Doping in Elite Sports Assessed by Randomized-Response Surveys

Rolf Ulrich[1]

Harrison G. Pope, Jr.[2*]

Léa Cléret[3]

Andrea Petróczi[4,5]

Tamás Nepusz[4,6]

Jay Schaffer[7]

Gen Kanayama[2]

R. Dawn Comstock[8]

Olivier Rabin[3]

Perikles Simon[9]

[1] Department of Psychology, University of Tübingen, D-72076 Tübingen, Germany

[2] Biological Psychiatry Laboratory, McLean Hospital, Belmont Massachusetts, USA 02478 and Department of Psychiatry, Harvard Medical School, Boston, Massachusetts, USA.

[3] World Anti-Doping Agency/Agence Mondiale Antidopage, Montréal, Canada

[4] School of Life Sciences, Kingston University, Kingston-upon-Thames, Surrey, KT1 2EE, United Kingdom

[5] Department of Psychology, The University of Sheffield, Sheffield, S10 2TP, United Kingdom

[6] Department of Biological Physics, Eötvös Loránd University, 1117 Budapest, Hungary

[7] Department of Applied Statistics and Research Methods, University of Northern Colorado, Greeley, Colorado, USA

[8] Pediatric Injury Prevention, Education, and Research Program, Colorado School of Public Health, Aurora, CO, USA

[9] Department of Sports Medicine, Rehabilitation and Disease Prevention, Johannes Gutenberg University Mainz, D-55131 Mainz, Germany

*To whom correspondence should be addressed. E-mail: hpope@mclean.harvard.edu

Doping – the use of prohibited substances or methods to improve athletic performance – compromises fair play and endangers health[1-3]. To deter doping among elite athletes, the World Anti-Doping Agency (WADA) organizes worldwide biological testing. In 2010, WADA-accredited laboratories analyzed 258,267 athletic blood and urine samples, of which 1-2% tested positive[4]. Biological testing, however, likely fails to detect many cutting-edge doping techniques[5-9], and thus the true prevalence of doping remains unknown. Here we show that doping among elite athletes is far more prevalent than suggested by biological testing. We surveyed 2163 athletes at two major elite sport events, using a specialized instrument that visibly guarantees confidentiality, thus encouraging truthful responses. At the 13th International Association of Athletics Federations World Championships in Athletics (WCA) in Daegu, South Korea, we found that the prevalence of reported past-year doping was at least 29%, and at the 12th Quadrennial Pan-Arab Games (PAG) in Doha, Qatar, the prevalence was at least 45%. In subsequent sensitivity analyses, assessing the robustness of these estimates under numerous hypothetical scenarios of intentional or unintentional noncompliance by respondents, the estimates remained little changed, or even appeared too low. These findings demonstrate that doping is remarkably widespread among elite athletes, and remains largely unchecked despite current biological testing programs. We anticipate that the survey technique presented here will allow investigators at future sporting events to generate continued reference estimates of the prevalence of doping, which will be of crucial importance in developing novel potent and effective anti–doping strategies.

The last several decades have seen increasingly sophisticated biological testing programs to deter doping among athletes, especially at elite international competitions[1-3]. This testing typically detects doping in 1-2% of Olympic-level athletes[4]. However, with sophisticated modern doping schemes[5-9], many athletes may beat the tests. Given the

numerous recent highly publicized doping scandals in major sports[10-12], one might guess that the proportion of such undetected cheats is high. Still, the true rates of both false-negative and false-positive cases among tested athletes remain unknown, while subject to much speculation and debate[13-16]. Unfortunately, one cannot estimate the rates of such false test results without an estimate of the true underlying prevalence of doping[13,17].

Given these concerns, we developed specialized survey methods to estimate the prevalence of past-year doping at two elite international athletic competitions in 2011: the WCA in Daegu, South Korea and PAG in Doha, Qatar. To encourage truthful responses on this sensitive issue, we surveyed athletes using a "randomized-response method," whereby the confidentiality of the athlete's response is visibly guaranteed[17-18]. We summarize these methods below; full details are provided in the Supplementary Information, sections 1-3.

