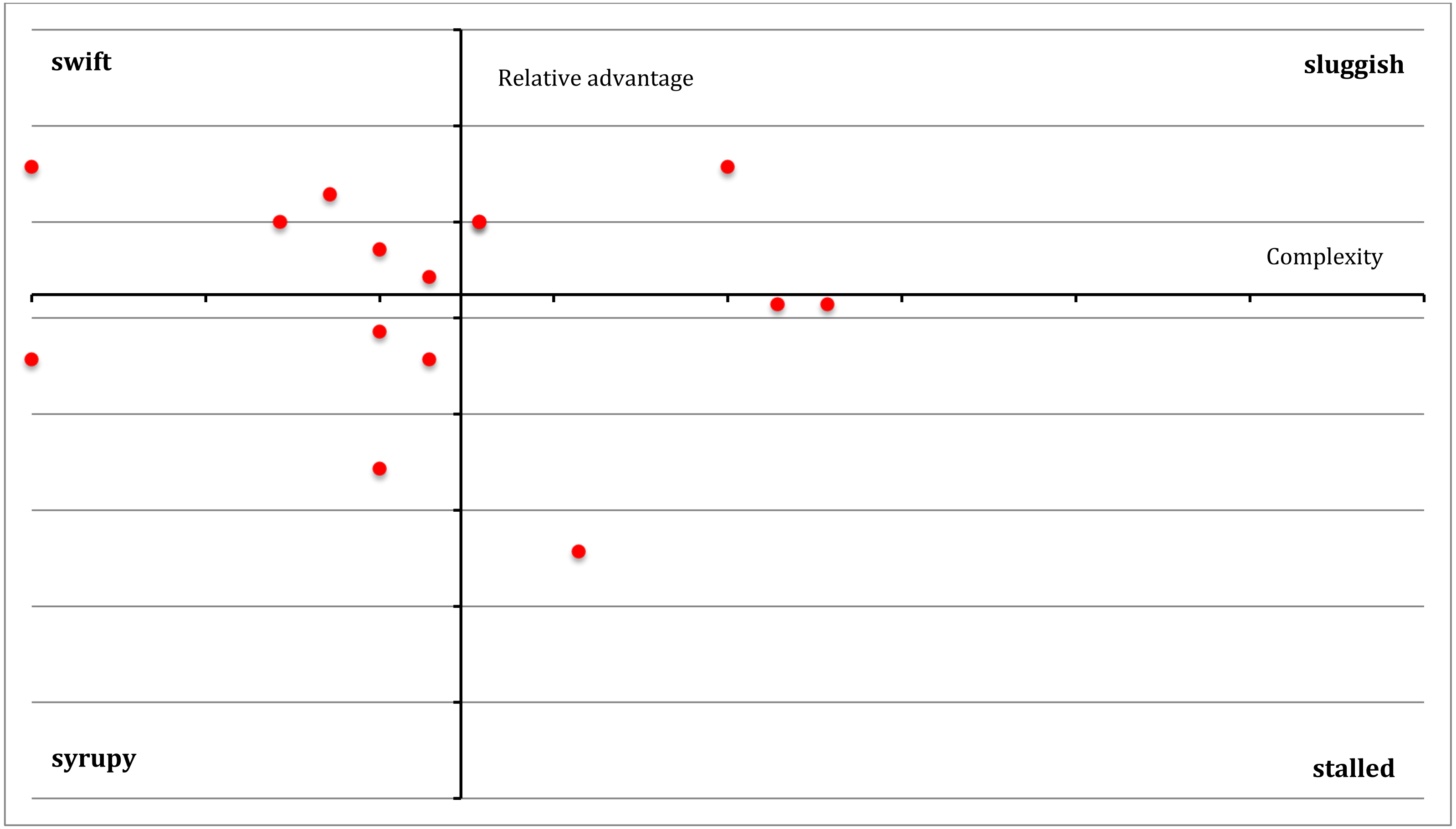

Figure 6: Stickiness in the adoption of a new pasture variety

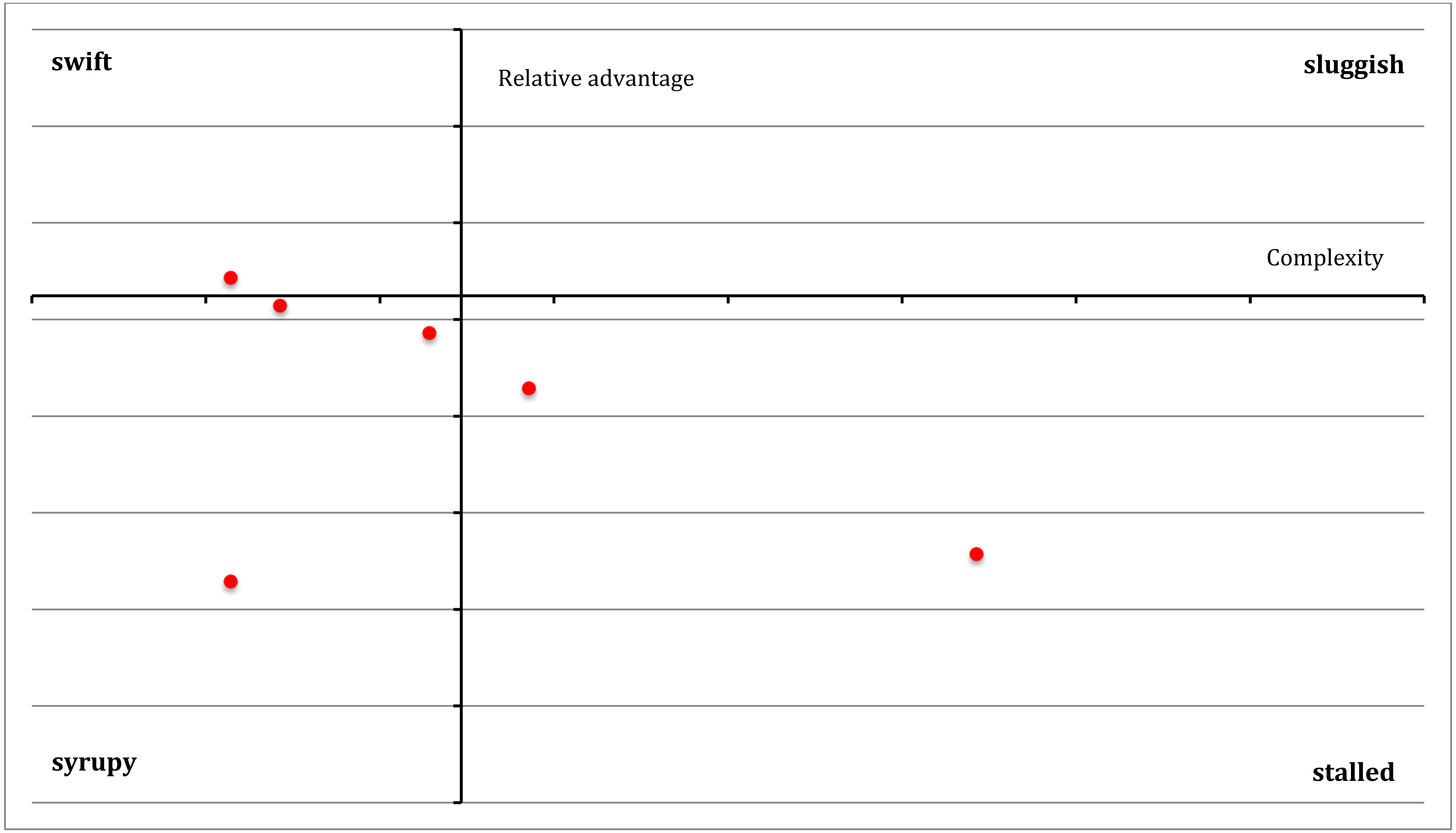

Figure 7: Stickiness in the adoption of a different breed of cattle

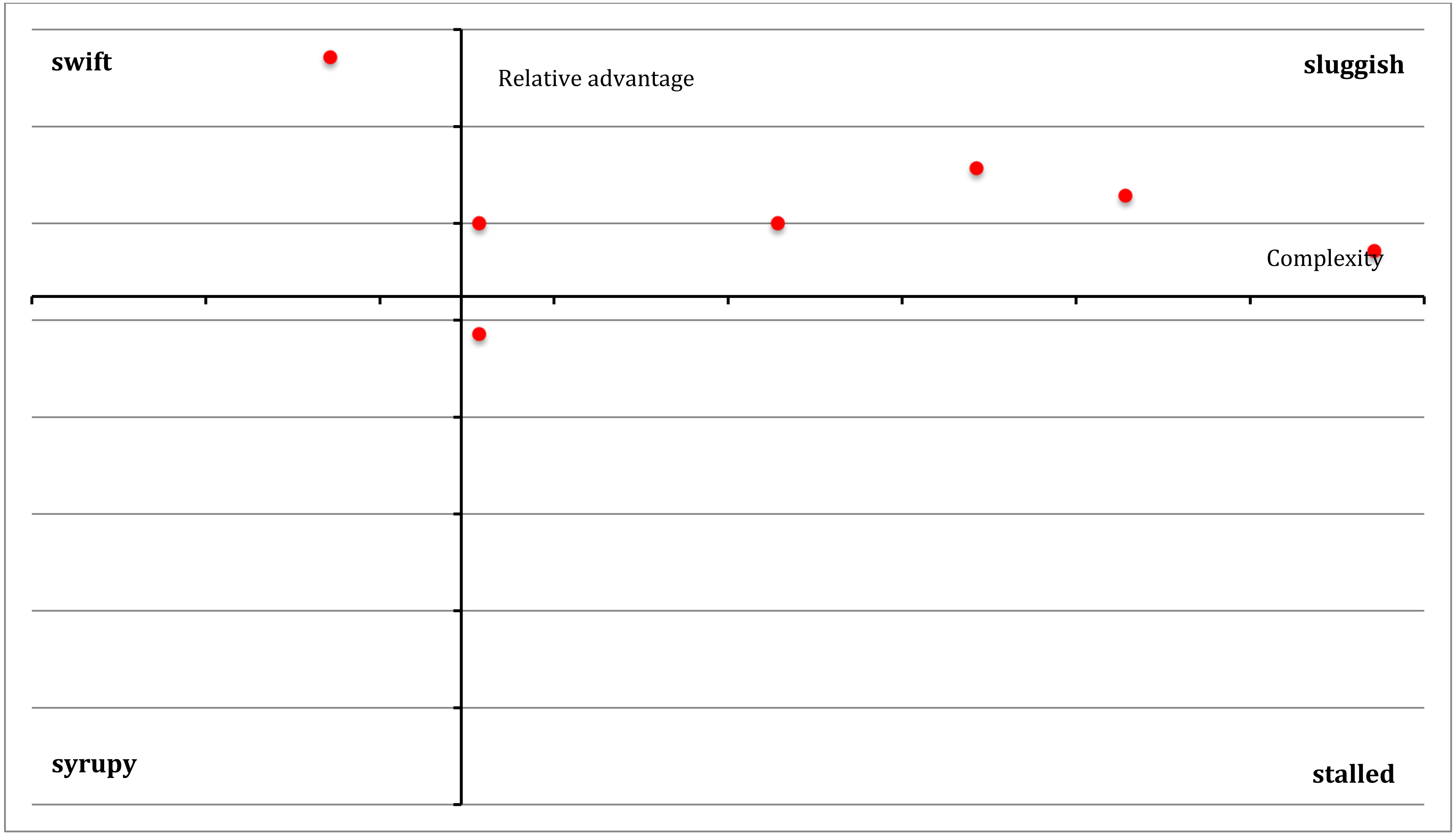

Figure 8: Stickiness in the adoption of a change in calving period

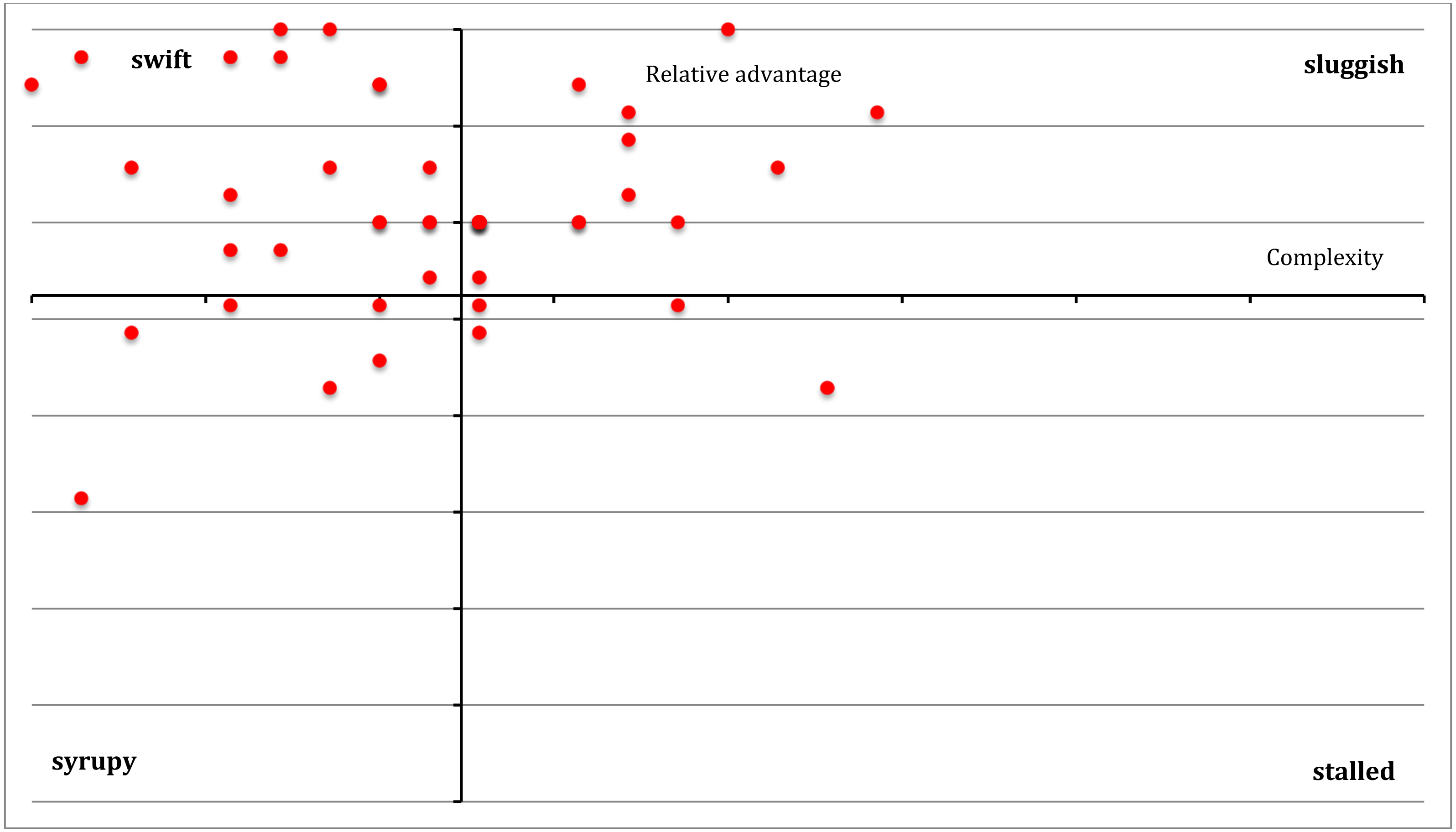

Figure 9: Stickiness in the adoption of artificial insemination

Table 7: Complexity of technologies and practices

	Relative advantage	Complexity	Novelty	Architecture	Stickiness
New type of fertiliser	3.80[c,f]	2.18[a]	3.23	2.98[a]	3.25[c,e]
Slow release fertiliser	3.41[a,b,c]	1.93[a,b,c]	3.05[a]	2.63[a,b]	3.00[a,b,c]
Discontinuing nitrogen in winter	2.58	2.61	2.63	2.58	2.29
New pasture variety	3.63[c,f]	2.16[a]	2.49[a]	2.87[a]	3.05[c]
Feeding palm kernel	3.92[c]	1.91[a,c]	2.81[a]	2.81[a]	3.57[c]
New livestock breed	3.05	2.19	2.67	2.73	3.08
Artificial insemination	4.09	2.14[a]	3.36	2.61[a]	3.41
Changing calving period	4.08	3.18	3.67	4.04	3.82
Feed pad	4.10	2.96	3.44	3.59	3.84
Effluent area	4.04	2.20	2.59	2.80	3.70
Effluent storage	3.48[d]	2.70[d]	3.25	2.56	3.50
Grazing heifers off-farm	3.77[b]	2.11[b]	2.61[b]	2.72[b]	3.38
Grazing cows off-farm	3.76	2.09[b]	2.67[b]	3.25	3.30

Notes: (a) Statistically significantly different from mean for changing calving period.
(b) Statistically significantly different from mean for installing feed pad.
(c) Statistically significantly different from mean for discontinuing winter nitrogen.
(d) Statistically significantly different from mean for spreading effluent over larger area.
(e) Statistically significantly different from mean for new pasture variety.
(f) Statistically significantly different from mean for changing cattle breed.

Interestingly, respondents viewed adopting artificial insemination (Figure 9) as less complex than changing calving period (Figure 8). The adoption of artificial insemination may be viewed as input substitution, straw technology replacing bulls, but with the nutritional and health management of heifers and cows largely unchanged. Hence, the adoption of artificial insemination may be interpreted as a modular change in terms of innovation type (Henderson and Clark 1990, Kaine et al. 2008).

In contrast, changing calving period entails reconfiguring breeding, pasture, feed and health management. Therefore, the latter may be interpreted as an architectural change in terms of innovation type, a qualitatively more complicated change to implement successfully. Supporting this interpretation, the mean scores for complexity and architecture were statistically significantly higher for changing calving period compared to adopting artificial insemination.

