A highly anisotropic electronic phase, not driven by lattice degrees of freedom, has been proposed in some unconventional superconductors, from cuprates to iron-based compounds. In the iron pnictide BaFe2As2, this nematic phase arises in the paramagnetic phase and is present for wide doping and temperature ranges. Here we probe the in-plane electronic anisotropy of electron- and hole-doped BaFe2As2 compounds. Unlike other materials, the resistivity anisotropy behaves very differently for electron- and hole-type dopants and even changes sign on the hole-doped side. This behavior is explained by Fermi surface reconstruction in the magnetic phase and spin-fluctuation scattering in the paramagnetic phase. This unique transport anisotropy unveils that the primary role is played by magnetic scattering.