Data collectors at both events approached athletes and invited them to perform the survey, administered on tablet computers. We obtained excellent cooperation: of the 1841 registered athletes at WCA, we approached 1290, of whom 1202 (93.3%) agreed to participate. Of 3346 athletes accredited at PAG, we approached 1030, of whom 965 (93.4%) agreed to participate. At both games, the number of athletes approached was limited simply by the availability of data collectors and tablet computers; the groups approached appeared representative of the entire population registered (see Supplementary Information, section 1). The tablet computers recorded both responses ("yes" or "no") and response times – the latter measure to identify athletes who responded very quickly and hence perhaps carelessly (see below). The initial tablet screen included a prominent button offering athletes the option to decline participation; additionally, if athletes reached a subsequent screen and showed unwillingness to participate, they were directed back to this "decline" option – thus effectively ensuring a consent process (Supplementary Information, section 3.1). The subsequent screens used the "unrelated question method" (UQM[19]) to assess past-year doping among respondents in a manner that guaranteed confidentiality, as can be seen by progressing through the four screens In Figure 1. Although the UQM disguised the doping status of each individual athlete, we could nevertheless estimate the population prevalence of doping,

knowing the odds that respondents would receive nonsensitive question A and that their answer to this question would be "yes" (Figure 2; Supplementary Information, section 2). With adequate sample size, this technique yields high statistical power[20].

To evaluate the validity of this methodology, we added a control question in the survey administered at PAG: "Have you used herbal, mineral, or vitamin supplements in the past 12 months?" This question was administered identically to the doping question (e.g., an introductory "choose a person" screen, followed by Questions A and B, where "B" was the "supplements" question), with the order of doping and control questions counterbalanced across respondents.

We then calculated estimates, together with confidence intervals, of the prevalence of past-year doping and supplement use among athletes (the latter calculation in PAG only). We also performed *post hoc* sensitivity analyses to assess the stability of the estimates under various hypothetical assumptions of noncompliance or carelessness among the respondents. We obtained strikingly high estimates of past-year doping: 43.6% (95% confidence interval 39.4%-47.9%) at WCA and 57.1% (52.4%-61.8%) at PAG. The estimated prevalence of past-year supplement use at PAG was 70.3% (65.7%-74.8%).

We next considered the potential effects of three possible forms of respondent noncompliance. First, refusal to participate might have introduced sample bias, although this was likely minor, since of the athletes approached, only 6.7% declined participation. Furthermore, doping athletes would seem more likely to have declined than non-doping athletes, thus potentially causing us to underestimate the true prevalence. Second, doping athletes receiving Question B might have lied and answered a self-protective "no" despite the assurance of confidentiality. This too would have led us to underestimate the true prevalence (Supplementary Information, section 5.2). Third, some dopers, upon receiving Question B, might have surreptitiously reverted to nonsensitive Question A (e.g., they might have retroactively chosen a different "close person" born within the first ten days of the month). This also would have biased our estimates downwards, since only 50% of these noncompliant dopers would consequently have answered "yes" (Supplementary Information,

4

section 5.3). Thus each of these three possible forms of noncompliance would have caused us to underestimate the true prevalence of doping.

We also considered three other seemingly less plausible scenarios. First, some non-dopers receiving Question B might have reverted to Question A, even though they (unlike dopers) would have had no obvious motivation to do so. Even assuming such unlikely behavior, our estimates would remain little changed. For example, if 20% of dopers and 20% of non-dopers receiving question B had inappropriately reverted to A, our estimates would be biased by less than 2% (Supplementary Information, section 5.3). Second, some non-dopers might have falsely claimed to be dopers. However, there is little plausible motivation for such behavior, and empirical evidence suggests that such false self-incrimination is very rare[21]. Third, some athletes, regardless of doping status, might have randomly pressed "yes" or "no" without actually considering the questions, due to haste or poor reading ability. Such behavior would drive the estimates towards 50%, and again would have little effect on our results. For example, if 20% of athletes had answered randomly, our prevalence estimates would still be biased by less than 2% (Supplementary Information, section 5.1).