The placement of installing a 90-day effluent storage (Figure 17) relative to increasing the area over which effluent is spread (Figure 16) may be explained as follows. Expanding the area over which effluent is spread could be interpreted as an incremental innovation (Henderson and Clark 1990) because it is likely to involve little more than minor upgrading of farm infrastructure. Installing a 90-day effluent storage pond, in contrast, could be interpreted as a modular innovation (Henderson and Clark 1990) because it is likely to entail a major upgrade of existing infrastructure. Supporting this interpretation, the mean scores for complexity were statistically significantly higher for changing calving period compared to increasing the area over which effluent is spread; but not the scores for architecture.

In terms of adopting different forms of an input, the adoption of a new pasture variety (Figure 6) appears equally simple as changing to a new type of fertiliser (Figure 3). The simplicity of adopting a new breed of cattle (Figure 7) appeared to match that of changing fertiliser type or pasture variety, as well. However, the relative advantage offered by adopting a new breed of cattle was lower than for changing fertiliser type or for changing pasture variety. For example, the mean scores for relative advantage were statistically significantly higher for adopting a new type of fertiliser or pasture variety compared to adopting a new breed of cattle.

The adoption of round bale technology and round bale silage (Figure 10) is interesting as there is a markedly large variation in respondents' perceptions of the relative advantage offered by this technology, but the variation in their perceptions of its complexity was comparable to other technologies and practices. This suggests that the relative advantage offered by this technology was highly sensitive to differences in farm contexts (Kaine et al. 2007; Kaine and Bewsell 2008; Kaine et al. 2011).

The unusual degree of variation in respondents' perceptions of the complexity and relative advantage of fencing to keep stock out of waterways and wetlands (Figure 18) was striking. This suggests that both the relative advantage offered by this technology, and its complexity, were highly sensitive to differences in farm contexts (Kaine et al. 2007; Kaine and Bewsell 2008; Kaine et al. 2011). This seems reasonable as the benefits, costs and practicalities of fencing streams and lakes will vary across properties depending on topography and property layout (Bewsell et al. 2007).

A few observations can be made about the placement of the technologies and practices that may be employed to control the discharge into waterways of nutrients and sediment from farms:

- In regard to the use of fertilisers, inspection of Table 7 reveals that discontinuing the application of nitrogen fertiliser in winter (Figure 5) was perceived to be more complex, and offering a lower relative advantage, than switching to a slow release nitrogen fertiliser (Figure 4);
- In regard to effluent management, inspection of Table 7 reveals that installing a 90-day effluent storage pond (Figure 16) was perceived to be more complex, and offering a lower relative advantage, than expanding the area over which effluent was spread (Figure 17);

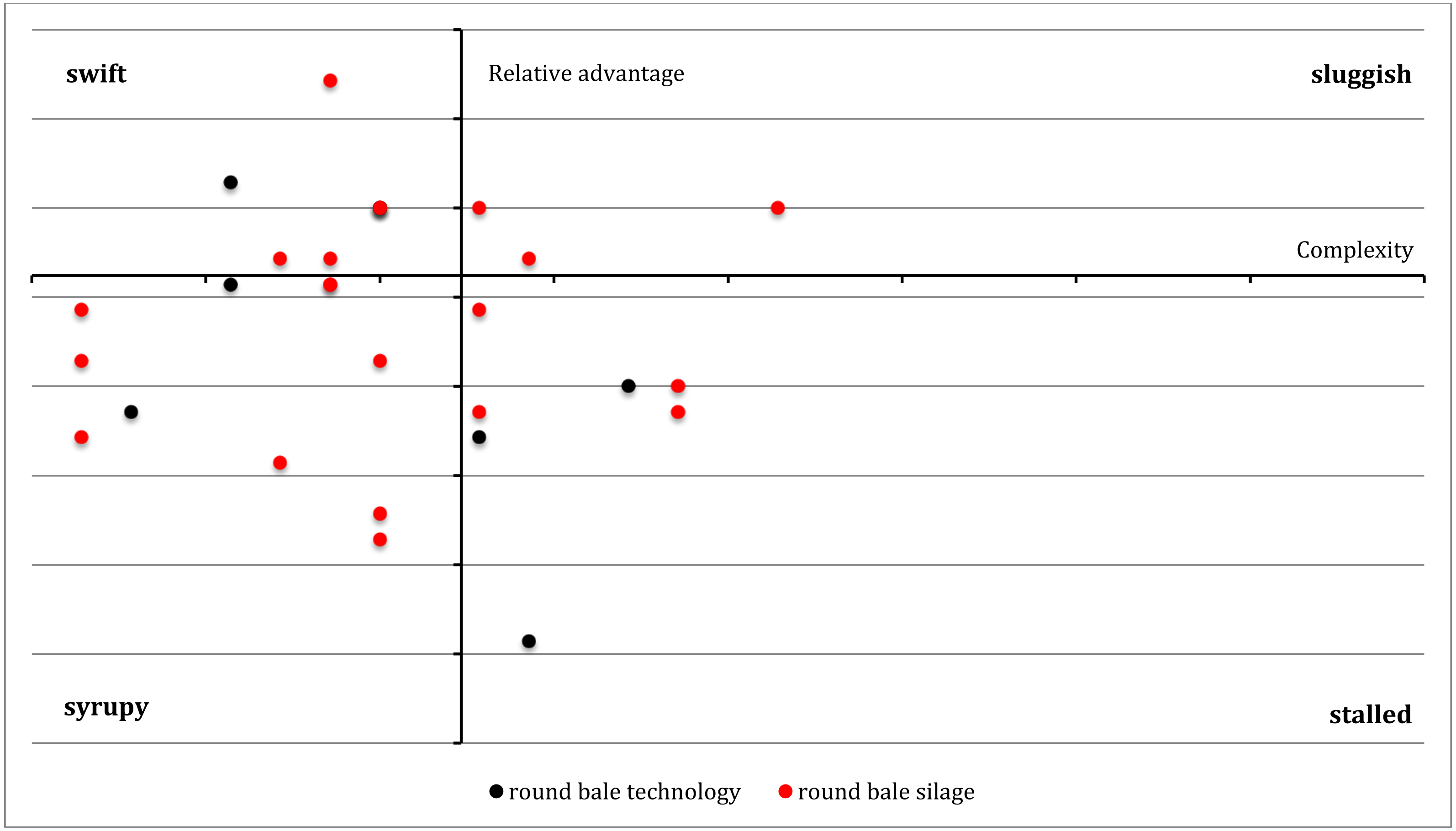

Figure 10: Stickiness in the adoption of round bale technology and round bale silage