Finally, we noted that some athletes showed very rapid response times, suggesting possible carelessness or failure to adequately read the instructions. Interestingly, at both athletic events, fast responders yielded even higher prevalence estimates than normal responders, possibly as an artifact of hasty responding. Specifically, athletes had to touch "yes" twice on the opening tablet screens to reach the beginning of the survey (Supplementary Information, section 3 and Figures 3-4), and thus some hasty athletes might have continued to mechanistically respond "yes" on successive screens. Such behavioral rigidity has been documented in prior psychological studies[22]. Accordingly, we performed sensitivity analyses in which we deleted 0%, 10%, 20%, 30%, 40%, or 50% of the fastest responders (Supplementary Information, section 4). The prevalence estimates decreased upon deleting the 10%-20% of fastest responders, but stabilized thereafter (Figure 3).

Thus, even assuming conservatively that (a) none of the first three above-mentioned plausible forms of noncompliance caused any underestimate of the doping prevalence,

despite their mutual risk of doing so; and (b) the entire surfeit of "yes" responses among the fast responders was artifactual, and did not reflect any surfeit of genuine dopers; we would estimate a 29%-34% prevalence of past-year doping among athletes at WCA and 45%-50% at PAG. A comprehensive analysis of possible noncompliance scenarios, detailed in the Supplementary Information, and summarized in section 5.8, finds no combination of plausible noncompliant response behaviors likely to have caused our findings to be overestimates. By contrast, there are numerous reasons to suspect that we may well have underestimated the true prevalence of doping among these athletes.

In summary, our estimates of 29%-34% and 45%-50% likely represent lower bounds for the prevalence of past-year doping at WCA and PAG, respectively. The reasons for the higher PAG estimate remain speculative, but notably, adverse analytical findings on biological testing were also higher at PAG (Supplementary Information, section 4). Our control question at PAG, assessing past-year supplement use, yielded an estimate of 64%-65% after deleting fast responders – a finding consistent with prior surveys of supplement use among elite athletes[23], which have variously produced estimates of 52%[24], 62%[25], 69% and 74%[26], 77%[27], and 80%[28]. The consistency of our results with these prior surveys offers support for the validity of our survey methodology.

These results suggest that the prevalence of doping in elite athletes is much higher than biological testing indicates. Given these provocative findings, we will continue to apply and refine this methodology to estimate the prevalence of doping in future sports events. Our findings argue for even more vigilant future anti-doping efforts to maintain the principles of fair play, ensure that elite athletes are appropriate role models for youth, and reduce the medical dangers that doping creates for the athletes themselves[29].

References

1. A. Dirix, The doping problem at the Tokyo and Mexico City Olympic Games *The Journal of Sports Medicine and Physical Fitness* **6**, 183 (1966)

2. A. Ljungqvist, The use of anabolic steroids in top Swedish athletes *Britisch Journal of Sports Medicine* **9**, 82 (1975).

3. V. Scarpino *et al.*, Evaluation of prevalence of "doping" among Italian athletes *Lancet* **336**, 1048 (Oct 27, 1990).

4. http://www.wada-ama.org/Documents/Resources/Testing-Figures/WADA_2010_Laboratory_Statistics_Report.pdf

5. A. W. Butch, J. A. Lombardo, L. D. Bowers, J. Chu, D. A. Cowan, The quest for clean competition in sports: are the testers catching the dopers? *Clin Chem* **57**, 943 (Jul, 2011).

6. A. Thomas, M. Kohler, W. Schänzer, P. Delahaut, M. Thevis, Determination of IGF-1 and IGF-2, their degradation products and synthetic analogues in urine by LC-MS/MS, *Analyst* **136**, 1003 (Mar 7, 2011).

7. T. Beiter *et al.*, Direct and long-term detection of gene doping in conventional blood samples *Gene Ther* **18**, 225 (Mar, 2011).

8. M. Ashenden, C. E. Gough, A. Garnham, C. J. Gore, K. Sharpe, Current markers of the Athlete Blood Passport do not flag microdose EPO doping *Eur J Appl Physiol* **111**, 2307 (Sep, 2011).

9. P. E. Sottas *et al.*, Prevalence of Blood Doping in Samples Collected from Elite Track and Field Athletes *Clin Chem* **57**, 762 (May, 2011).

10. C. McKenzie, The use of criminal justice mechanisms to combat doping in sport *Bond University Sports Law eJournal* (Bond University, Gold Coast, 2007).

11. Sparling, P. B. The Lance Armstrong saga: A wake-up call for drug reform in sports. Current Sports Medicine Reports 12:53-54, 2013.

12. Callaway, E. Sports doping: Racing just to keep up. Nature 475 (7356):283-285 (2011).

13. Berry, D.A., The science of doping. Nature 454 (7205) 692-693 (2008).

14. Sottas, P-E., Saudan, C., Saugy, M. Doping: A paradigm shift has taken place in testing. Nature 455 (7210): 166 (2008)

15. Baird G. Doping: Probability that testing doesn't tell us anything new. Nature 455 (7210): 166 (2008)

16. Ljungqvist, A., Horta, L., Wadler, G. Doping: World agency sets standards to promite fair play. Nature 455 (7217): 1176 (2008)

17. Pitsch, W. The science of doping revisited: Fallacies of the current anti-doping regime. *Eur J Sport Sci* **9**, 87-95, (2009).

18. H. Striegel, R. Ulrich, P. Simon, Randomized response estimates for doping and illicit drug use in elite athletes *Drug Alcohol Depen* **106**, 230 (Jan 15, 2010).

19. B. G. Greenberg, A.-L. A. Abul-Ela, W. R. Simmons, D. G.Horvitz, The Unrelated Question Randomized Response Model: Theoretical Framework *Journal of the American Statistical Association* **64**, 520 (1969)

20. Ulrich, R. Schröter, H. Striegel, H. Simon, P., Asking Sensitive Questions: A Statistical Power Analysis of Randomized Response Models *Psychological Methods*, **17**, 623-641 (2012).

21. R. Tourangeau, T. Yan, Sensitive questions in surveys *Psychological Bulletin* **133**, 859 (Sep, 2007).

22. A. S. Luchins, E. H. Luchins, *Rigidity of behavior: A variational approach to the effect of Einstellung.* (University of Oregon Press., Eugene, OR, 1959).

23. J. Sobal, L. F. Marquart, Vitamin Mineral Supplement Use among Athletes - a Review of the Literature *Int J Sport Nutr* **4**, 320 (Dec, 1994).

24. J. Sundgot-Borgen, B. Berglund, M. K. Torstveit, Nutritional supplements in Norwegian elite athletes - impact of international ranking and advisors *Scand J Med Sci Spor* **13**, 138 (Apr, 2003).

25. A. Nieper, Nutritional supplement practices in UK junior national track and field athletes, *Brit J Sport Med* **39**, 645 (Sep, 2005).

26. S. H. Huang, K. Johnson, A. L. Pipe, The use of dietary supplements and medications by Canadian athletes at the Atlanta and Sydney Olympic Games, *Clinical Journal of Sport Medicine* **16**, 27 (Jan, 2006).

27. G. Slater, B. Tan, K. C. Teh, Dietary supplementation practices of Singaporean athletes *Int J Sport Nutr Exe* **13**, 320 (Sep, 2003).

28. Braun H. *et al.*, Dietary Supplement Use Among Elite Young German Athletes *Int J Sport Nutr Exe* **19**, 97-109 (2009).

29. Wiesing, U. Should Performance-Enhancing Drugs in Sport be Legalized under Medical Supervision? *Sports Med* **41**, 167-176 (2011).

Author Contributions

All authors contributed to the conception and design of the study. T.N. And A.P. Designed the software for the study instrument, and provided the resulting data in a form suitable for analysis. L.C. Supervised the administration of the study instrument to athletes at both study sites. R.U., P.S., and H.P. performed statistical analysis of the data and wrote the initial draft of the manuscript. All authors provided commentary and revisions to the initial draft and approved the final version of the manuscript.