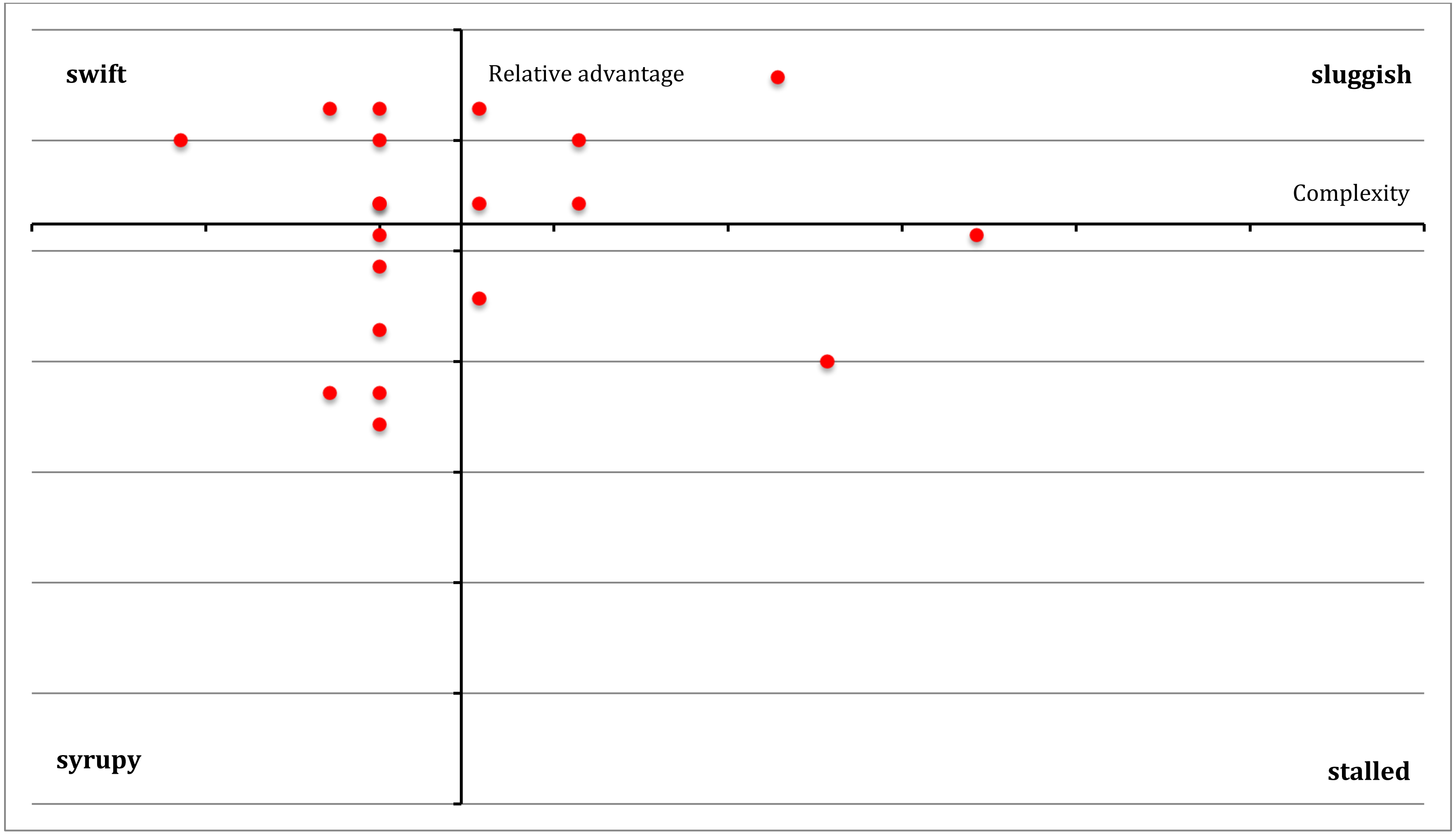

Figure 12: Stickiness in the adoption of palm kernel

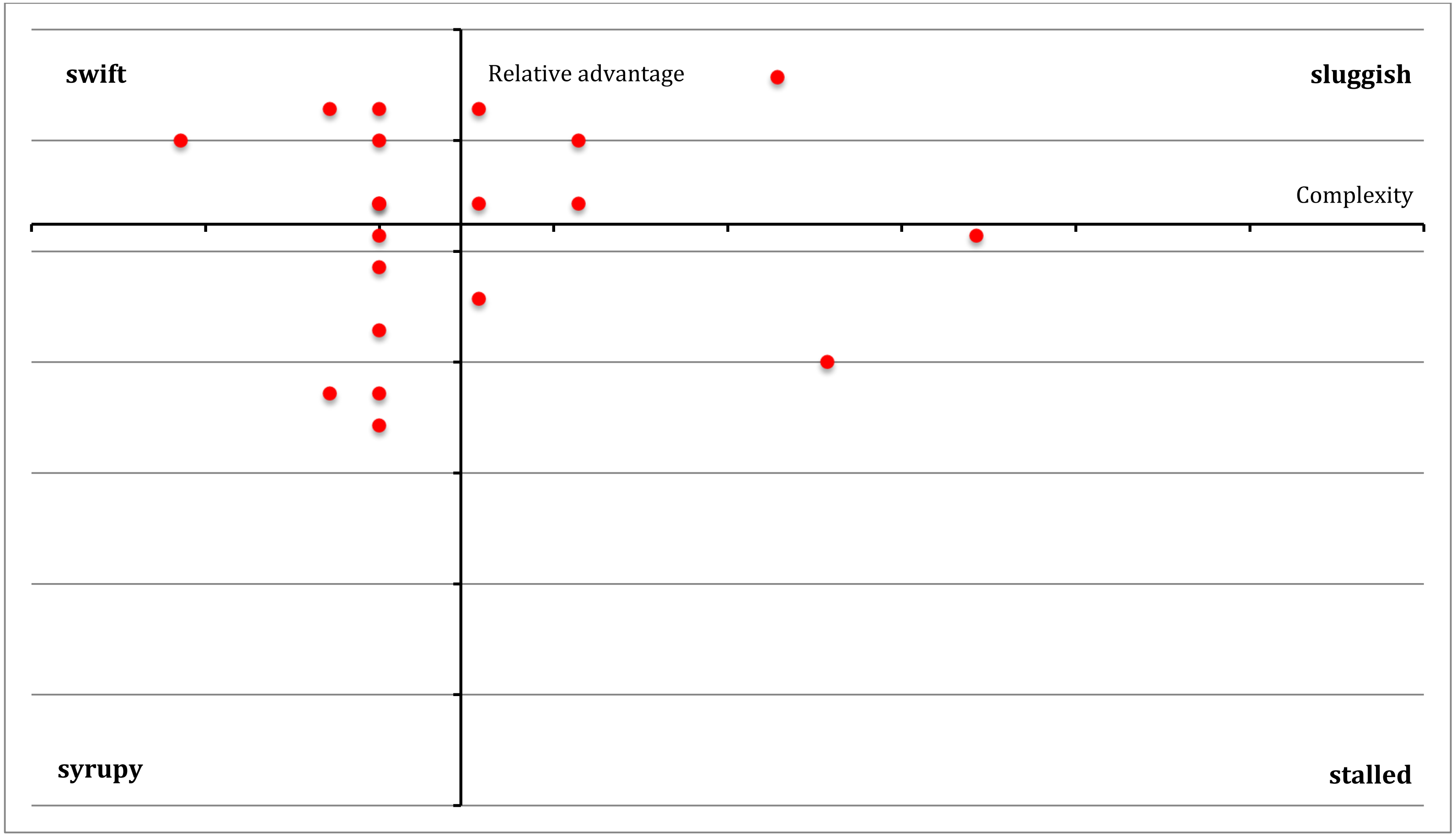

Figure 13: Stickiness in the adoption of a summer crop such as chicory

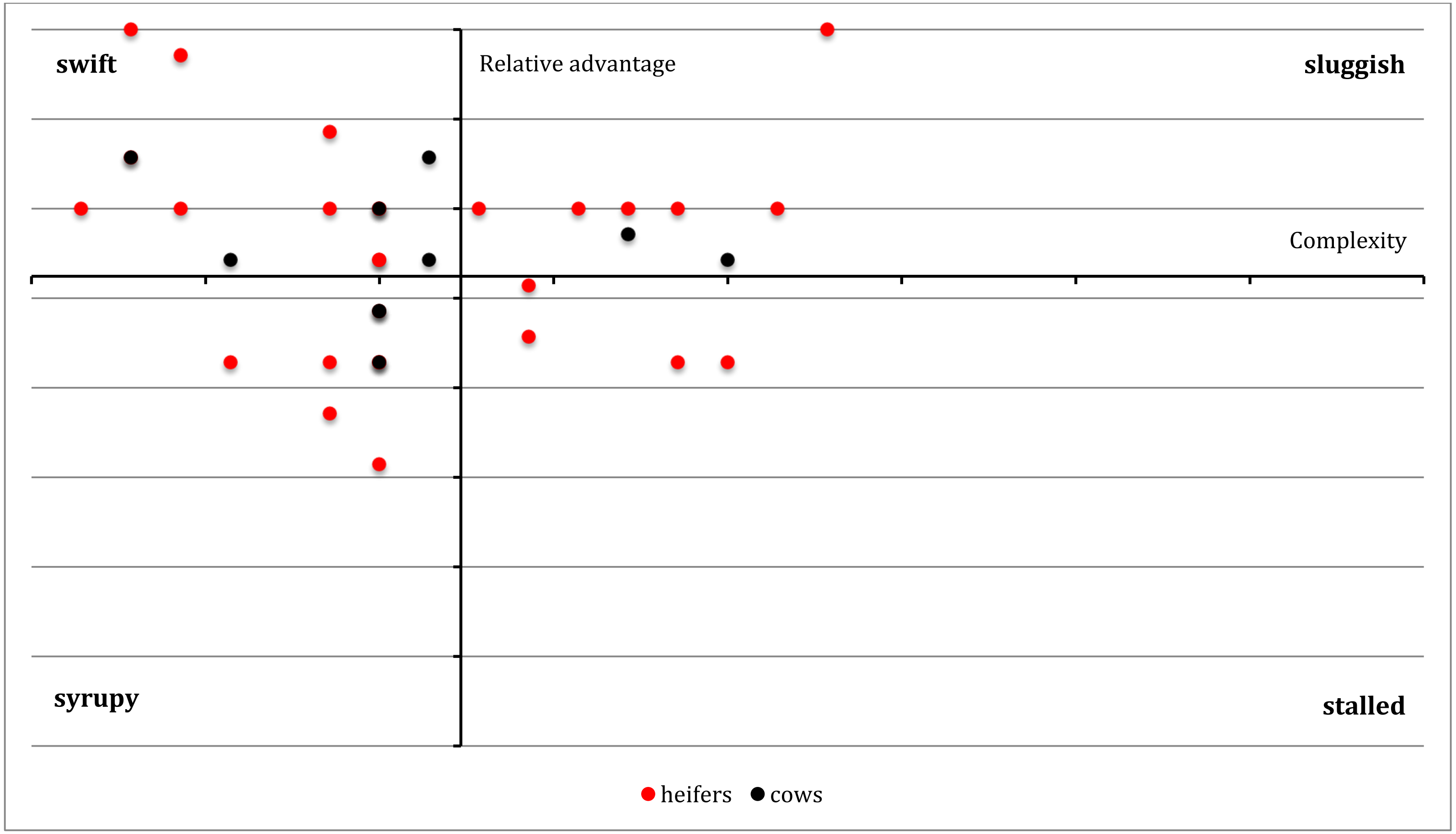

Figure 14: Stickiness in the adoption of off-farm grazing of heifers and cows

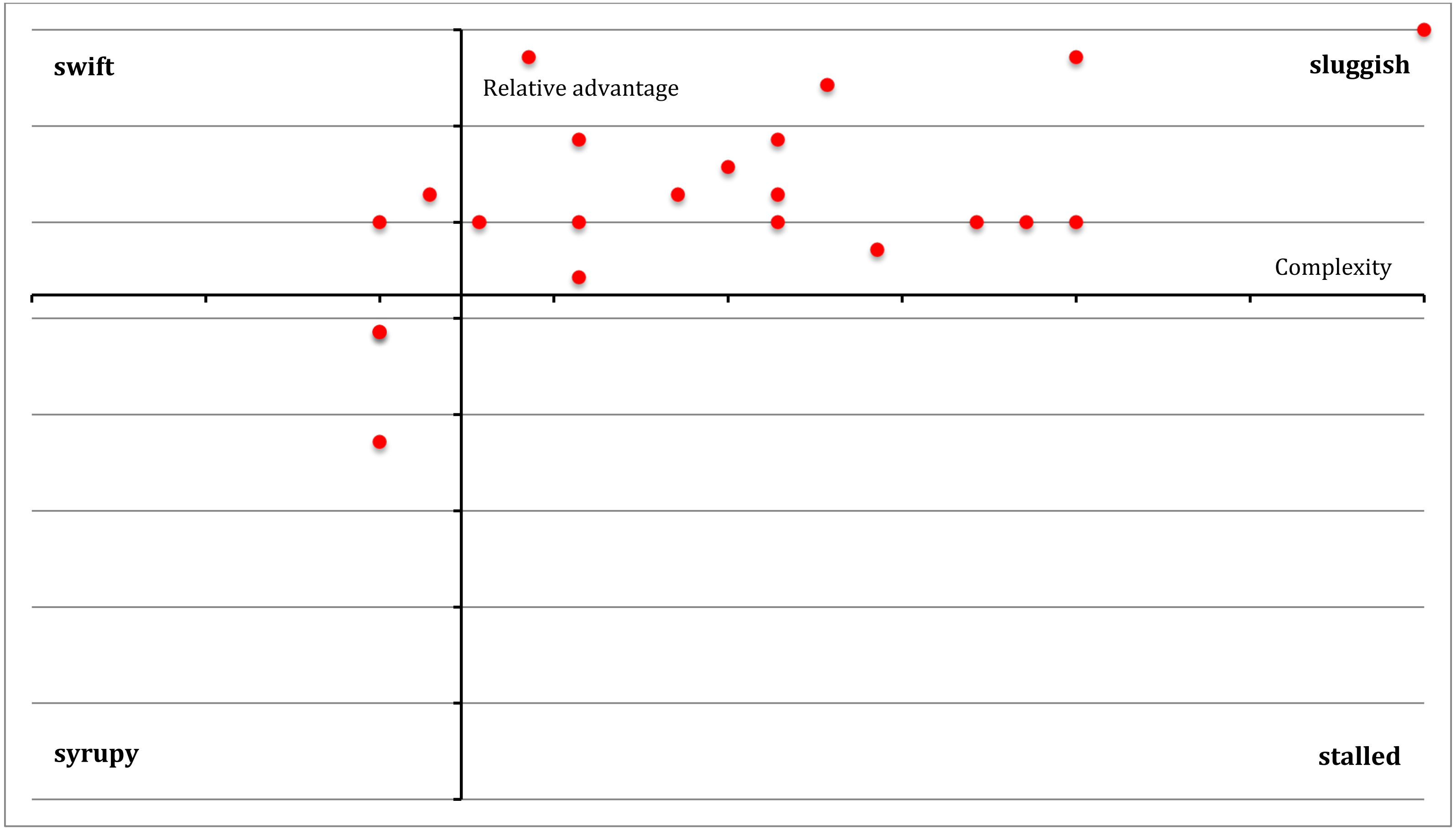

Figure 15: Stickiness in the adoption of feedpads

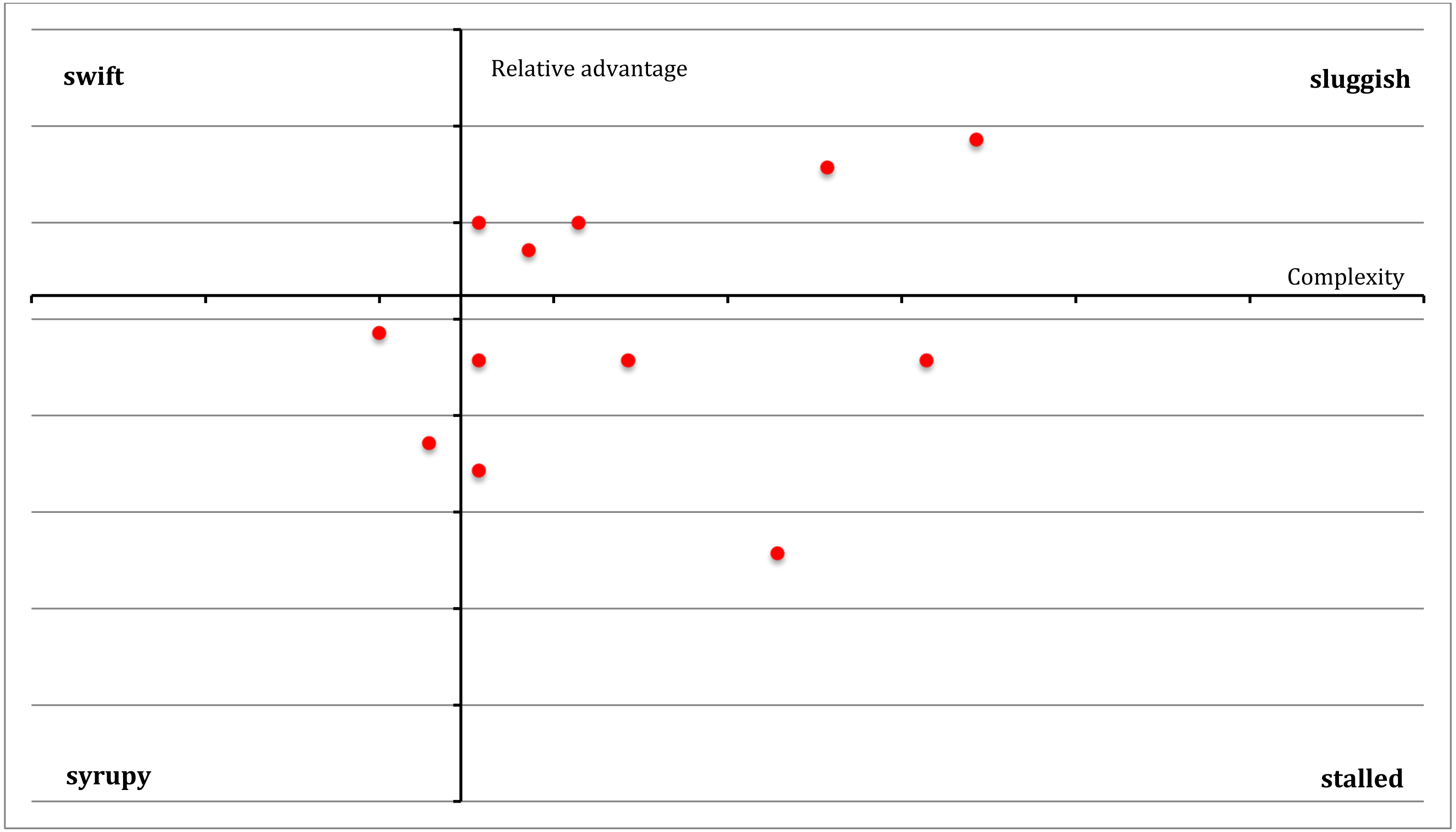

Figure 16: Stickiness in the adoption of 90-day effluent storage

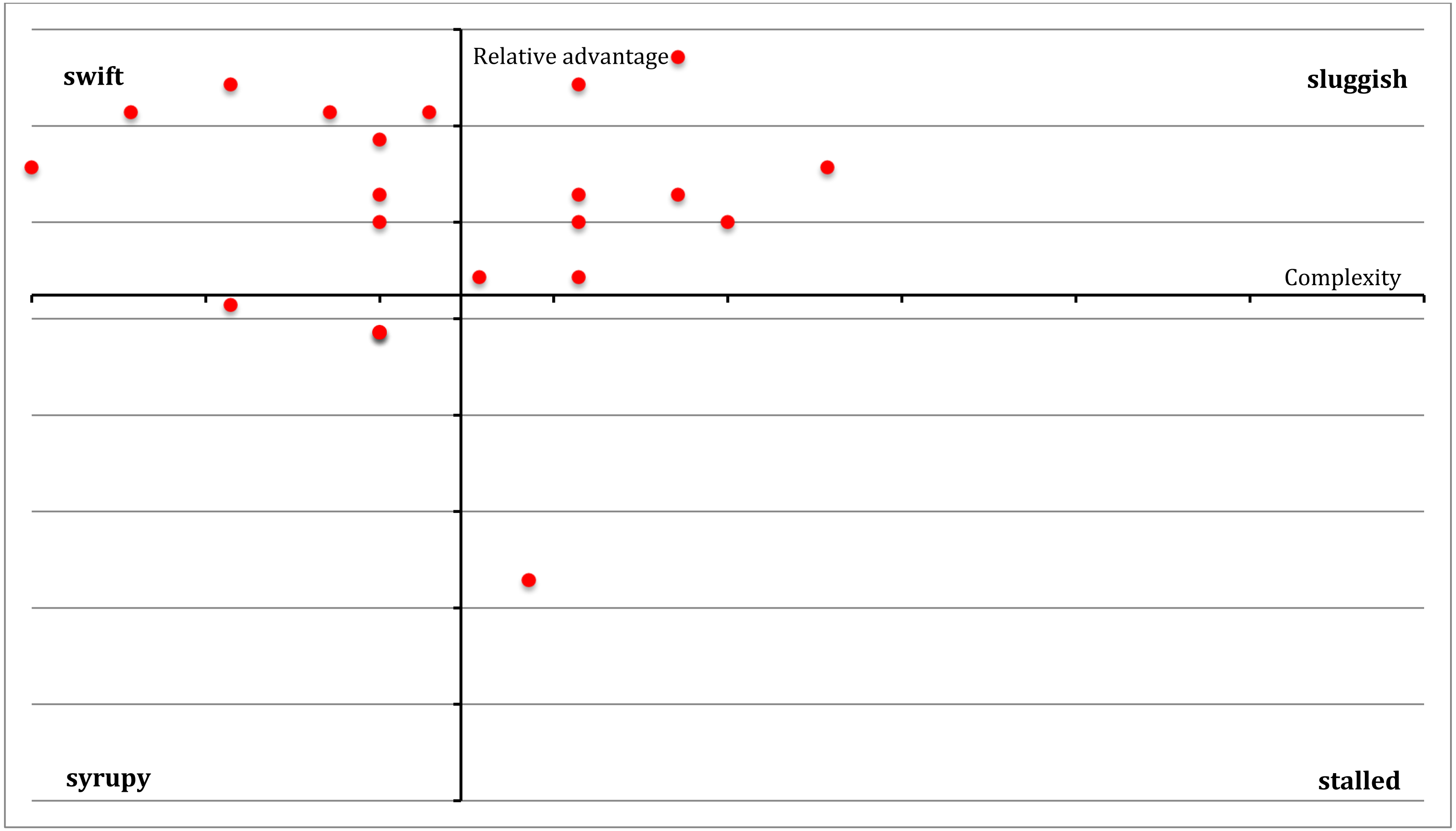

Figure 17: Stickiness in the adoption of increased area for effluent application

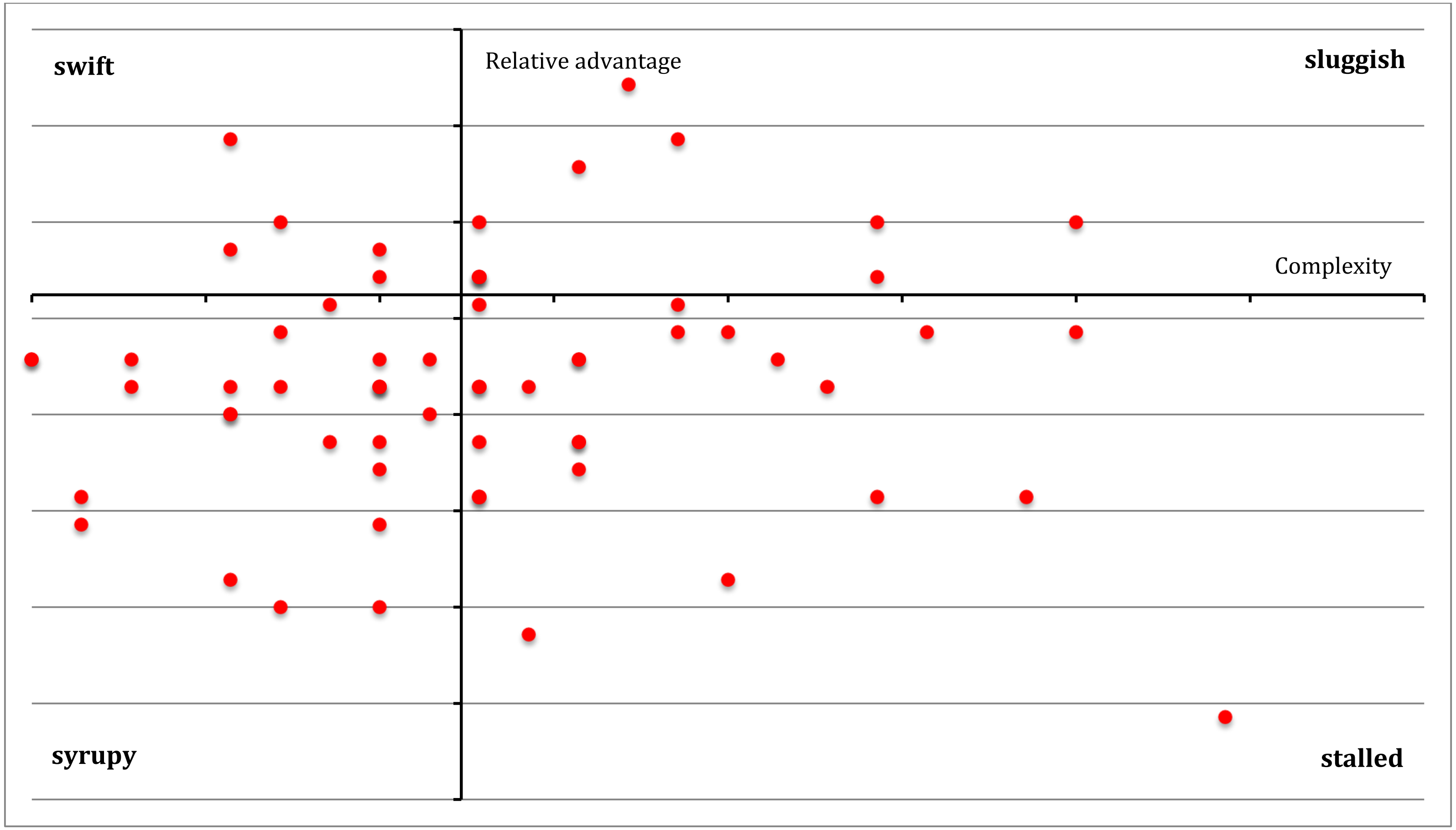

Figure 18: Stickiness in the adoption of fencing to keep stock out of waterways and wetlands