Author Information

The authors declare no competing financial interests. Correspondence should be addressed to Dr. Pope at hpope@mclean.harvard.edu.

Figure Captions

Figure 1: Sequential screens of the tablet-computer survey instrument.

Following an initial screen eliciting consent for participation in the study (not shown; see text and Supplementary Information, section 3.1), athletes were: **a.** introduced to the instrument; **b.** asked to choose a random individual whose birthday was known to them; and **c.** instructed to answer one of two possible questions based on the birthday of the chosen individual. The computer then presented: **d.** a screen showing the two questions, where question "A" concerned a non-sensitive issue for which the expected proportion of "yes" answers was known, and where question "B" concerned the sensitive issue under study (past-year doping). This screen contained a phrase reminding respondents that no one could know which of the two questions they were answering. At the PAG event, respondents also received a second series of screens identical to screens **b-d**, but with a question about use of supplements substituted for the doping question (screens not shown; see text).

Figure 2. Probability tree for the unrelated question model (UQM).

a. The respondent is asked an initial personal question for which only the respondent knows the answer, but for which the probability p of a "no" response and the complementary probability $q = 1 - p$ of a "yes" response in the overall population are known (e.g., a birthdate; see Figure 1). Respondents answering "yes" to the initial question are directed to a subsequent nonsensitive question A, for which the probability π_N of a "yes" answer is again known (e.g., another birthdate). Respondents answering "no" on the initial question are directed to a sensitive question B (e.g., past-year doping), where the probability π_S of a "yes" answer is unknown and represents the target of the investigation. **b.** The expected proportion λ of "yes" answers from the total group of respondents is therefore a function of p, π_N, and π_S. In the present study, the probability p of being directed to the sensitive question was approximately 2/3. In addition, the probability π_N of answering the nonsensitive question with "yes" was approximately 1/2. Using these values and solving for π_S, the prevalence of past-

year doping would be expected to be approximately $(\lambda - 0.167)/0.667$. (See Supplementary Information, section 2, for exact numbers.)

Figure 3. Estimated prevalence of past-year doping with various proportions of fast responders removed. Estimated past-year prevalence (± 1SE) for doping (red, green) and use of supplements (black) at WCA and PAG. In order to examine the effect of fast responding on the estimates, separate sensitivity analyses were performed by deleting 0%, 10%, 20%, 30%, 40%, or 50% of the fastest responders from the total sample. The data reveal that fast responses are associated with slightly higher prevalence estimates.

Figure 1

Figure 1

a

Thank you for taking part in this three-step survey. It will take less than 2 minutes of your time.

It is very important to answer truthfully.

No one will ever know what you answered apart from you.

Are you ready to start?

| YES | No |

b

Think of someone close to you (it can be anyone, such as your parent, sibling, partner, friend or even yourself) whose date of birth you know.

Are you ready to proceed?

| YES | No |

c

Now think about the date of birth of the person you have chosen.

If the date is between the 1st and 10th day of a month, proceed to Question A and please answer it honestly.

If the date is between the 11th and 31st day of a month, proceed to Question B and please answer it honestly.

| Press to continue |

d

Now think about the date of birth of the person you have chosen.

If the date is between the 1st and 10th day of a month, proceed to Question A and please answer it honestly.

If the date is between the 11th and 31st day of a month, proceed to Question B and please answer it honestly.

Question A: Is the person's date of birth in the first half of the year (January through June inclusive)?

Question B: Have you knowingly violated anti-doping regulations by using a prohibited substance or method in the past 12 months?