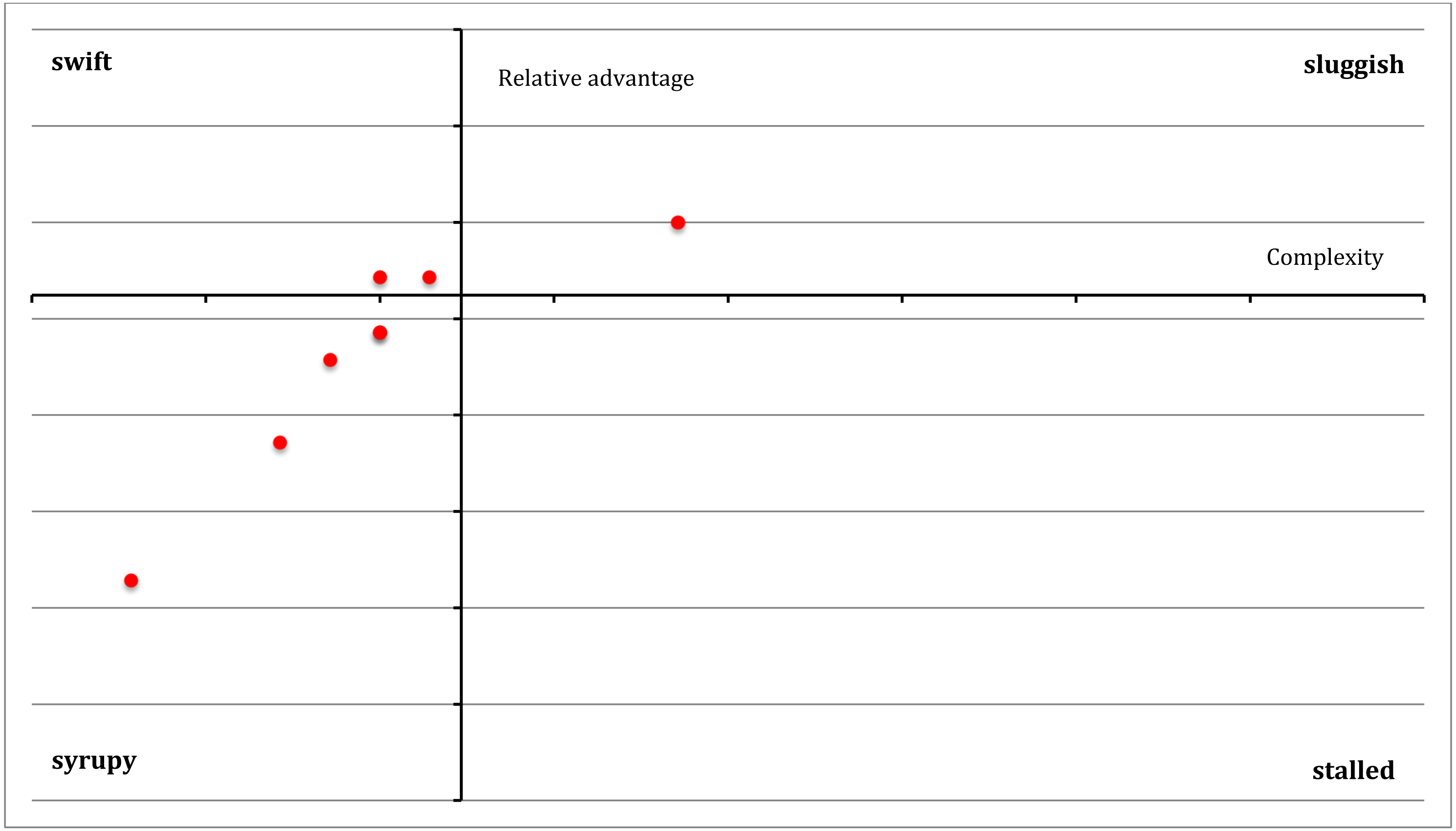

Figure 19: Stickiness in the adoption of a constructed wetland

- In regard to reducing stock on pasture, inspection of Table 7 reveals that installing a feed pad (Figure 15) was perceived to be more complex than, though offering a similar relative advantage as, grazing cows off-farm. However, an inspection of the table also reveals that, while installing a feed pad was perceived to be more complex than grazing heifers off-farm (Figure 14), installing a feed pad offered a higher relative advantage. This seems consistent with the popular proposition that cows are 'more easily managed' than heifers;
- The striking variation among respondents in the relative advantage and complexity of fencing (Figure 18) was described previously. This variation suggests that constructing wetlands (Figure 19) to absorb nutrients and sediment may be a simpler option than fencing, at least for some farmers, to exclude stock from waterways.

In Table 8 the average time taken to try, and then adopt, technologies and practices is reported. An inspection of the Table reveals that there is substantial variation in these times, with respondents being aware of some technologies and practices for many years before deciding to try them. For some technologies and practices, a number of years elapsed before, having tried them, respondents committed to using them. These included new pasture varieties, new breeds of livestock, artificial insemination, round bale technology, grazing heifers and cows off-farm and feed pads.

On the whole, and where statistically significant, the differences among the technologies and practices in the average time taken to try and then adopt them seem plausible. For example, respondents knew about feed pads for approximately six years before trying them compared to two years for a new type of fertiliser. This was consistent with respondents viewing feedpads as a more complex technology, particularly architecturally, than a new type of fertiliser, and costlier to abandon if adopted.

Table 8: Trying and adopting technologies and practices

Technology or practice	Time to trying (Months)	Time to adopting (Months)
New type of fertiliser	25.1	6.2
No longer apply nitrogen fertiliser in winter	45.2	13.3
Slow release nitrogen fertiliser	12.0	4.9
New pasture varieties	22.3	52.5
Different breed of livestock	84.0	59.0
Round bale technology	90.0	67.8
Round bale silage	42.0	6.0
Growing a summer crop (e.g. chicory)	70.5	37.8
Feeding palm kernel	64.1	36.2
Different calving period (e.g. split calving)	36.0	3.6
Artificial Insemination	105.2	75.1
Grazing heifers off-farm	97.3	84.6
Grazing cows off-farm in winter	82.5	62.7
A feed pad	74.3	34.2
Increased land application area for effluent	18.0	4.3
90 day effluent storage	17.7	2.3
Fencing stock out of waterways or wetlands	53.8	46.1
Constructing a wetland	126.9	62.0

Note: Time to adopting is period of time elapsing between trying and committing to using.

On average, respondents knew about grazing heifers off-farm for approximately eight years before trying it. Another seven years passed after trying it, on average, before they committed to it. This compares with two years and six months, respectively, for a new type of fertiliser. This is consistent with respondents viewing grazing heifers off-farm as a more innovative change compared to switching fertiliser type; these are modular and incremental innovations, respectively.

The average time taken to try and then adopt artificial insemination by respondents was approximately nine and six years, respectively. This was surprising given that artificial insemination was generally viewed as a relatively simple innovation, comparable with changing fertiliser type in complexity and relative advantage (see Table 7). The only significant difference between the two technologies for respondents was a greater need, with respect to artificial insemination, to acquire new knowledge and learn new concepts and skills compared to changing fertiliser type.

A few observations can be made about the time taken to adopt technologies and practices that may be employed to control the discharge into waterways of nutrients and sediment from farms:[5]

- In regard to the use of fertilisers, respondents took significantly longer on average to discontinue applying nitrogen in winter than to switch to a slow release nitrogen fertiliser (Table 8);
- The time taken to try, and to commit to, installing a 90-day effluent storage pond was similar to that for expanding the area over which effluent was spread. These times may have been influenced by regional council regulations;

[5] Statistical significance was set at $p < 0.01$ for these tests.

Table 9: Relative advantage, complexity and adopting technologies and practices

	Swift	Syrupy	Sluggish	Stalled
Time to trying*	65.6	100.3[a]	31.1[a]	42.0[c]
Time from trying to adopting*	42.2	78.5[a]	7.1[a]	25.3[b]
Architecture	2.74	2.41[a]	3.25[a, c]	2.55[b]
Novelty	2.90	2.30[a]	3.46[a, c]	2.76[b, c]
Decision effort	3.20	2.75[a]	3.65[a]	3.20[b, c]
New skills	2.39	2.08[a]	3.19[a, c]	2.58[b, c]
Experience	3.71	3.47[a]	3.79[c]	3.53[b]
Means	4.30	3.99[a]	3.96[a]	3.48[a, b, c]
Anticipatory	4.33	4.16[a]	4.04[a]	3.90[a]
Anticipated	3.90	3.42[a]	3.86[c]	3.16[a, b, c]
Stickiness	3.64	2.86[a]	3.76[c]	2.85[a, b]

Notes: (a) Statistically significantly different from mean for swift.

(b) Statistically significantly different from mean for sluggish.

(c) Statistically significantly different from mean for syrupy.

(*) $p < 0.10$ for time to trying and time to adopt, $p < 0.05$ elsewhere.

- In regard to reducing stock on pasture, the times taken by respondents to install a feed pad and adopt the practice of grazing cows off-farm were not significantly different. However, they took significantly longer on average to try grazing heifers off-farm (Table 8). This seems consistent with the proposition that cows are more easily managed than heifers;
- In regard to fencing and constructing wetlands, respondents took significantly longer on average to construct wetlands than to install fencing (Table 8).

In summary, these results suggest that dairy farmers would switch to slow release nitrogen fertilisers faster than discontinuing the use of nitrogen fertiliser: less than two years on average compared to more than eight years on average, respectively. Dairy farmers are relatively slow to remove stock from pasture by installing a feed pad or grazing cows and heifers off-farm: more than eight years on average to adopt. Dairy farmers will fence stock out of waterways and wetlands faster than constructing wetlands: approximately eight years on average compared to approximately fifteen years on average, respectively. These estimates apply where the technology or practice is likely to offer some degree of relative advantage.

The effect of relative advantage, complexity and stickiness on the time taken to try and to adopt technologies and practices is reported in Table 9. The results indicate that the relationship between these variables was more complicated than we hypothesised. On one hand, we hypothesised that technologies and practices offering a higher relative advantage would be adopted more quickly than those offering a lower relative advantage. Supporting this hypothesis, the time taken to try and to adopt technologies and practices placed in the swift quadrant is less than for technologies and practices placed in the sluggish quadrant. Similarly, as hypothesised, the time taken to try and to adopt technologies and practices placed in the syrupy quadrant is less than for technologies and practices placed in the stalled quadrant.

On the other hand, the time taken to try and to adopt technologies and practices placed in the swift quadrant is more than for technologies and practices placed in the syrupy or stalled quadrants. This contradicts our hypothesis that simpler technologies and practices are adopted more quickly than complex technologies and practices. Yet, the differences across the quadrants in regard to mean scores for architecture and novelty, decision effort and the need for new skills and knowledge generally match with expectations.

Furthermore, the mean scores with respect to affect towards means, anticipatory and anticipated emotions also accord well with expectations. Comparing scores for the technologies and practices placed in the swift and sluggish quadrants reveals that respondents tended to have a more favourable attitude toward the process of adopting simpler technologies and practices. They were also likely to be more confident about success in, and feel more strongly about, the outcome of adopting simpler technologies and practices.

In short, these results suggest the relationship between relative advantage and time to try and to adopt is largely as we hypothesised. However, the relationship between complexity, described as extent of change to the farm system, and time to try and adopt is more complicated than we hypothesised. We analyse this further below.

Based on the degree of architectural and component change they entailed, the practices and technologies were classified into the four types of innovations: incremental, modular, architectural and radical (Table 10).

A surprising feature of the Table is the high proportion of changing fertiliser type classified as a radical innovation. Clearly, even so apparently simple a change as switching to a new type of fertiliser can have profound implications for the farm system and farm performance.

Table 10: Innovation type and technologies and practices

Technology or practice	Incremental	Modular	Architectural	Radical
New type of fertiliser	8	15	31	46
No longer apply nitrogen fertiliser in winter	42	8	25	25
Slow release nitrogen fertiliser	21	21	29	29
New pasture varieties	27	20	40	13
Different breed of livestock	17	17	50	17
Round bale technology	0	38	50	13
Round bale silage	29	19	29	24
Growing a summer crop (e.g. chicory)	5	20	60	15
Feeding palm kernel	18	15	44	23
Different calving period (e.g. split calving)	0	14	0	86
Artificial Insemination	13	44	24	18
Grazing heifers off-farm	18	21	54	7
Grazing cows off-farm in winter	0	20	60	20
A feed pad	0	5	27	68
Increased land application area for effluent	27	9	41	23
90 day effluent storage	8	25	42	25
Fencing stock out of waterways or wetlands	55	16	13	17
Constructing a wetland	63	13	0	25

Note: Values are percentage of respondents adopting a technology or practice

Differences among the types in the time to try and to adopt technologies and practices were then investigated (see Table 11). The results indicate that there were significant differences among the types in the time taken to try and adopt them, with incremental and architectural innovations adopted more slowly, on average, than modular or radical innovations. Generally speaking, incremental innovations are adopted more quickly than modular, and modular more quickly than radical and architectural. Architectural innovations may be adopted more slowly than radical innovations.

An examination of Table 11 reveals that architectural innovations were adopted more slowly than the other types of innovations. However, contrary to expectations, radical and modular innovations were adopted more quickly than incremental innovations. This may be partly ascribed to the fact that, on average, the relative advantage of modular and radical innovations was greater than for incremental innovations.

Further analysis revealed the time taken to adopt incremental and architectural innovations was influenced by their relative advantage; incremental and architectural innovations offering a higher-than-average advantage were adopted significantly faster than those offering a lower-than-average advantage (see Table 12 and Figure 20). Reassuringly, the rate at which incremental innovations offering higher-than-average advantage were adopted was comparable to that for modular and radical innovations.

Modular, architectural and radical innovations had a higher average score on 'stickiness' than incremental innovations, and radical innovations had a higher score than modular innovations. This is largely consistent with the proposition that, once adopted, having to discontinue using complex technologies and practices is more disruptive than is true for simpler technologies and practices.

Table 11: Innovation type and adopting technologies and practices

	Incremental	Modular	Architectural	Radical
Time to trying*	65.1	40.8	96.6[a, b]	30.6[a, c]
Time from trying to adopting*	42.2	16.5	76.8[a, b]	10.1[a, c]
Architecture	1.91	2.13[a]	3.10[a, b]	3.60[a, b, c]
Novelty	1.88	3.67[a]	2.39[a, b]	3.74[a, c]
Decision effort	2.74	3.29[a]	3.19[a]	3.54[a, b, c]
New skills	1.98	2.80[a]	2.39[a, b]	3.06[a, b, c]
Experience	3.73	3.57[a]	3.74[a]	3.75[a]
Means	3.92	3.99[a]	4.06	3.92
Anticipatory	4.23	4.14	4.12	4.04[a]
Anticipated	3.40	3.74	3.59	3.79[a, c]
Stickiness	2.85	3.56[a]	3.21[a, b]	3.68[a, c]
Relative	3.14	3.92[a]	3.63[a, b]	3.85[a, c]

Notes: (a) Statistically significantly different from mean for incremental.

(b) Statistically significantly different from mean for modular.

(c) Statistically significantly different from mean for architectural.

(*) $p < 0.10$ for time to trying and time to adopt, $p < 0.05$ elsewhere.

Table 12: Innovation type, relative advantage and adopting technologies and practices

	Incremental	Architectural
Relative advantage greater than mean:		
Time to trying*	33.2	76.3
Time from trying to adopting*	18.8	49.5
Stickiness	3.65	3.36
Relative advantage less than mean:		
Time to trying*	74.9	120.6
Time from trying to adopting*	49.2	108.4
Stickiness	2.60	3.04

Note: (*) $p < 0.10$ for time to trying and time to adopt, $p < 0.05$ for stickiness.

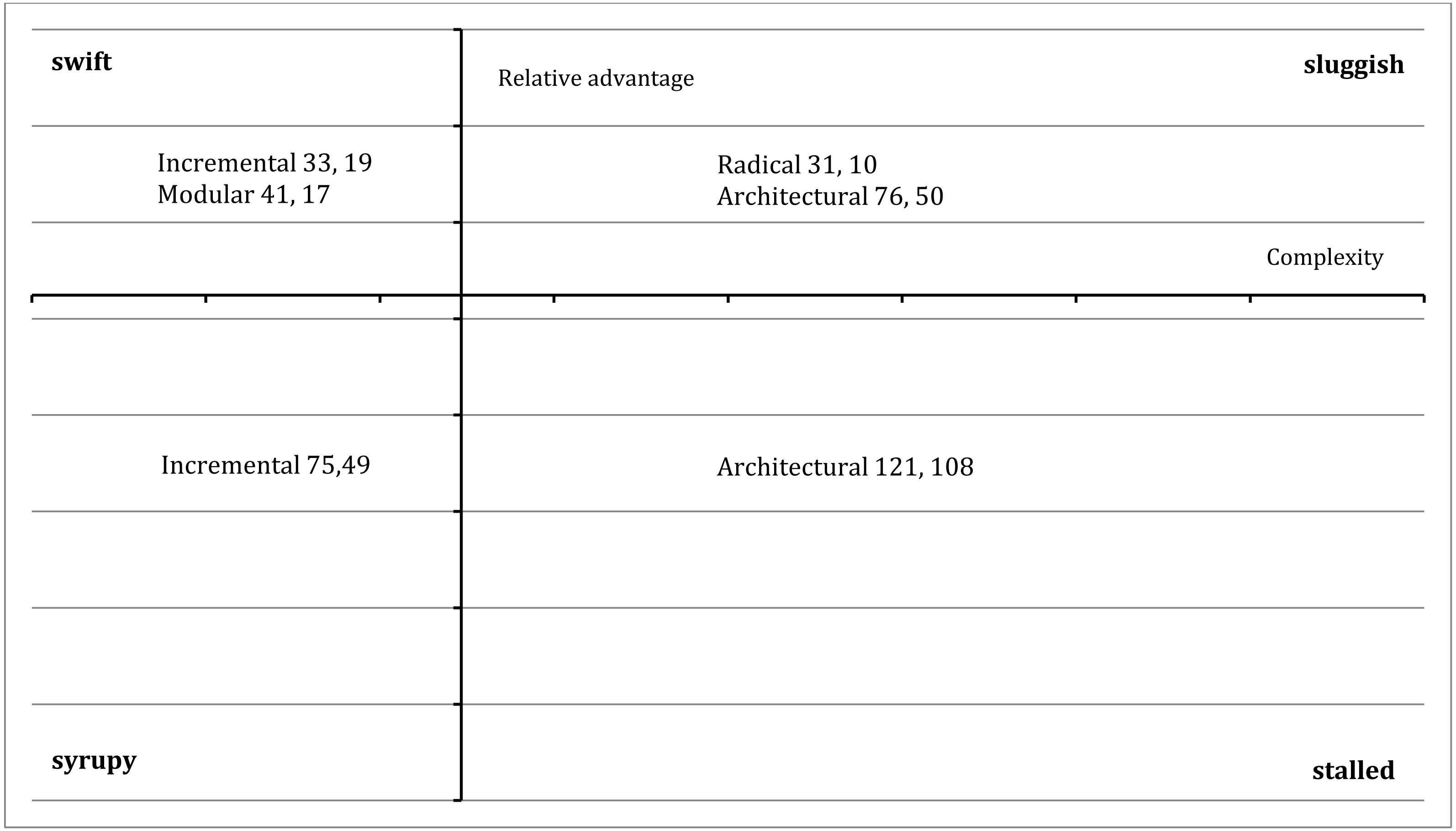

Figure 20: Complexity, advantage and time to adopt

Note: Values represent the average time taken (in months) to try and to adopt practices, respectively (see Tables 11 and 12)

Furthermore, incremental and architectural innovations offering a higher-than-average advantage had higher mean scores for stickiness than those offering below-average advantage. This result is consistent with the proposition that, once adopted, having to discontinue using technologies and practices offering a higher relative advantage is more disruptive than discontinuing technologies and practices offering a lower relative advantage.