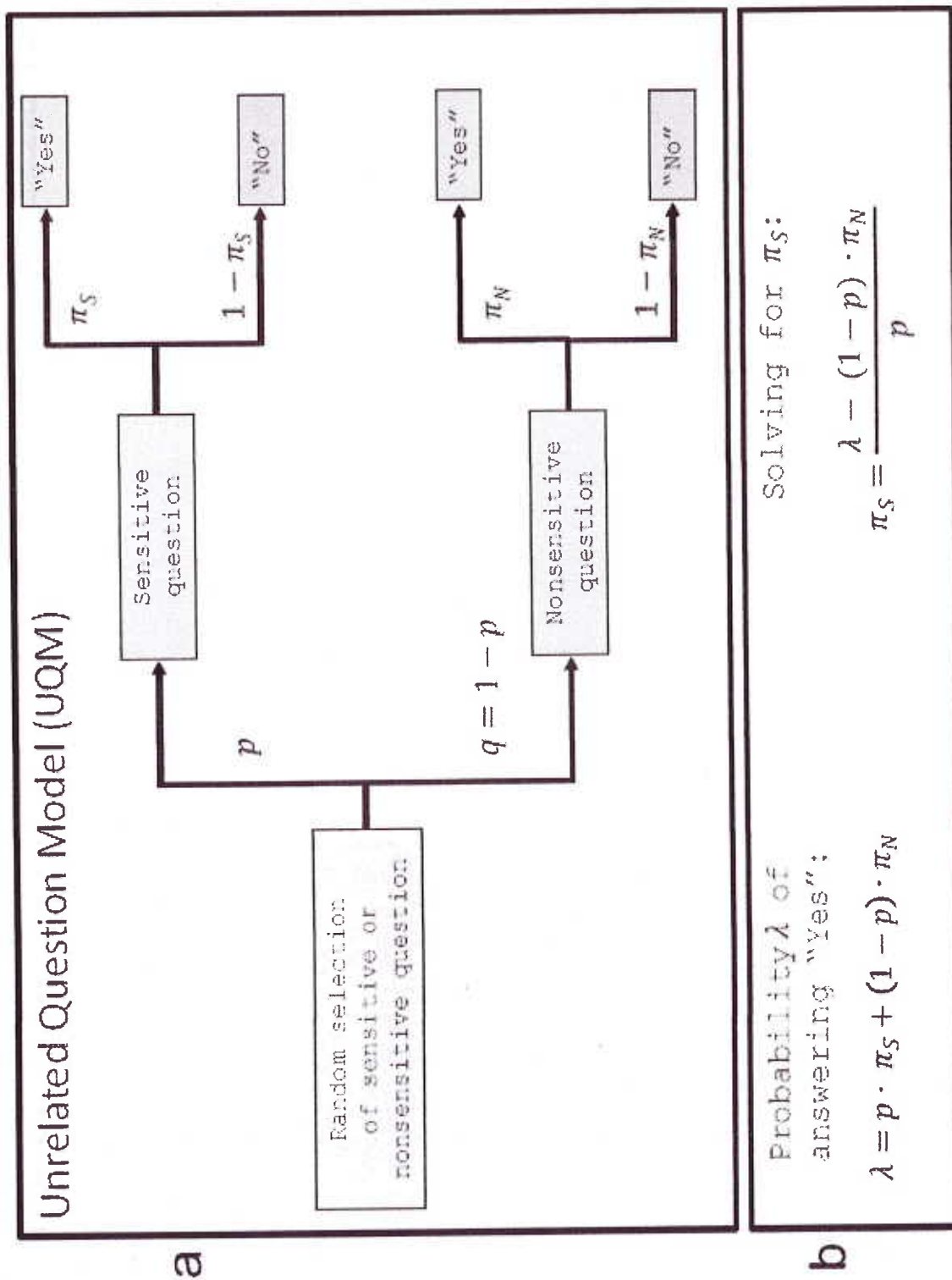Note that only you can know which of the two questions you are answering!

| YES | No |

Figure 2

Unrelated Question Model (UQM)

a

Random selection of sensitive or nonsensitive question

Sensitive question

Nonsensitive question

p

$q = 1 - p$

π_S → "Yes"

$1 - \pi_S$ → "No"

π_N → "Yes"

$1 - \pi_N$ → "No"

b

Probability λ of answering "yes":

$$\lambda = p \cdot \pi_S + (1-p) \cdot \pi_N$$

Solving for π_S:

$$\pi_S = \frac{\lambda - (1-p) \cdot \pi_N}{p}$$

Figure 3