A bivariate correlation analysis was undertaken to identify any simple association between time taken to try, time taken to adopt, assessments of complexity, relative advantage and so on, and characteristics such as farmer's age, their years farming, their years on their current farm, farm area and size of cow herd. A weak correlation was found between time taken to try and years in farming (0.12). Weak correlations were found between farmers' assessments of the need for new skills and their age and years on their farm (-0.13 and -0.11 respectively). Similarly, weak correlations were found between farmers' assessments of decision effort and their age, years in farming and years on their farm (-0.16, -0.11 and -0.18 respectively). A weak correlation was found between farmers' assessments of relative advantage and their years in farming (-0.10). These results suggest that demographic characteristics of farmers and farm scale have little direct influence on the rate of adoption of technologies and practices. The influence of education remains to be investigated.

Discussion

The positioning of technologies and practices in the maps largely accords with expectations based on interpreting them as examples of technical improvements in an input, or as examples of classical substitution between inputs, the latter being expected to be more complex than the former. This result engenders confidence in our approach to predicting rates of adoption. This confidence is reinforced by the fact that the key correlations among the structural and motivational scales were statistically significant and of the expected sign.

The results suggest that there is a positive association between relative advantage and the time to try and adopt technologies and practices, as expected. However, the relationship between complexity and the time taken to try and adopt technologies and practices was more complicated. The relationship between complexity and the time taken to adopt technologies and practices appears to be sensitive to the way in which complexity is defined.

Radical and modular innovations were adopted at similar rates, in approximately four years on average, the greater complexity of radical innovations compared to modular innovations being offset by their higher average relative advantage. Architectural innovations were adopted at the slowest rate, averaging approximately 15 years on average.

The time taken to adopt incremental innovations was influenced by their relative advantage; incremental innovations offering a higher-than-average advantage being adopted in less than half the time of those offering a lower-than-average advantage: approximately four years and ten years, respectively. The rate at which incremental innovations offering higher-than-average advantage were adopted was comparable with that for modular and radical innovations: approximately four years. These results provide strong evidence that the rate at which dairy farmers adopt technologies is strongly influenced by their complexity and relative advantage, and that these influences create profound differences in the rate at which technologies and practices are adopted.

They also suggest that there will be substantial differences among technologies and practices in the disruption created should farmers be compelled to discontinue using them. This was confirmed by the differences among innovation types, allowing for differences in relative advantage, in the mean scores for stickiness.

Overall, the results lead to the conclusion that where incremental improvements in technologies or practices offer above-average relative advantage, such as slow release nitrogen fertiliser, the opportunity to accelerate the already swift adoption is limited. On the other hand, there is scope for incentives to reduce time to adoption for incremental and architectural innovations that offer below-average advantage such as discontinuing winter applications of nitrogen fertiliser.

This suggests the proper targeting of incentives to maximise the return to public funds would require a sound knowledge of the factors in the farm context that influence the magnitude of relative advantage offered by a technology or practice. A sound knowledge of these factors is also critically important in distinguishing between farmers who may respond to a relatively small incentive and those that will not, 'small' being a fraction of the cost of adopting the technology or practice. Where a technology or innovation does not offer a relative advantage, an incentive would need to cover most of the cost of adopting the technology or practice to induce adoption.

The results for technologies and practices for reducing nutrient and sediment discharges from farms suggest that, from an adoption perspective, technologies such as slow release nitrogen fertilisers would spread more rapidly among dairy farmers than practices such as fencing streams and lakes or constructing wetlands, and discontinuing the application of nitrogen fertiliser in winter. The results also suggest that grazing cows and heifers off-farm would spread at a similar rate, among dairy farmers for whom this practice offers a relative advantage, as would the installation of feed pads among dairy farmers for whom this practice offers a relative advantage. The relative complexity of placement of feed pads in particular suggests that there would be scope for extension and promotion to accelerate their rate of adoption.

The placement of technologies and practices in the maps suggests that, from a compliance perspective, dairy farmers would respond more favourably to a regulation making the use of slow release fertilisers compulsory than they would to a regulation making, for example, the fencing of streams and lakes, or constructing wetlands, compulsory.

The placement of technologies and practices in the maps also suggests that, from an adoption or compliance perspective, dairy farmers would be more responsive to incentives making the use of slow release fertilisers compulsory than they would to incentives for the fencing of streams and lakes, or constructing wetlands.

Overall, the results suggest that there is limited potential for incentives to accelerate the rate of adoption of, or compliance in regard to, the following technologies and practices for reducing nutrient and sediment discharges from farms:

- Installing 90-day effluent storages
- Installing feed pads
- Grazing heifers and cows off-farm
- Fencing stock out of waterways and wetlands
- Constructing wetlands.

This will be the case even where these technologies and practices offer farmers a production advantage. However, the results did indicate there was potential for extension and promotion to accelerate the installation of 90-day effluent storages, feed pads and, at least for some farms, fencing of waterways and wetlands.

The results indicated that incentives could accelerate the rate of adoption of, or compliance in regard to, slow release nitrogen fertiliser and discontinuing applying nitrogen fertiliser in winter, especially where these technologies and practices offer farmers a production advantage. However, there may be little value in using public funds to offer incentives to accelerate the adoption of slow release nitrogen fertiliser, as this technology is likely to be adopted rapidly in any case.

Overall, the results reported here suggest that the approach taken here to predicting the rate of adoption of technologies and practices by dairy farmers has substantial merit. The results make plain that there is a relationship between types of innovation, farm context features and the time taken to adopt technologies and practices. Once this relationship is accurately described then the roles played by other plausible influences on the rate of adoption such as learning, social influence and targeted communication (Rogers 2003) can be rigorously analysed.

Further work

There are opportunities to extend this research by further analysis of the data that has been collected. These include:

- investigating in more detail the influence of demographic characteristics (age, education, experience farming) and farm attributes (farm size, herd size, location) on assessments of relative advantage, complexity, stickiness, and time to adopt;
- pairwise comparisons of farmers' responses.

There are a number of opportunities to extend this research by surveying a different sample of farmers, by modifying the questionnaire slightly, or both. These include:

- conducting the same survey on a larger sample of dairy farmers to obtain more robust statistical results, especially in regard to practices and technologies that had only been adopted by a small proportion of farmers in this sample;
- conducting a similar survey of dry-stock farmers in the Waikato and Waipa to identify similarities and differences in the time taken to adopt practices and technologies;
- conducting a similar survey of dairy farmers in other regions, or nationally, to identify similarities and differences in the time taken to adopt practices and technologies;
- conducting a similar survey focussing on practices and technologies in relation to other policy matters such as biosecurity, biodiversity, water use, animal health and welfare, adaptation to climate change and mitigation of greenhouse gases;

- modifying the questionnaire by incorporating additional questions to verify respondents' answers to questions on time taken to try and to adopt practices and technologies. A small proportion (less than 5%) of the responses to the questions on time taken to try and to adopt practices and technologies appeared inconsistent with the age of the respondent and so were excluded from the analysis. While some of these inconsistencies appeared to be coding errors, this does suggest the robustness of the results could be improved by incorporating additional questions to verify respondents' answers to these questions.

The value of this research could also be taken further by:

- quantifying the market size, penetration and rate of adoption of practices and technologies of particular interest. This kind of study would provide robust data for evaluating the impact of marketing programs, extension programs, incentive programs and regulations;
- investigating the strength of association between farm context and assessments of relative advantage and complexity to establish how much the variation in these assessments is due to real differences in farm context versus purely personal differences in farmers' assessments. The greater the variation due to personal differences the greater the opportunity for extension and marketing activities to accelerate compliance and adoption;
- linking this research with models of compliance behaviour, such as the I_3 compliance model (Kaine et al. 2010), to quantify the link between stickiness and farmers' favourable (or unfavourable) reactions to policies.

Conclusion

In this paper a novel approach to predicting the rate of adoption of technologies and practices by dairy farmers has been described and tested. The approach applies equally to predicting rates of non-compliance with policies prescribing the use, or abandonment, of particular agricultural practices and technologies.

The results of analysing data gathered from 200 dairy farmers in the Waikato and Waipa indicates that the approach has substantial merit. The positioning of technologies and practices in the 'stickiness' maps largely accorded with expectations based on interpreting technologies and practices as examples of technical improvements or advances in an input, or as examples of classical substitution between inputs, the latter being expected to be more complex than the former. Confidence in the approach was reinforced by the fact that the key correlations among the structural and motivational scales were statistically significant and of the expected sign.

The results suggest that the relationship between relative advantage and time to try and adopt technologies and practices was as we hypothesised. However, the relationship between complexity, described by extent of change to the farm system, and time to try and adopt technologies and practices was more complicated than we hypothesised. We found that radical and modular innovations were adopted at similar rates, the greater complexity of radical innovations being offset by a higher average relative advantage. Architectural innovations were adopted at the slowest rate.

The time taken to adopt incremental innovations was influenced by their relative advantage: incremental innovations offering a higher-than-average advantage being adopted significantly faster than those offering a lower-than-average advantage. Reassuringly, the rate at which incremental innovations offering higher-than-average advantage were adopted was comparable with that for modular and radical innovations. Furthermore, incremental and architectural innovations offering a higher-than-average advantage had higher mean scores for stickiness than those offering below-average advantage.

In conclusion, the results reported here suggest that the 'stickiness' framework has merit as an approach to explaining and predicting the rate of adoption of agricultural technologies and practices. The use of the framework, or something similar, to capture the interactive effects of the component elements on adoption would seem essential to avoid the conflation of determinants of adoption in more simple approaches.

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